LINCOLN CATHEDRAL: THE EVOLVING PERCEPTION AND PRACTICE OF CARE IN AN HISTORIC MASONRY STRUCTURE

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Abstract

The study concentrates mainly on the circumstances that surround Lincoln Cathedral, a major masonry structure that appears always to have possessed an in-house maintenance team. During the past century, several significant campaigns of repair have produced sufficient documentation to examine the evolution of changing attitudes in caring for the masonry structure. Examination of such records, combined with study of the relevant areas of the building itself, are influential in addressing the needs of the building by forming a critical awareness, not only of the actual work applied to the structure, but of the nature of the skills that are available to carry the work out.

In carrying out effective maintenance it is necessary to gain an intelligence of the structure itself, in its historic context. This will help to identify the likely weaknesses in engineering design as environmental conditions change and the constructional materials weaken due to attrition and the passing of time. An intimate knowledge of limestone, the principal structural material, and the agencies of deterioration and decay, is essential in combating what may be perceived as inevitable failure. This is assisted by understanding the local systems of decision-making, as policy is formulated within national perceptions of cathedral care.

The thesis is structured in six parts, the first five covering areas of necessary understanding, both in the technical and historical sense, prior to outlining methods of initiating maintenance action. Case studies present illustrations of relative success and failure in understanding and implementation. It can be seen that failure can impose serious consequences that reach far into the future. Practical examples are presented of areas of difficulty in the routes of communication and approval. The question of skills is addressed, and the main methodologies associated with care of historic buildings are described. Part six identifies and defines deficiencies in these skills, and recommendations are made for improvements.

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Lincoln Cathedral: The Evolving Perception and Practice of Care in an Historic Masonry Structure

Michael O'Connor

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Introduction

Introduction

This study is concerned with the understanding and actions of caring for a medieval masonry structure, with particular emphasis on both the historic and present maintenance experience of Lincoln Cathedral. Effective maintenance relies on several important factors, each of which is concentrated on in this study. It is necessary to be aware of the unique cultural value of the building, and an outline of the Cathedral's history, structural design, and the accompanying development of construction skills is presented in *Part 1.0 A Structural Foreword*. Emphasis is given throughout, that remedial actions should not be implemented without understanding the causes of failure. Therefore the characteristics of the main elements of the physical structure are described separately, with a focus on areas of vulnerability where both monitoring and maintenance are essential. The study moves from the macro view of the structure to detailed analysis of the constructional material, limestone, an understanding of which is instrumental to the intelligence of caring for the masonry structure. A description is given in *Part 2.0 The Weathering and Decay of Limestones*, in which the geology of limestone and the principal agencies of deterioration and decay are described. In *Part 3.0 Lincoln Cathedral: Its Pathology and Care* researches a campaign of repair when structural and material considerations were not adequately accommodated. This resulted in major works to the fabric that were unsympathetic, largely unnecessary, and which have had lasting consequences.

In *Part 4.0 Towards Effective Conservation Policy*, a period is covered when perceptions of care of historic buildings are changing, legislation for the first time establishing a formal system of control of maintenance to cathedrals, and state grant aid being made available. These changes will affect all involved in cathedral conservation, and new disciplines are already emerging to meet changing needs. Difficulties were encountered in pursuing the complex conservation of the Lincoln Romanesque Frieze. Despite overt attempts to draw knowledge and advice from international opinion, reservations were held with regard to motives and abilities to satisfactorily complete this work. Agreement was difficult to establish in producing an agreed policy for action. In the event, it was determined that policy could be determined only as conservation progressed. The conclusion is drawn that practice must take the lead in such cases, and confidence should be placed in those entrusted to carry out work. Current methods of distributing funding does not allow this, in the name of accountability of public funds.

The focus inevitably falls on the skills employed in the practice of conservation, where complementarity is essential to the implementation of effective care. In *Part 5.0 Towards a Practical Discipline: A Review of Conservation Methodology* the skills examined are those of archival recording, the traditional skills of the stonemason, and the relatively recent applications of the conservator to such work. Respective differences exist in the relationship to the work, and in their received understanding of ethical practice, both of which require to be addressed.

It is concluded In *Part 6.0 Conclusions and Recommendations* that masonry practice will need to make radical adjustments in its perception of historic building care, and in its own standards of ability. A larger understanding of the masonry structure, through geometry and material science, will help to facilitate a shift from the current poor practices of the modern stone industry. The conservators, currently unsure of their place within historic building maintenance, are recommended to maintain sight of their craft base. In both cases, parity of training will assure equality in the workplace, and the effective and sympathetic care of historic building fabric.

Background to the Study

Working for more than twenty years as a stonemason in the maintenance of historic buildings has presented the opportunity to observe many past repairs of varying efficacy and ingenuity, which have extended a range of benefits or detriments to respective buildings.

Most significant to note from such experience has been the relative range of skills either present or absent. At Hardwick Hall, the most painstaking and skilful SPAB repairs had been accomplished, using dressed quarry tiles and cement mortar, and on the fabric of Hawksmoor's Christchurch, Spitalfieds, past masonry repairs betrayed little understanding of fundamental masonry procedure, with straight joints and harsh mortars. At York Minster, it seemed imponderable why in the 1970s the upper shaft of a single Chapter House buttress should be cast in concrete and then cladded with dressed natural stone. Several observations could be made in the case of parish church maintenance. The regular commissioning of the local builder, often a bricklayer or joiner who rarely had access to proper masonry practice, could be detected in wrongly applied techniques, such as pointing types and mortars. Evidence existed of slavish reliance on single remedies applied across the board. Portland cement mortars, for example, were often used as a cure-all, or panacea, on the basis of giving a structure additional strength. In the wrong context, hard and impervious Portland mortars are analogous to 'forcing' a result, with the subtleties of investigation and trial ignored.

During the early 1980s, many changes began to take place in the context of maintenance care of historic buildings. Not least of these changes was the conceptual move away from the convention of restoration. A notion of 'minimum intervention' was introduced in instances of replacement, repair, and other treatments. The new perception included the revitalisation, or consolidation, of areas of masonry, particularly in instances of stonework representing the personal statement of the medieval worker, such as carving and sculpture. The work felt as though it was associated with museum disciplines, documentation needing to accompany work at all levels, and archaeologists began to appear above ground in order to fulfil these duties. A general increase in value was appreciated and, in the case of cathedrals, it became clear that changes were to be confirmed by legislation, the intention being to halt restorations that were felt to be excessive.

The new conception of historic building conservation soon assumed significance to the craftsman, on being presented with a catalogue of 'do's and don'ts', where previously only advice had been offered. Higher levels of ethical practice became binding, with renewed emphasis on retaining ancient elements, and reference made to the 'cultural significance' of the property. During the same period, new skills began to emerge to accommodate what were perceived as gaps in performance. These areas would be the domain of conservators, who were to be engaged in fine repairs and matters relating to the actions of decay. The new members of the team brought with them a fresh sense of value and it quite quickly became evident that their contribution was a valid one, in which case they were here to stay.

At Lincoln Cathedral, pressing concerns relating to problems of decay in the carvings, statuary, and sculpture gave rise to two consecutive conferences, and shortly after, a programme of conservation was embarked upon to remedy the worst of the problems. Recently completed major projects of the west façades of Wells and Exeter Cathedrals produced an abundance of papers which were to influence the new wave of conservators, in that they presented an attractive system of treatment known as the lime method. Needless to say, these were quickly countered by papers explaining the development of chemical consolidants, known as silanes. The question at Lincoln was how to proceed, and which philosophy to adopt. As the new practical discipline of stone conservation has sought to establish its place amongst the traditional skills, the proliferation of research papers has continued, much of it going over familiar ground. Progress at Lincoln has adopted an approach of understanding before implementation, which is slow moving, but true to the historic and contemporary circumstances associated with the building and its cultural values.

Aims and Objectives

The aims and objectives of the study are:

Aims:

- to examine the evolution of changing attitudes in caring for the masonry structure
- to identify the consequences of failing to meet the needs of the building
- to determine deficiencies in today's performance of care

Objectives:

- to examine the Gothic structure in its historic context and locate likely points of failure
- to determine the nature of the principal material (limestone) and the influences of deterioration
- to identify the efficacy of past radical repair work
- to trace the introduction of new decision-making methods in line with national concerns
- to identify the blockage in approvals and progress in conservation work
- to review contemporary skills employed in caring for the historic masonry structure
- to make conclusions and recommendations relating to the care of the fabric

The main locus of the study is towards identifying the evolving views of caring for a major historic masonry structure and how this can influence performance today. The constant focal theory of the thesis is that actions of care must be driven by comprehensive understanding of the object, in its historic context, as well as maintaining an awareness of the causes of deterioration and decay.

Methods of Research

A large part of this study forms a review of currently available literature related to the subject of historic buildings and their care, and about Lincoln Cathedral specifically. In terms of the history of the Cathedral, available literature is almost limitless, but those works that refer to contemporary issues encountered during work, for instance analysis of the west end, have been studied. No attempt is made to remark on matters of archaeology, since this is not within the scope of the study. Where possible, comment is made only on issues that cast light on maintenance of the historic fabric. In this respect, where sections have an engineering, or science, emphasis, knowledge is sought strictly where it might help to defend the structure from deterioration or decay

A great deal of documentation was generated during the period that Robert Godfrey was Clerk of the Works, from 1916 until his death in 1953. Many of the records appear to have been made either following work, or as proposals to press ahead with new work. In any event, the methods that Godfrey employed varied so little that his reports tend to be repetitive and a cartoon-like quality and are improbable in what they convey. More informative is the early communication between Architect, Engineer, and Clerk of the Works (Sir Charles Nicholson, Sir Francis Fox, and Godfrey), which highlight some glaring anomalies. Added to this, an intimate scrutiny of parts of the medieval fabric referred to in the reports often raises questions about the validity and reliability of the recording.

Significant changes in approach to conservation have given rise to a plethora of recent research, possibly due to the academic provenance of the new discipline. Much of it goes over the same ground, but there are germs of new information that make the digestion of it worthwhile. Conservators often, and masons almost always, are more revealing in conversation and the opportunity has been taken to engage craftsmen and women, from a range of situations, on issues current to this study. Architects and other professionals respond better to the written word, the early realisation of which has proved useful. In summary, the data for this study is a combination of searching through the relevant literature, close physical study of the principal building, Lincoln Cathedral, and other masonry structures, and consultation with colleagues in the field, as well as lengthy experience of related work in maintenance of historic structures.

Part 1.0

A Structural Foreword

Part 1.0 A Structural Foreword

Introduction

Part 1.0 *A Structural Foreword* is divided into three sections. The first of these 1.1 *A Brief History of Lincoln Cathedral and the Development of Skills* forms an introduction to the cultural property and gives a description of its historical and cultural significance (Figs 1.1 and 1.2). Some attention is paid to major significant social and political events, to give verity to the period. Parallel to this description is a commentary on the state of the contemporary masonry construction industry and the development of skills. Many details of which, such as tooling and joint widths, are informative of style and the identification of the period. A significant development, for example, came in the first quarter of the twelfth century with the discovery of a numerical system of measurement, ie geometry, which was to provide a major development in construction, design, and symbolism. Such an improvement in the language of construction demanded similar progress in other areas, such as the winning of superior selections of stone from the ground and general methods of construction, and a way forward in terms of architectural development was paved.

A review of the structure is provided in the second section, *1.2 The Medieval Structural System: A Review.* This is separated into the main structural elements, such as foundations, walling, vaulting etc. Where it was felt to be helpful in understanding how structural solutions were arrived at in the context of the building, some historical comment has been made. However, the intention has been to illustrate and impress the necessity of understanding how the structure works, and the logic of the damage that is encountered in the daily work of maintaining such a large medieval building. It is important to be aware of the constructional order of the building so as to be safely able to prescribe treatment. A fundamental structural theory is provided, with suggested ways of reading the major movements that may occur within its masses.

In *1.3 Failure in Gothic Buildings*, the areas of wear and the potential for collapse are outlined. It is explained that the medieval cathedral is an unreinforced compressive structure that is highly susceptible to change in local conditions, such as might be due to the lowering or raising of the water table, or in cases of significant structural intervention. In such cases, imbalances might be introduced into the system which may convert compressive forces into tensile ones. It is at these points, which are to some extent predictable, that serious failure may occur, and which might logically lead to partial collapse. The underlying message is that it is essential to the safe upkeep of the building for those charged with its care to be provided with a basic intelligence of how the structure performs, statically and dynamically, where the likely points of instability may be, and where tensile forces may wreak the greatest havoc. This will rely on a combination of the principles of structural theory and an intimate knowledge of the unique repair history of the building. It is the contention of this study that the mason, as an engineer, and the person most familiar with the nature of the primary constructional material, is most usefully armed with this knowledge and is best placed to anticipate the likelihood of major structural problems.

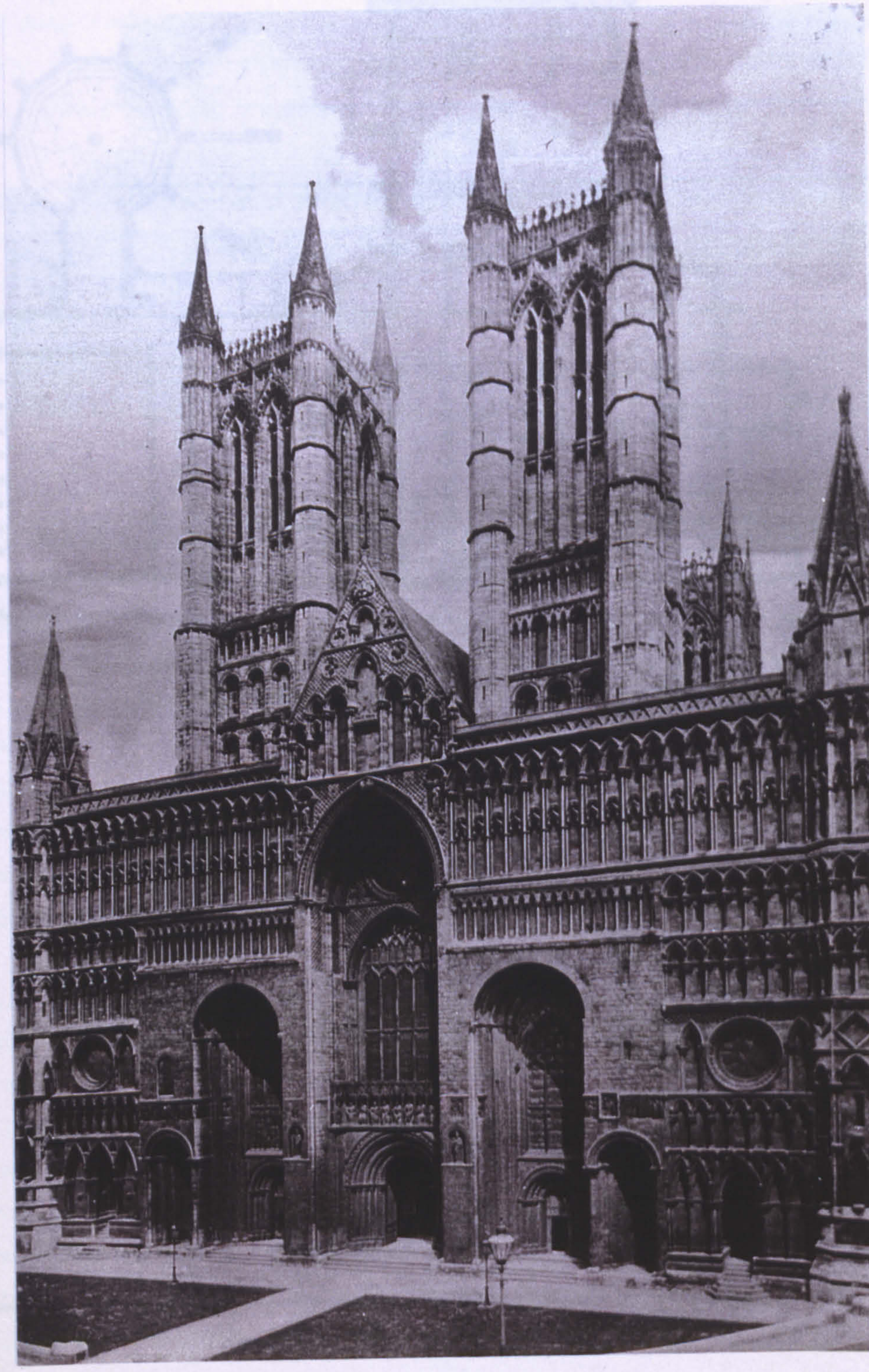

Fig 1.1 Lincoln Cathedral West Façade (Lincoln Cathedral Works Archive)

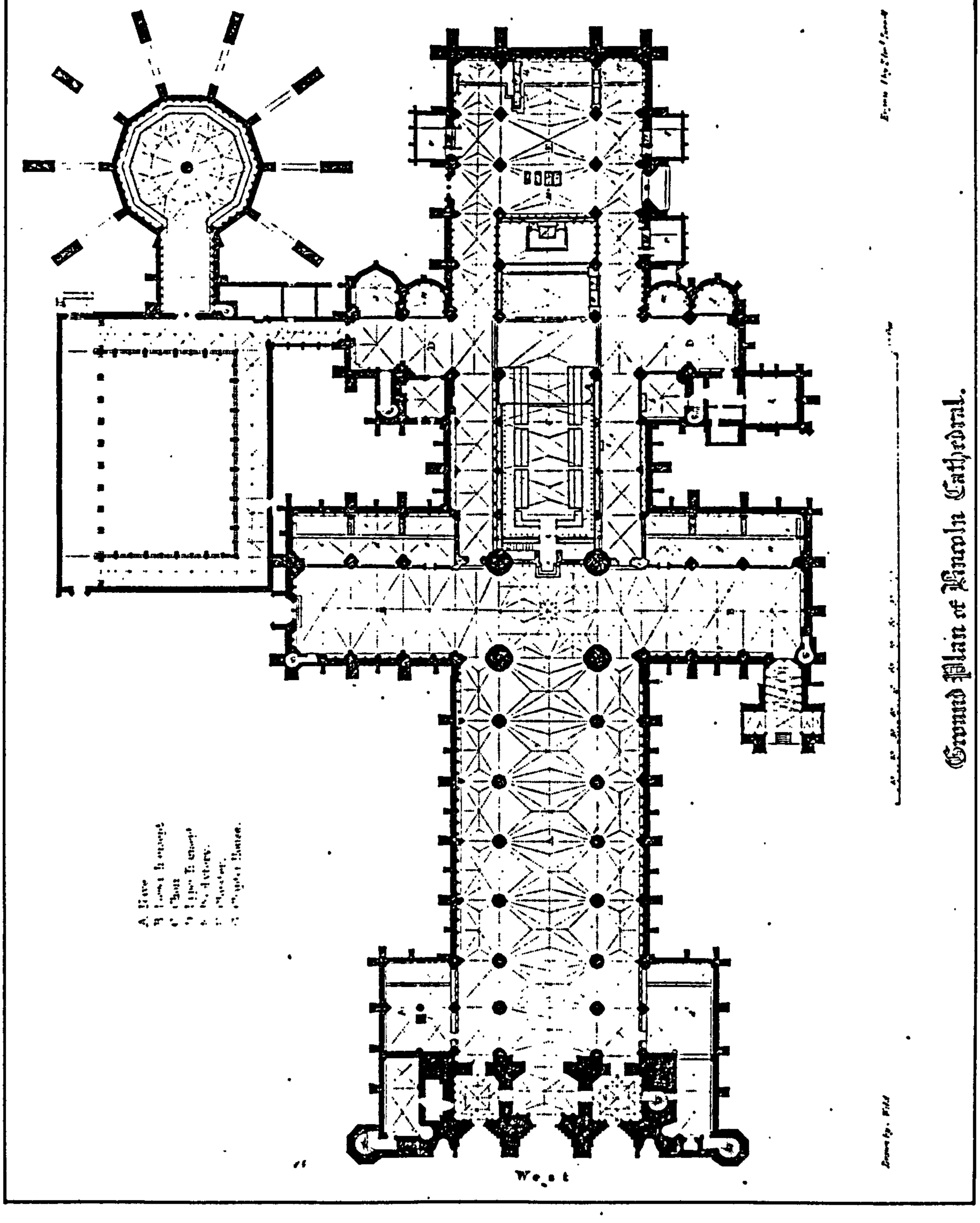

Fig 1.2 Lincoln Cathedral Ground Plan (WILD, C *An Illustration of the Architecture and Sculpture of the Cathedral Church of Lincoln*, London, Wild, 1819)

1.1 A Brief History of Lincoln Cathedral and the Development of Skills

Early City and Cathedral

The city of Lincoln, named *Lindum Colonia* by the Romans, was valued by the occupying legionary forces as being of strategic significance due to its local geography and its ideal location as a hilltop fortification. *Lindum*, literally meaning 'hill fort by the pool', was later suffixed with *Colonia*, indicating a colony of wealth and prestige. Recent archaeological research, including finds of the remains of a Roman forum-basilica on Ermine Street, south of the contemporary Newport arch, confirmed the city's importance. Further excavations revealed the grid-pattern of a symmetrical Roman defense system, defined by ditches, mounds, and walls. According to Jones, 'it is now clear what a formidable barrier they presented by the 4th century - a thick wall 3 to 4m wide and c. 7m high backed by a substantial rampart and fronted by a ditch perhaps 25m wide.' (1) Parts of Lincoln Cathedral were later constructed across that wall, to the south-east corner of the fortress, extending eastwards over the made-up ground filling the defensive Roman ditch . (Fig 1.3)

During the turbulent times of the Saxons, the country was governed by a heptarchy, consisting of the seven kingdoms of Wessex, Sussex, Kent, Essex, East Anglia, Mercia, and Northumbria. The venerable Bede records the preaching of the gospels by Paulinus in the province of Lindsey, a province near Lincoln, during which he reputedly 'converted the governor of the city of `Lincoln, Bleacca, with his whole family.' (2) Paulinus is said to have constructed a splendid church of stone in Lindsey, possibly at Barton on Humber, and is said to have consecrated Honorius as Archbishop of Canterbury there. Lindsey, long under dispute by the Kings of Mercia and Northumbria, was finally seized in the year 678 by the King of Northumbria, who is said then to have proclaimed the bishop's seat to be at Stow near Lincoln. In order to repel the Danish invasions, the sees of Lindsey and Leicester were united, and the Episcopal seat was transferred to Dorchester on Thames, remaining there until after the Norman invasion of 1066.

In the year following the conquest, Wulfig the last Saxon Bishop of Dorchester died and was succeeded by Remigius, the first bishop appointed by the Norman King William. Remigius (c.1067 - 1092) was a Benedictine Monk and had been almoner at the abbey of Fecamp. By assisting William in the invasion, supplying ships and men and even accompanying the forces himself, Remigius had secured favour. Episcopal sees were ordered to be removed to walled towns in 1072, and Remigius was transferred from Dorchester to Lincoln. The King had also 'given land there free from all customary payments for the building of the mother church of the whole diocese and other buildings (*officinas*) thereof.' (3) In 1072 construction of the Cathedral began, although Remigius was to die three days before the dedication, on 9 May 1092.

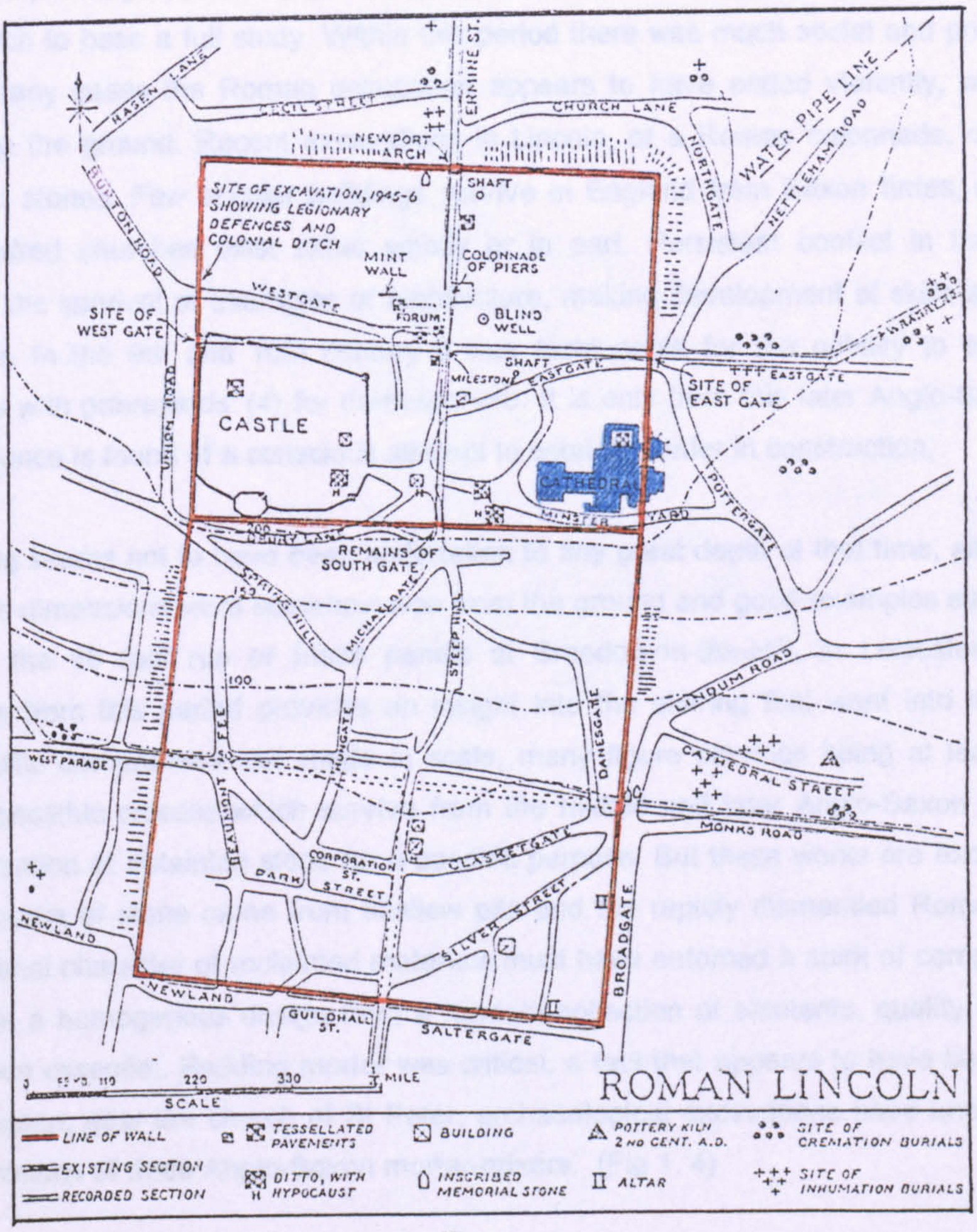

Fig. 1.3 Map of Roman Lincoln: outlined is the boundary of the Roman city of Lindum Colonia in relation to the later medieval Cathedral. Note how the city wall passes under the east end of the choir and the chapter house (HILL, F. *Medieval Lincoln*, Stamford, Watkins, 1990.)

The Springs of Medieval Construction

The concept of a 'construction industry', though well understood by the Romans, could not have applied to any organised building endeavour in the period known as the Dark Ages that followed the evacuation of the Romans in the early fifth century. Anglo-Saxon, as a term of architectural style is only barely applicable, given the insufficiency of complete and well preserved examples upon which to base a full study. Within this period there was much social and political instability, and in many cases the Roman occupation appears to have ended violently, with towns being burned to the ground. Recent excavations in Lincoln, of a Roman colonnade, discovered heat-reddened stones. Few secular buildings survive in England from Saxon times, although around four hundred churches exist either wholly or in part. Persistent conflict in the Saxon period inhibited the survival of examples of architecture, making development of skills and style difficult to define. In the 9th and 10th century it was fashionable for the nobility to establish 'lesser churches with graveyards' (4) for domestic use. It is only from this later Anglo-Saxon period that any evidence is found of a conscious attempt to establish order in construction.

Quarrying seems not to have been undertaken to any great depth at that time, although stones of generous dimensions were somehow won from the ground and good examples still exist, as in the case of the 18 foot run of frieze panels at Breedon-on-the-Hill, in Leicestershire. Surviving sculpture from this period provides an insight into the striving that went into the realisation of ideas. Little compromise was made in scale, many figure carvings being at least full-size. The huge monolithic crosses which survive from the middle and later Anglo-Saxon period show the clear intention of obtaining stone for a specific purpose. But these works are exceptional and the major source of stone came from shallow pits and the rapidly dismantled Roman heritage. The dimensional character of reclaimed materials must have enforced a spirit of compromise. In order to realise a homogenous design from a random collection of elements, quality in mortars would have been essential. Bedding mortar was critical, a fact that appears to have been addressed. In Northampton, near the church of St Peter, archaeological excavations have uncovered evidence of the remains of three Anglo-Saxon mortar-mixers. (Fig 1. 4)

These are of substantial scale and indicate a serious approach to the logistics of construction. Varying mortar recipes were devised for appropriate constructional purposes and extremely durable plasters were employed on both internal and external walls. Bedding mixes used for walling were particularly robust, enabling great height to be gained in only thin walls. Due to the reliance on curing of mortars, the building process must have been slow and precarious, with accidents inevitable.

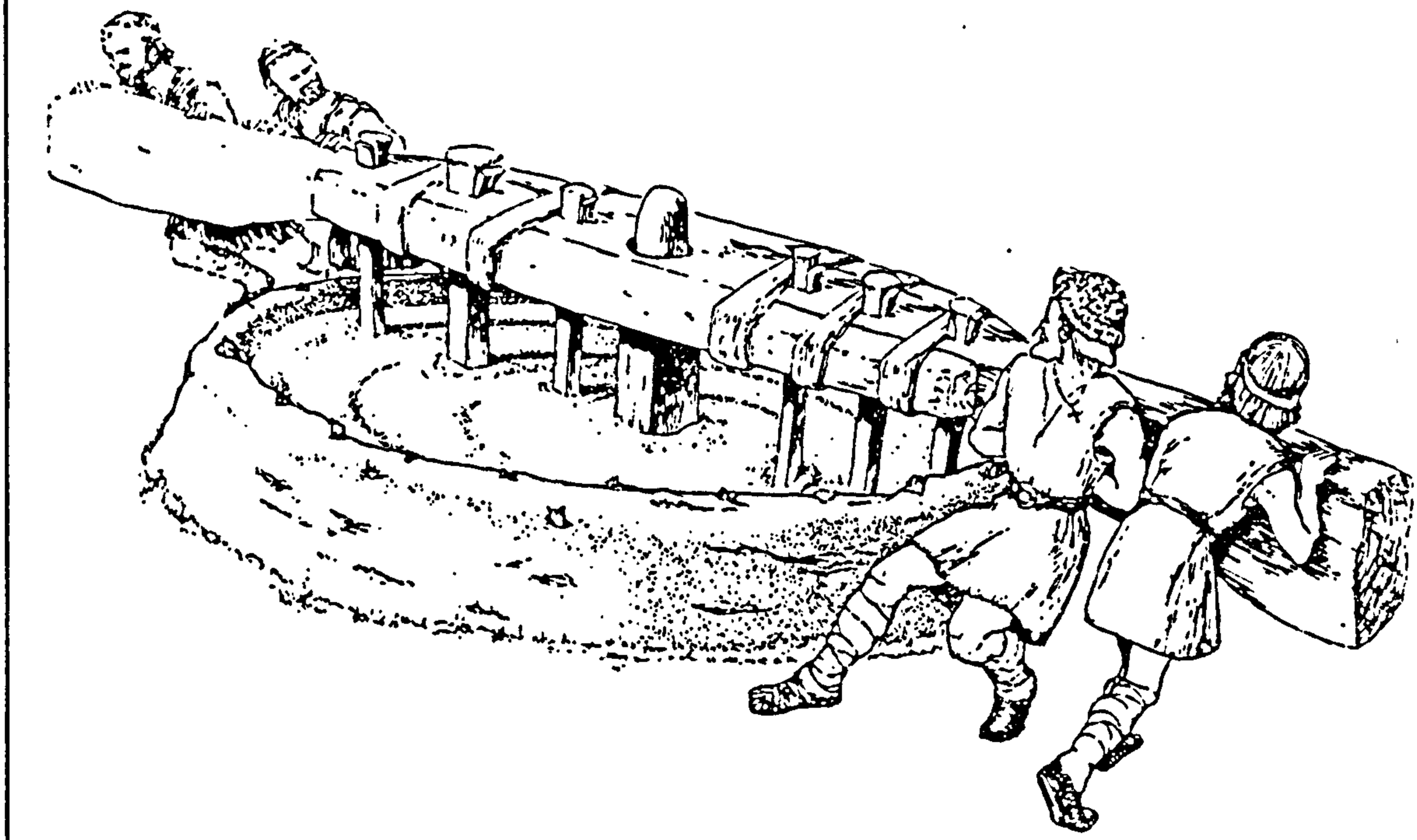

Fig. 1.4 Impression of an Anglo-Saxon mortar mixer, one of three excavated near St Peter's Church in Northampton (Kerr, M and N. Anglo-Saxon Architecture, Aylesbury, Shire Pub.1983.)

The Eleventh Century Cathedral

Little remains of the eleventh century church, those sections belonging to the first design being contained within the west end. Early twentieth century attempts to establish the lay-out of the church of Remigius (c1067-1092), 'found it possible to recover its main lines with comparatively little excavation,' (5) since it conformed so well with mainstream building of that period. This reconstruction of the first Cathedral of Lincoln is by Bilson (with alterations by Frankl),[1] and shows a nave of ten bays, transepts of two bays, and a choir of three bays, terminating at the east end in an apse. Aisles followed the full body of the church, probably with an ambulatory at the east end. Kendrick observes of the evidence remaining, which relates to the west end: 'To judge from the portions yet remaining, the building must have been severely plain; not a moulding softens down the rugged edges in those parts which are still as Remigius left them.' (6) The facade of the west front follows two vertical planes; the outer wall, possibly rising to a gable and containing small windows, is pierced by 'three tall and deep vaulted recesses flanked by two niches' (7). The inner plane, forming the rear wall of the portals eleven feet behind the outer face, possibly rose to form the front face of the twin towers. This theory is illustrated in Figure 1.5 where the front face is seen to form four buttresses, two on the corners, with the remaining two in the centre. Such powerful buttressing would have been consistent with the kind of support required to restrain the towers. The corners, hollowed out to form re-entrant niches, unite the massive front block with the church behind. 'This conception is not without vigour and grandeur. The three arches strike the dominant note, and the niches provide a harmonious decrescendo.' (8)

The austere design of the original structure may be explained in a theory extended by Dr Richard Gem, in which 'ecclesiastical and military were welded most closely together' (9). The basis of his theory is presented by Henry of Huntingdon (1080 -1155), stating of the construction of the church that 'it was to be both agreeable to the servants of God and also, as suited the times, invincible to enemies.' (10) Comparison is made by Gem with contemporary situations at Rochester and Durham, where Cathedral and Castle were, as at Lincoln, built adjacent. Amongst the architectural features which lend support to this idea are the pierced machicolations 'between the two middle orders of the soffits of the arches' in the main west portal. (11) David Bates, in his biography of Remigius, agrees that the Cathedral may have been prepared for refuge during uncertain times, but insists that the stylistic origins of the surviving features of the façade are representative of Norman attitudes. 'The style and the scale of Norman power at Lincoln embodies the starkness and the violence of Norman power after 1066.' (12) Bates doubts the theory of the defensive church, viewing construction as being carried out by similar hands to those that built the Castle, employing familiar styles and technology. 'We must distinguish between a building which might include features typical of fortifications and one which itself was fortified.' (13)

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[1] In Cathedrals and Abbeys of England and Wales, 1979. London, Dent. Richard Morris finds Bilson convincing in the main, but with some anomalies. In his evidence of the original nave, Bilson's evidence shows only the outer walls, and none of the inner arcading. Kidson is more impressed with the interpretation

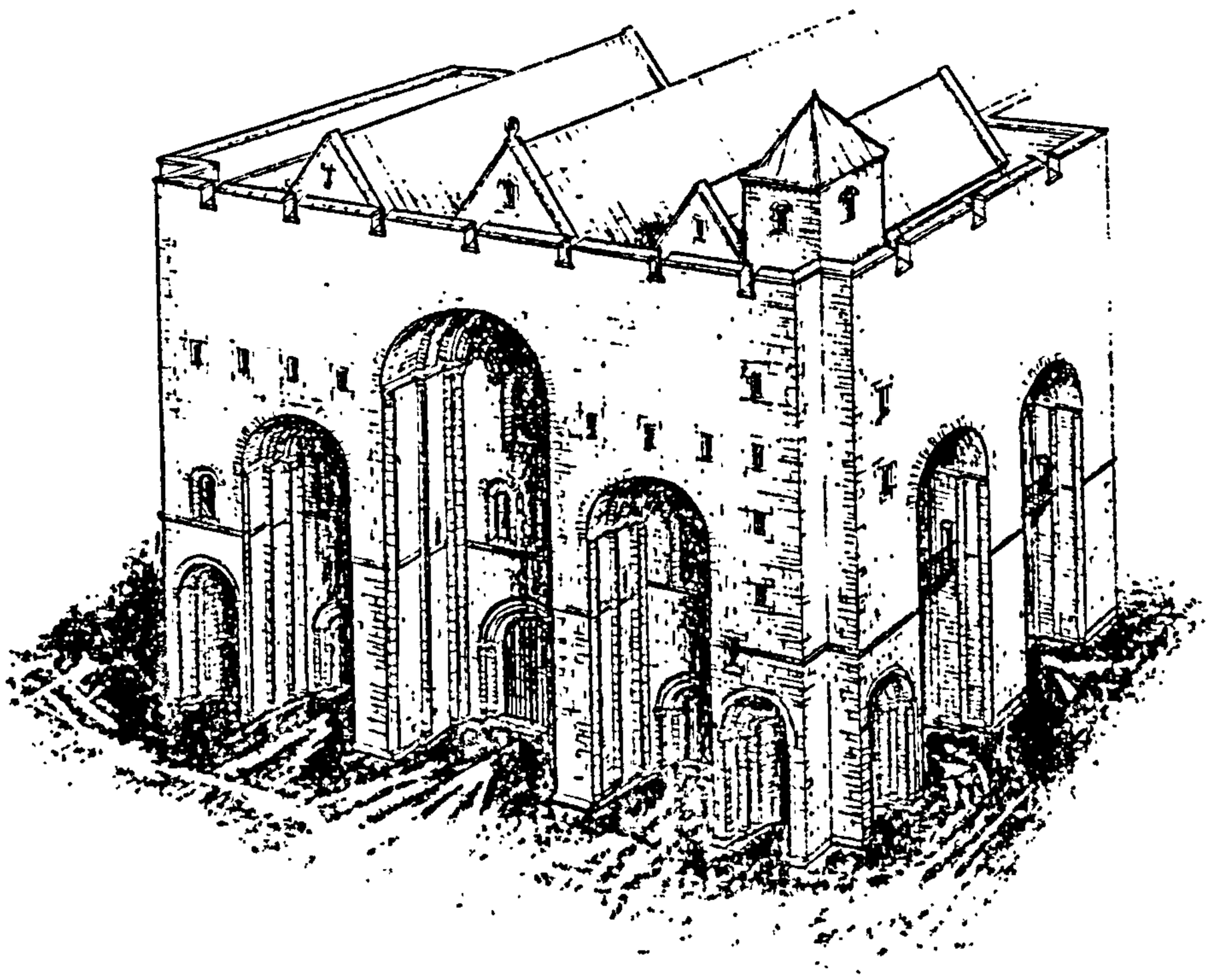

Fig. 1.5. A reconstruction drawing of the eleventh century Lincoln Cathedral by David Vale (after Gem), showing the massive buttresses between the portals necessary to resist the tendency of large cathedral structures to rack outwards towards the west. The string course can be seen cutting across the façade, under which the Romanesque Frieze was later inserted.

The Twelfth Century Cathedral

The fabric is felt to have remained as Remigius left it until 1141 when the roof was destroyed by fire. At this time Alexander (1123 - 1148) was Bishop, known as the Magnificent, and a notable builder of 'the three castles at Banbury, Newark, and Sleaford, and four monasteries including Haverholme and Louth Park'. (14) Alexander set about restoring the cathedral with the aim of surpassing 'its first newness.' (15) This is now mainly represented by the west block since the body of the building, the choir, transepts, and nave were later destroyed by earthquake. The remaining achievements of Alexander include the three pierced west portals, each having finely carved doorways in the elaborately decorated late Norman style. An intersecting arcade was also introduced during this campaign, which extended the height of the façade, as well as extensions to the west towers with arcading along the lower sections, and gables facing north and south. Evidence is still visible inside the west block, showing that his replacement of the roof was with stone vaulting. Most significant of Alexander's innovations was the introduction across the west façade of a scheme of sculptured panels, forming a frieze in which scenes from the old and new testaments are dramatically depicted. Inside the nave, from this period, is positioned a black Belgian limestone font,[1] carved by the marblers of Tournai, and which now stands within the colonnade of the south nave aisle.

According to Benedict, Abbot of Peterborough, a great earthquake was felt throughout the whole of England in 1185 and the 'Church of Lincoln was rent asunder from top to bottom.' (16) No mention is made of any other building being so damaged, and it is easy to surmise that Alexander's vaulting, built onto a structure designed to carry a wooden roof, was triggered to failure by a lesser action. The fabric of the Cathedral was left in an almost ruinous condition until Hugh, a Carthusian monk, was chosen by Henry II to be the next bishop of Lincoln. With great energy Hugh set about the major task of fund-raising and rebuilding, urging the archdeacons of his diocese to 'secure a better observation by the faithful [and] to induce them to bring their offerings to the Mother Church of Lincoln.' (17) Hugh commenced preparation of the new foundations around 1192 and his main contribution to the Cathedral's development was the choir which bears his name. This consisted of four bays running eastwards from the crossing, terminating in an apse at the east end. The apse was confirmed following excavations in 1886, the findings published by Precentor Venables in 1887. (18) Additional lesser transepts, having apsidal chapels on their eastern side, were added during this period. The most distinctive features of the new choir were its length and the eccentric design of the vaulting. An extension, breaching the city wall, would have required Royal permission, a factor that may account for the seven year delay between the collapse of 1185 and the commencement of rebuilding in 1192. 'This leisurely response to the situation indicates that the inconvenience was not unbearable. Money had to be raised. ' (19)

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[1] Although the black stone of Tournai is referred to as 'marble', it is in fact a fossiliferous limestone, although those local craftsmen who traditionally worked the stone were termed 'marblers.'

A Period of Transition

Hugh was a worldly and attentive man, deeply concerned with the welfare of the church. His awareness helped foster innovation in the reconstruction of his cathedral, with ideas observed elsewhere often surpassed at home. The search to achieve the ultimate architectural goals of the time, great height to obtain greater light, had already produced the pointed arch. At Canterbury, completed in 1184, the pointed arch is used extensively across the triforium chamber and the decorative use of Purbeck marble can be seen during this time, both at Canterbury and at Lincoln. The enhanced carving of stiff-leaf foliage is clearly demonstrated, and at Lincoln the designers of the late twelfth century dispensed with the tradition of the square abacus, introducing a rounded version throughout. According to Parker, the choir of St Hugh marks the 'earliest known example of the pointed style carried out consistently in its detail.' (20) The death of Hugh, soon followed by his canonisation, far from marking the end of an era became the inspiration for one of the finest examples of the first truly English style, the Angel Choir, built between 1256 and 1280.

Some Notes on Norman Building

Accomplished in their ability to organise campaigns of a military nature, the Normans were not slow in adapting their skills towards a systematic approach to building. They soon began to apply Italian and Sicilian achievements in art and architecture, assimilated whilst conquering these regions in the earlier part of the century. Moorish military engineering abilities were gained during the capture of areas such as Barbastro in north-east Spain in 1064. 'It seems probable that the spoils of war included a substantial number of craftsmen who possessed a degree of technical skill hitherto unknown north of the Alps and Pyrenees.' (21) Essentially imperialist, the Norman occupation of Britain was intended as a permanent installation, and many elaborate domestic properties, some still extant such as the Jew's House in Lincoln, were constructed solely for the purpose of housing those members of society who held sway over financial matters. Economic stability enabled Norman culture to establish itself, and this was manifested in the construction of such large-scale building projects as castles, churches, and cathedrals. Such projects called for tremendous organisational skills to supply secure manpower for the clearing of large areas of ground, ensure the provision of materials, and make available skills for construction. A programme of reconstruction accompanied the campaign of building, extending the meagre dimensions of Saxon minsters, and reconstructing the principal bases of the Benedictine abbeys and monasteries.

Early Norman buildings relied on mass to secure stability. Stones were crudely split into rough blocks before being dressed to a clean face using axes and adzes. Lacking the knowledge to work from master-plans, individual buildings developed in stages. In the later Norman period, when refined methods of stone shaping began to emerge, the work fell under the control of a single master. The development of lime burning techniques produced refined lime-mortars, enabling joints between stones to be more precise, creating a more tightly bonded structure than previously,

important in defensive structures. The Normans progressed to constructing walls of greatly reduced thickness, using larger stones, as quarrying and splitting techniques improved. These developments, which produced dressed ashlar walls with fine joints, marked major advancements in building, and helped to integrate a construction industry.

The Thirteenth Century Cathedral

Within fifty years of the death of St Hugh, during the tenure of three subsequent bishops, the Cathedral continued its development towards a point where it could be regarded as complete. Those bishops responsible for building construction during this period were William of Blois (1203 - 1206), Hugh of Wells (1209 - 1235), and Robert Grosseteste (1235 - 1253), the last being revered as a 'great scholar and statesman'. (22) The English style by this time was admirably represented at Lincoln by the chapter house, built around 1230, and the nave which was completed by the time of Robert Grosseteste's death in 1253, of which Kendrick comments: 'Taken as a whole, it is one of the best examples of the Early English style we possess.' (23)

Although documentation is scarce throughout this period, with the sequence of building uncertain from around 1220 to 1235, the *Metrical Life of St Hugh* (24) appears about 1220 and is able to illuminate certain details. The author refers to the 'Dean's Eye' and the 'Bishop's Eye', the two rose windows set into the gables of the north and south transepts respectively. It is chronicled by Matthew Paris that the central tower fell in the year 1237, although the unknown author of the *Metrical Life of St Hugh* makes no mention of a tower, indicating that collapse might have quickly followed construction. It is safe to presume that the great transept and the east end of the nave were in place to provide sufficient abutment for the central tower. The vault ridge of the transepts follows the level of the ridge of St Hugh's Choir, leaping upward to clear the rose windows.

The rebuilding of the rood, or central tower, was undertaken by Bishop Grosseteste, at least up to the first two stages, and was extended early next century. 'In 1311, an entry in the Chapter Acts says the new tower had just received its bells and was crowned with a spire of wood and lead, raising its height to 525 feet. This made it the tallest structure in England.' (25) In 1255 Henry III granted permission for the nave of Lincoln Cathedral to extend across the city wall. Between 1256 and 1280 the Angel Choir replaced the apse of St Hugh's Choir in order that his remains be translated there. 'It is in five bays, carried eastward at a uniform height and breadth with St Hugh's Choir.'(26) The Angel Choir is often considered to be the high point of architectural achievement at Lincoln, deriving its name from the series of sculptured angels set in the triforium spandrels.

Towards an English Maturity in Building

It was necessary for the master builder to form meaningful links between liturgical messages and the physical aspects of construction. It may have been felt that such an association should express the words of Augustine who said several centuries earlier: 'God made the world in measure,

number and in weight'. (27) In interpreting that need, the builder discovered a numerical, structural, and expressive reference in the disciplines of geometry. Geometry means *measurement of the earth,* and about 1120 Euclid's *Elements of Geometry*, possibly imported along with many other spoils of the crusades, was translated from the Arabic into Latin by Abelard of Bath. Introducing its precepts to masons throughout the West, together with the ability to study Islamic architectural and engineering achievements, possibly suggesting the pointed arch, European masons eagerly created a practical and spiritual synthesis as the basis of their craft.

The new theoretical base upon which masons worked, gave freedom to experiment, with the many inevitable mistakes consigned to the setting-out floor, rather than realised in costly materials and labour (Fig 1.6). This facility allowed the master mason to coordinate construction in an orchestrated manner, generally unifying the whole design structure on a theoretical basis. This allowed him to know where each masonry course and joint was going to be, enabling falsework to utilise the structure as it grew, cutting scaffold costs and yet facilitating the possibility of more spectacular achievements. Within a cathedral's massive configuration the mason was able to install a continuous network of service passageways and stairways, known as 'vices', which permitted access for the maintenance of the fabric, eg providing assurance that roofs were not leaking, with undetected damage occurring over an extended period (Fig 1.7). A distinct advantage of being able to operate from rising levels during construction, considering the desire the clergy might have expressed to practise ceremony within the church, was that it 'made possible the freeing of the ground floor as the building rose during erection.' (28)

Often the cathedrals of England were built during intermittent waves of activity as the vagaries of fund-raising fluctuated. As work recommenced, the loose ends would need to be picked up, not always by the same master nor even the same team of masons. John James has traced the various building campaigns at Chartres, identifying several individual masters by their use of technique, mason's mark, and the interpretation of design in mouldings. Around the Paris basin alone, James identifies twenty-five substantial crews, of which 'But a good dozen seem to have worked across the region and, of these, six are found at Chartres'. (29) The necessity of a rigorous and immediately comprehensible common language within the craft, in order to ensure the successful continuity of work of such magnitude, cannot be emphasised too strongly .

As quarrying techniques improved, the mason was provided with a greater range of stone from which to select, further enhancing the developing ability to shape stone. These significant advances in building technology, together with a new tighter control over design, gave the thirteenth century mason a fresh command over his structural arrangements. A rapid stylistic freedom was experienced, occurring mainly in England, embracing a desire to explore real space. Skeletal structures spanning space succeeded mass as the primary engineering device in achieving height, with walls daringly pierced at regular intervals. The strong vertical lines of architectural elements, such as shafts and columns, began to be emphasised rather than hidden,

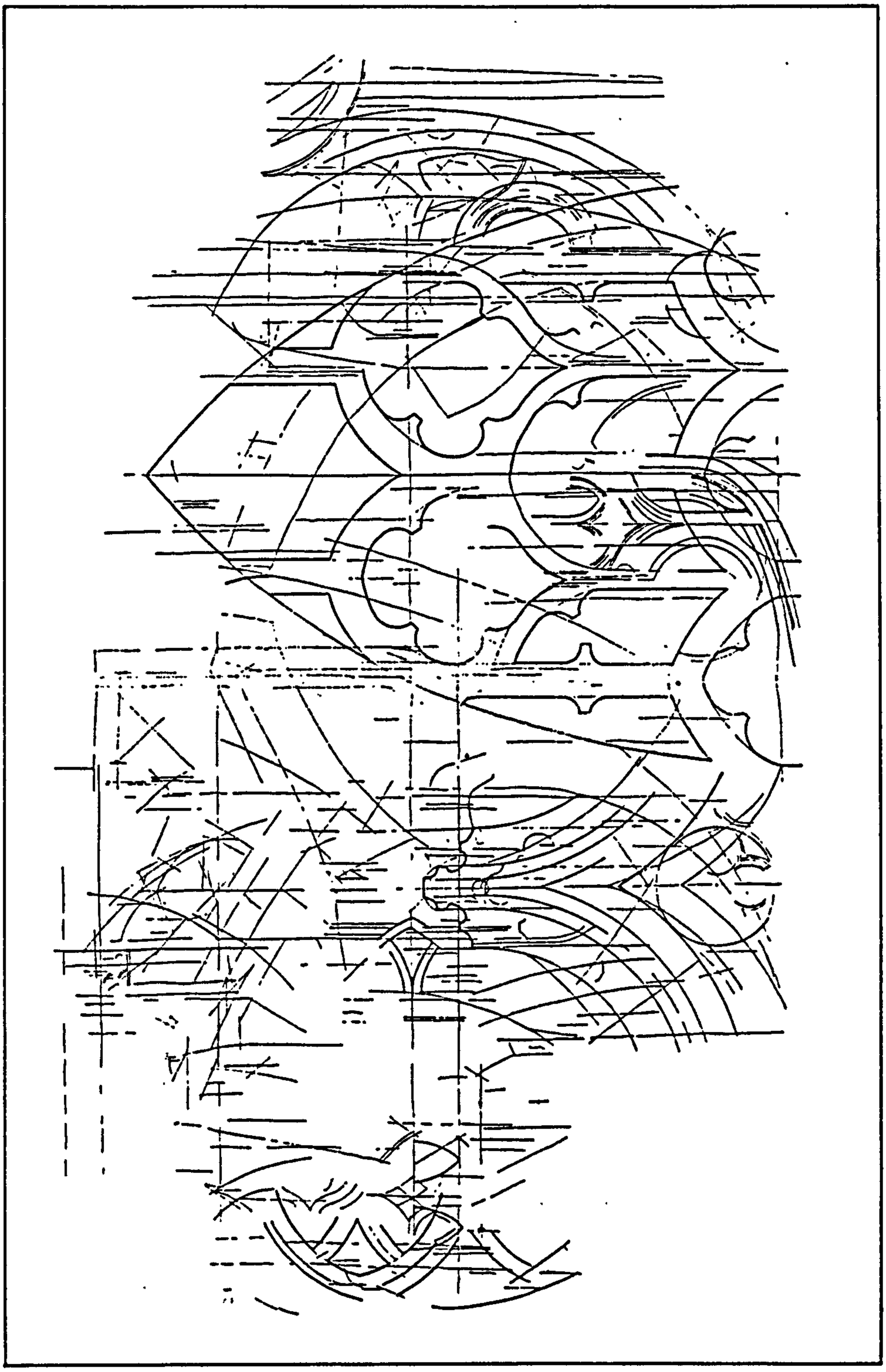

Fig. 1.6 A line diagram of the fourteenth century setting-out floor in the Monk's Chamber over the vestibule to the chapter house at York Minster. (AYLMER, G.E. and CANT, R. eds. *The History of York Minster*, Oxford, Clarendon Press, 1977.)

Fig. 1.7 Built-in access was normal in medieval construction. Steps have been constructed into the masonry to permit access from one level of the north nave roof of Lincoln Cathedral to another.

sometimes being made detached. The Angel Choir at Lincoln Cathedral is an example of such celebration, with dark Purbeck marble[1] accentuating the sense of soaring verticality. The use of this fossiliferous limestone from Dorset became highly fashionable due to its ability to emphasise line and rhythm in architectural schemes, further intensifying their spiritual significance over structural demands. 'Such exploitation of vertical members was one of the main features of mature Gothic.' (30) The continued development of the theme of verticality was eventually to lead to the first truly English style, known as Perpendicular.

[1] Confusion in terminology is explained in the words of Roy Butlin in a BRE report: *The Decay of Polishable Limestones*. 'Sometimes these limestones are erroneously described in literature as marbles, unfortunately in the geological sense this statement is not quite precise. True marbles are limestones that have been crystallised by metamorphism. Polishable limestones such as Purbeck have not undergone any such metamorphic process, they are merely hard stones that are capable of taking a polish. Many varieties have been quarried though few are still now in production.'

1.2 The Medieval Structural System: A Review

In the case of all concerned with the maintenance of cathedral fabric, some knowledge of how the structure performs is helpful, but in the practical skills of the stonemason and conservator, this knowledge is essential to evaluating the causes of problems. A major deficiency in caring for such large structures is the tendency to focus on one or another small part at a time, assuming that the larger view is the duty or prerogative of another, perhaps the architect or engineer. In both cases, where consulting services are commissioned, the continuous monitoring of the building is not likely to be provided. Where a permanent in-house works team is employed, such as a cathedral works department, the potential for long-term continuous specialist inspection can hardly be improved upon. Suffice it to say, this depends on the appropriate brief to those members of staff most capable of relaying useful information from the site to a central point, perhaps the architect, or clerk of works. Access where scaffolds are erected can be taken immediate advantage of for the purpose of such inspections.

Where the stonemason is concerned, a comprehensive knowledge of the functioning structure is essential, although it will be pointed out in the conclusions that such training or instruction is rarely provided. Where intrusion is made into the fabric, when chopping out eroded stonework for example, it should need little pointing out that movement may occur at the position being worked on or elsewhere. Loads may be redirected and perhaps create extra stress at another part of the structure where no inspection is being made, possibly due to the fact that scaffolding is not erected there. The result can be undetected damage, that may be left to get progressively worse as time elapses. The specific agencies of decay, such as the weather and pollution, must at all costs be kept from entering the core of the masonry, where rapid progressive damage can then occur. Being aware of the particular pressure points of a structure, for example the haunches of buttress shafts, will provide an alert view of the specific positions of likely ingress of moisture and pollutants. These areas may be of particular value to the conservator, for instance during a stone cleaning operation.

Some salient types of masonry building stresses will be identified and commented upon, and instances of specific forces will be outlined. This section will also examine ground conditions, foundations, moving to the superstructure, which will include walling construction, the nature of arches and their tendencies to fail, and vault construction and the mechanisms of cracking and failure. A summary in 1.3 *The Failure of Gothic Buildings* will illustrate positions of likely instability on the structure of the cathedral, and potential regions of failure.

The Principles of Gothic Masonry Structures

It has already been mentioned that the cathedrals of the Gothic period were constructed to convey a lasting impression of great height and maximum light. Walls began to be built ever higher and pierced at regular intervals with window openings. In order to emphasise the feeling of rising space, and to satisfactorily cast water away from the structure, the roofs were often of an extremely steep pitch (the choir roof at Lincoln Cathedral for example is at an angle of around 70 degrees), which made it necessary to place the mechanics of support on the exterior of the building, in order to contain the outward-pushing forces. The strength of the stone, employed in compression, operated easily within its crushing resistance, but the thrust from the high roofs and from soaring towers placed a great physical burden on the skeletal framework of the walls, tending to buckle them outwards. These tendencies were restrained by a system of buttresses, piers, and arches, placed at specific points of pressure, with little obstruction made to the interior spaces.

Structural Theory in Masonry

Modern building regulations state that 'the structure of a building shall safely sustain and transmit to the foundations the combined dead load, imposed load and wind load without such deflection or deformation as will impair the stability of, or cause damage to any part of the building.' (31) Although this stipulation was written during the present century, no part of its contents would have been unknown to the medieval builder, who reached all decisions intuitively or empirically.

Loads Imposed on Structures

With this understanding, several significant points can be presumed to have been considered by the master builder. In accommodating a level of tolerance relating to inevitable stresses and strains, both 'dead loading' and 'live loading' needed to be understood. The combination of these two forces create tension and are always present in built structures, the building design needing to incorporate methods of resisting them. The term dead load refers to that weight which is applied from above, including the weight of all materials and permanent fixtures. As the term implies these loads are static, and are unlikely to increase or decrease unless intended. Live loads, on the other hand, are those dynamic forces created by wind, rain, and snow, which impose variable stresses on the structure. As a consequence these are far more difficult to calculate and therefore resist.

Thrust and Counterthrust

Given that permanent buildings are subject to loads, due to gravity and the wind, in order to resist such forces a structure needs to possess the capacity to absorb them, to counter-balance them, or to deliver them safely to the mass of the ground. The builders of large cathedrals developed a system of thrust and counterthrust, the essential feature that characterises the Gothic, 'and not the rib vault and the flying buttress, as such.' (32) Buttressing can be placed directly against the walls, as at the Saint-Chapelle, Paris. (Fig. 1.8).

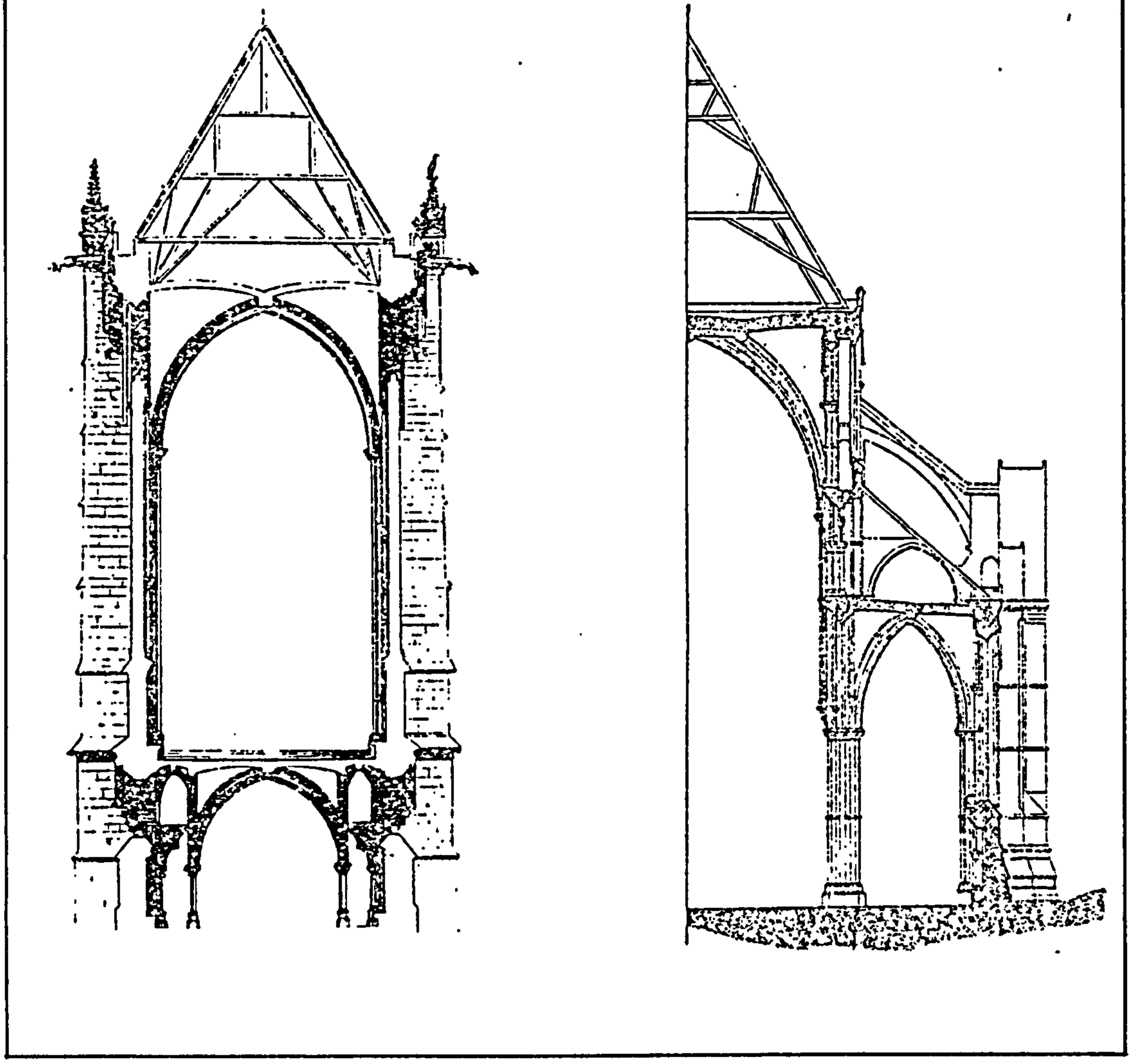

Fig. 1.8 Cross sections through the Sainte-Chapelle, Paris, and the nave of Lincoln Cathedral. Counterthrusts can be provided by direct buttressing against high walls, or through flying buttresses to bridge aisles. (HEYMAN, J. *The Stone Skeleton*, Cambridge, CUP, 1995, after Viollet-le-Duc 1858-68 and KENDRICK, A.F. *Lincoln The Cathedral and See*, London, Bell, 1898.)

Mainstone makes the following observations in relating thrust and counterthrust to simple human motions:

> 'Through feeling the actions of pushes and pulls on and through our bodies we 'feel' or 'see' similar actions, by analogy, in inanimate structures, and often such a feeling is almost inseparable from the purely geometric intuition of the role of a column, an arch voussoir, a buttress or a tie.' (33)

The forces and resistances that these constructions are subjected to are necessarily kept within a balance, with the arches and vaults of the aisles pressing into the middle area of the piers, forcing them into the nave or choir. At the same time the high vaults exert an outward pressure on the upper regions of the piers. The central four piers are likely to fare worse in this respect, since they cannot rely on abutment on two sides. Even the great lengths of the four arms of the structure are subject to distortion, which is symptomised in a racking motion, resulting in the upper reaches of the gables bowing outwards, despite the earnest efforts of the builders to direct the thrusts downwards as soon as practically possible.

The placing of squared blocks of stone, one on top of another in compressive building had hitherto proved adequate to basic human requirements, but the Gothic builders possessed a more adventurous spirit, denying material mass in construction. The early Norman builder constructed monuments as though building a mountain, introducing into it caves for dwelling and then gingerly piercing the walls to gain light. At this stage in development all loads were absorbed into the mass of the walls, but the Gothic builder in striving to admit more light, at the same time building ever upwards, developed a system of transferring forces through an elaborate network of arches, buttresses, and piers, to the mass of the ground.

These complex actions, with massive forces descending from the highest reaches of Gothic cathedrals, carry on even below ground. In fact, the stability of the entire structure relies heavily on a continuity of fixity, or bonding, through the point where superstructure becomes substructure. It can be seen at Amiens that the builders recognised the importance of this, taking enormous trouble in the preparation of footings,[1] though such thoroughness was not always felt necessary. At Salisbury Cathedral, recent strengthening work to the tower has revealed foundations of only four feet deep. Rigidity, it was realised by experience, was essential in the main 'props' of the superstructure, the buttresses and piers. The forces from high above could then be transmitted successfully through the stonework to the ground, within safe limits. This simple point is central to traditional masonry building and strives to deny, so far as possible, the opportunity for unsafe tensile forces to become too great a part of the constructional equation. Depending on conditions,

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[1] Beneath the Cathedral of Amiens are footings which extend some 8 metres (26 feet) into the ground and are comprised of varying materials. At the deepest point, above the natural clay, has been laid an initial layer of clay around 40cm thick, above which are 14 courses of mixed chalk and silica from a nearby quarry, finally topped by three courses of dressed sandstone.

the receiving ground can be regarded as an ideal arrangement for the ultimate abutment of the foundation. In the context of a thrust and counterthrust system of building, consistent with Newton's third law of motion,[1] the bearing capacity of the soil should be equal to the maximum forces it will ever be expected to contain from the building.

In the words of Viollet-le-Duc it can be deduced that accepted forces at work in the superstructure are effectively lured to the vault ribs and arches and dispersed to the ground:

> 'the whole structural system of the great naves is reduced to slender piers made rigid by the load, and kept in vertical equilibrium as a consequence of the balance achieved by the vault thrusts and the counterthrusts of the flying buttresses.' (34)

Through this series of slender piers and buttresses, the walls themselves were left to be exploited almost at will for the purpose of architectural decoration, sculpture and window spaces. The logical progression of this feature would eventually lead to clerestory walls becoming glass curtains such as at Saint Chapelle, Paris, and the choir of the Cathedral of Tours. It would have been quickly understood by the medieval builder that a large scale construction such as a cathedral would be subjected to immense tensile forces, with individual structural members becoming distorted in shape. Having at that time, no means to calculate deflection or the strains to which individual architectural members might be disposed before failing, the tendency to over engineer must have been hard to resist, but was severely tempered by the overwhelming need of the builder to reduce masonry mass in the structure and simultaneously admit more light to the interior of the building. Pressing economic factors of labour and materials used in the superstructure and the preparation of substructures could be reduced in more or less equal proportions.

Some Points Relating to Medieval Masonry Construction

Having no numerical understanding or method of calculating the stresses and strains in building, the medieval mason had also no scientific concept of establishing margins of strength in materials. The choice of stone as the primary material for construction of cathedrals, itself unwieldy, slow to process, and costly in comparison with wood, was most likely made initially through military imperatives and the avoidance of deliberate or accidental fire. By the time of the medieval building boom of the twelfth and thirteenth centuries, the mason had supplanted the carpenter as master of the trades. Continuity was given to skills of all the trades through rigorous training , a large measure of the success of which, through a direct transfer of skill and understanding, would have been the acquisition of intuitive understanding of materials and structures. At the same time, the rapid development of Gothic building was enabled by the apprenticeship system, with secrets of technical and aesthetic understanding jealously guarded and passed on in meticulous detail.

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[1] Newton's laws of motion are the fundamental laws on which classical dynamics is based. The third law - *To every action there is an equal and opposite reaction.*

The realisation that fundamental masonry structures could survive by virtue of a large factor of safety further persuaded the paring down of structural elements and greater control of the paths of compressive forces. Safety in experimenting along these lines was achieved partly by building in bays, with the threat of consequent collapse limited to a single portion of the building. Experience guided the mason in selection of materials, and in the characteristics of individual stones and their most favourable attributes for the purposes of construction (See 2.3 *Selection, Design, and Craftsmanship*).

In attempting to expand the limits of spiritual, creative, and technical expression, many errors in building were doubtless made and learned from. Masons must have become convinced that only the most minor tensile forces could be successfully employed using stone, its modular use relying on weak mortar joints that were incapable of transferring the slightest tensile force. If stability was to be assured it would be achieved only by obeying the force of gravity. In the case of masonry structures: 'a general state of compressive stress exists, but only feeble tensions can be resisted.' (35) In order to successfully predict the performance of proposed buildings, the medieval mason had to rely on intuition and experience, and it was not until the 19th century and the advent of new materials for use in construction that the science of mechanics was absorbed into theories of structural analysis. Up until then, the crushing resistance of stone was presumed to be far outside any demand placed upon it.

> 'It is convenient to recall that 19th century engineers expressed the strength of stone, not in terms of stress, but in terms of another equally good parameter, the height to which a prismatic column could be built before crushing at the base under its own weight.' (36)

If typically vulnerable masonry elements are similarly calculated, for instance a wall, column, or pier, it can be seen that these 'carry essentially their own weight [and] have a stress level of the order of one hundredth of the crushing strength of the material.' (37) At this point it is worth suggesting that decay might provide an influence which would seriously undermine the above assumptions, which assume that all elements are uniform, a point which emphasises the need to maintain good order in all parts of the structure.

The Nature of Foundations

The principal task of a foundation is to 'distribute the loads from roofs, floors and walls on to the earth below.' (38) These actions should be transacted as evenly as possible, ensuring that loads are transferred to the ground over a sufficient area to bear it safely. The area over which the load is spread is calculated against the nature of the load and the bearing capacity of the soil. Ground support is dependant on the behaviour of soils when subjected to loading. This will include both the imposed and dead loads of a building and can present complex problems. Distortion which may occur within the soil will be reflected in the distribution of stress in both the foundation and the

superstructure, so it is essential that once loads are established any ground movement is kept to a minimum. If movement appears to be unavoidable, it should be determined as either capable of being accommodated by the design of the superstructure or a remedy offered. Analysis of these problems relies on the disciplines of soil mechanics and structural mechanics.

There are two modes of distortion in ground conditions, each expressing distinctive patterns of cracking in building. These are usually referred to as sagging, and hogging. The former term describes the soil distorting in a manner resembling a saucer, with a dip in the middle. In hogging the distortion creates a hump. Low buildings are most vulnerable to cracking, and typical patterns of this will be will be described in the section *Foundation Failure*.

A Brief Note on Historic Foundations

The medieval empirical approach to building construction, it may be presumed, extended to those invisible elements which attest to its success, as well as the more obvious aspects. The technical understanding of the Roman builders and engineers did not survive into the Dark Ages, even though it had been chronicled meticulously by the architects Vitruvius and Alberti. Experiment was the only way forward for the medieval engineers. 'Foundations were a matter of guesswork, based certainly on experience but without any way of being verified' (39) The objective of the medieval builder was to establish a foundation technology adequate to carrying the massive loads of the great cathedrals. 'The fact that their works continue to stand is a memorial to their practical rather than to their theoretical skills.' (40)

The Romanesque builders generously over-engineered their structures, a feature that often also applied to the preparatory work below ground. 'The foundations of the Norman Durham [Cathedral],' wrote Francis Bond, 'were carried down more than fourteen feet, till the solid rock was reached,' (41) In describing the foundations of the north choir aisle at Durham, he observed that they 'are so broad as to provide a footing both for the buttresses outside and the bases of the vaulting shafts within.' (42) On the continent during the same period, according to Jean Gimpel, 'foundations of the cathedrals are laid as deep as 10 metres.' (43) Learning by experiment, however, inevitably incurs a level of failure, especially when there is the temptation to economise. Many collapses occurred due to inadequate foundations, as at Gloucester in 1170, when the north-west tower fell because of bad foundations. Frequent use was made of vertical timber piled foundations, as found at York in excavations in the 1970s, where they were even given iron-shod ends. Similarly piled oak foundations failed badly at Winchester and remedial work had to be carried out in the early part of this century, The third abbey of Croyland was reputedly destroyed by an earthquake, although subsequent archaeological excavation discovered that in places the 'foundations consist largely of layers of quarry dust.' (44) In these instances, the compacting of the subsoil 'with frequent blows of rams' (45) would have preceded the laying of other materials.

Ground Soils

Soil can be defined as 'the accumulation of loose weathered material which covers the land-surface of the Earth to a depth ranging from a fraction of an inch to many feet.' (46) Beneath the soil and above the bedrock is a layer of partly weathered rock known as the subsoil, and the geological term for both layers is the regolith. In engineering terms, the term 'soil' is applied to 'any soft, unconsolidated, deformable material.' (47) This study is primarily concerned only with the latter application. For construction engineering purposes the variable soil types can be conveniently divided into two separate categories. These are sandy soils and clay soils, and are defined respectively as non-cohesive (granular) and cohesive soils.

- Non-cohesive Soils (sands and gravels): These are composed of large particles of rock, with consequently large pore spaces between. These particles are chiefly quartz and remain both non-absorbent and indestructible. Settlement occurs rapidly once loading is imposed, which is due to the ease with which water movement is permitted to occur. Once total compaction has occurred the soil remains virtually unaffected by moisture changes.

- Cohesive Soils (clays and silts): These consist of fine mineral particles and changes in moisture will fundamentally affect their equilibrium. Water assimilation can considerably alter the size of the overall matter, either by expansion on absorption, or contraction on drying out (desorption). Movement of this nature is exaggerated as the ratio with any larger or coarse-grained particles is reduced. Some cohesive soils, known as 'fat' clays, actually retain water within their molecular structure. All clay soils are seriously affected by the presence of vegetation, notably large trees, which demand large quantities of moisture and can cause rapid drying and shrinkage, resulting in cracking of nearby building structures. 'In the UK the seasonal nature of the moisture content changes in clay soils is significant.' (48)

Typical Traditional Foundations

Different types of foundation are designed to contend with certain soil types, in order to fulfil their principal function. Taking into consideration both the nature of the soil and the details of the load, the following examples are typical:

- Pile foundations are used in the case of extremely poor soils where the load must be transferred to lower ground level. This can be effected by a system known as 'end bearing', with timber columns extending to a more solid strata, or the 'friction' method, where timbers adhere 'by the friction and adhesion to the soil.' (49)
- Vertical pile foundations were often employed by the medieval builders. At Winchester Cathedral loads were consigned along oak and beech tree trunks, necessary due to the inadequacy of the upper ground. Alder tree piles were employed at York Minster, and mention is found of mechanical pile driving 'rammes' (50) at London Bridge.

- Strip Foundations are effectively continuous masonry walls, which are used below ground level to deliver loads from the superstructure to lower and firmer ground. The walls may be supported laterally by abutment and be of varying depth and width, depending on variable soil conditions. This system of transmitting loads is common throughout the history of construction and is referred to as a 'footing' (Fig. 1.9).
- Raft Foundations are employed where a soil is very weak. A continuous slab, or raft, made of coursed stones or concrete is used to distribute loads over a wider area, 'large enough to avoid overstressing the soil beyond its bearing capacity.' (51)
- Isolated Pad Foundations are independent pads, or small rafts, similarly constructed to raft foundations, that are used to support framed buildings. Particular attention should be made to avoid differential settlement.

The Effects of Loading on Foundations

Settlement of the soil upon which a structure is built will take effect as compaction or consolidation occurs, causing a downward movement. Water is displaced from between the particles of the soil and driven to areas where there is less resistance. The extent of settlement will depend on the type of the soil and the total load placed upon it. Time is a feature in the action of settlement, since building construction occurs gradually, and as other environmental actions occur over a greater period.

Total or absolute movements of a building give less cause for alarm than differential movement, since the distribution of loads remains equal. Differential or relative movement can be a major cause of stress in building structures, causing cracking and crushing, as unequal loads become imposed on supporting areas that are unable to contend with them:

> 'loads are concentrated on to piers and buttresses enabling the windows to be large, and this means that not only are differential settlements likely unless the original foundations took this into account, but also that they can within reason be accommodated.' (52)

This was particularly taken into account by the medieval builders, who employed in their major structures a system of thrust and counterthrust. Ground movement is a common phenomenon and is caused by a number of actions, the principal of which are as follows:

Fig. 1.9 A typical strip foundation. This one is of Norman origin, and was exposed during the laying of electricity cables in the north transept at Lincoln.

- Continual geological movement, which can be traced back to a process known as istostasy.[1]
- Mining and underdrainage, where cavities are created underground, creating pockets of low resistance to loads of greater pressure.
- Landslip which can be created by heavy rain.
- Underground streams creating pot-holes and cavities in soils comprised of chalk or gravel.
- Diversion or abstraction of groundwater causing certain soils to shrink, i.e. peats and clays.
- Water tables rising where watercourses become blocked.

Foundation Failure

Any of the above causes of ground movement will cause weakening of the soil, and lead to at least partial foundation failure. In turn, unequal loading may eventually occur within an historic structure and stresses such as these will tend to encourage masonry shear, manifested characteristically, in vertical cracking. Load bearing masonry walls, comprising of two dressed skins and a rubble core, may be subjected to unequal stress, with one side carrying the greater load. The symptoms of this is characterised by snipping, or spalling, of the front arris, is in figure 1.10c. That side may as a consequence sink, leaving the other side relatively stable, again precipitating cracking. This symptom is referred to as differential movement and is countered by the building bearing down evenly on firm ground (Fig. 1.10).

Shear cracks can be created in these conditions and require a greater level of attention than mere patching, or other superficial repair. The source of the ground movement will probably require the investigation of a structural engineer, who may recommend underpinning or the introduction of a system of concrete piles. The conditions which create a secure foundation are the same elements which should be examined where failure occurs. In the case of an historic structure, the original foundation may have been subjected to deteriorating influences, which have brought about a change in loading function. As the foundation was empirically designed, it may never have actually operated within a satisfactory margin of safety. During a lecture given by Dr Malcolm Bolton of Peterhouse College, Cambridge, a simple conclusive statement was commended: 'If an existing building suddenly starts to deform, and the foundations come under scrutiny, suspect groundwater changes, and look at the drains.' (53) It must be recognised, he implied, that foundation engineering had now developed into a sound scientific discipline, based on quantitative methods. Where problems occurred and site investigations were commissioned, sound judgements, based on reason, were generally available.

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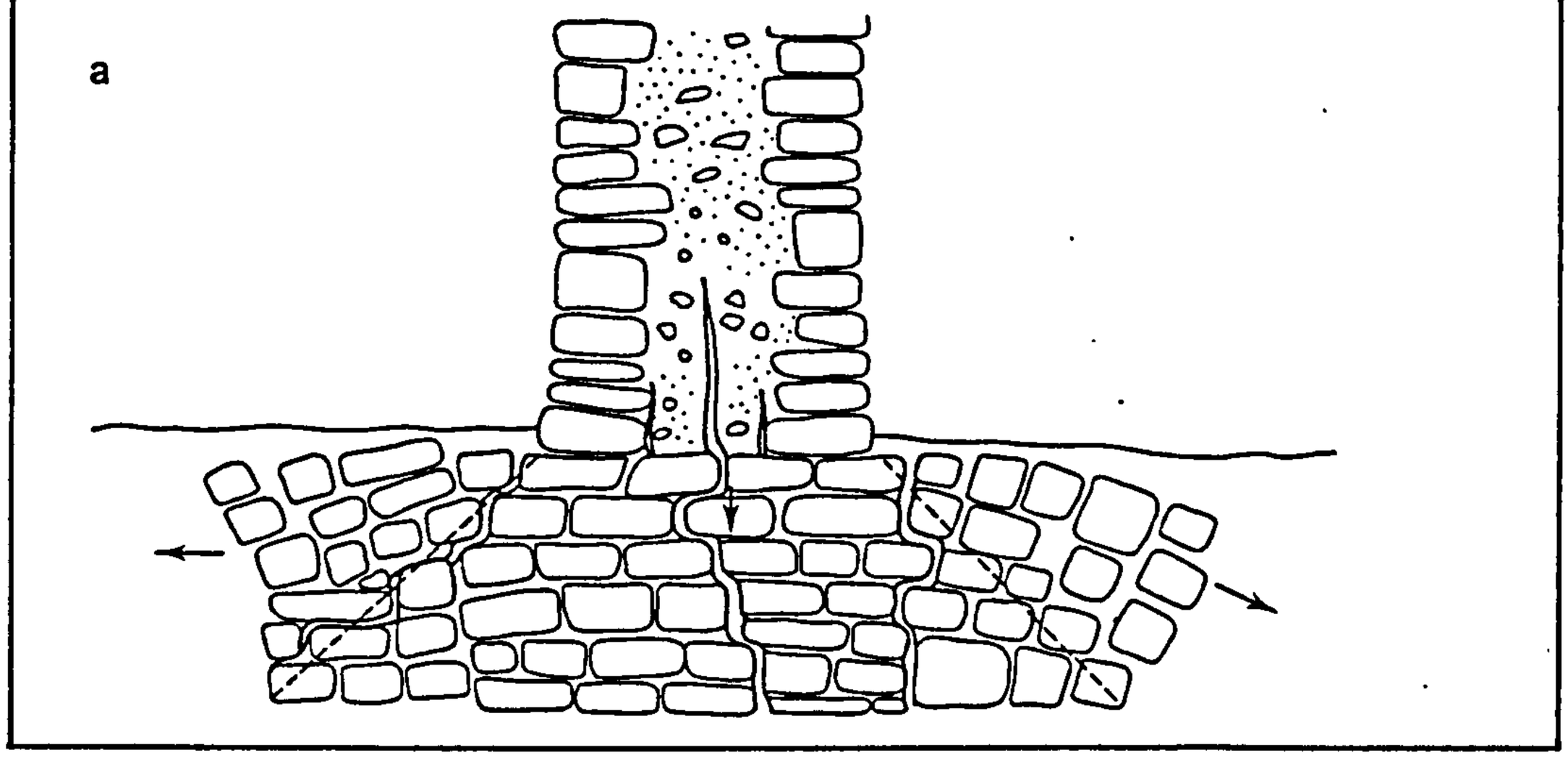
[1] This is 'the tendency of the Earth's crust to maintain a state of near equilibrium, ie if anything occurs to modify the existing state, a compensating change will occur to maintain a balance.' WHITTEN and BROOKES *Penguin Dictionary of Geology*, Middlesex,1972.



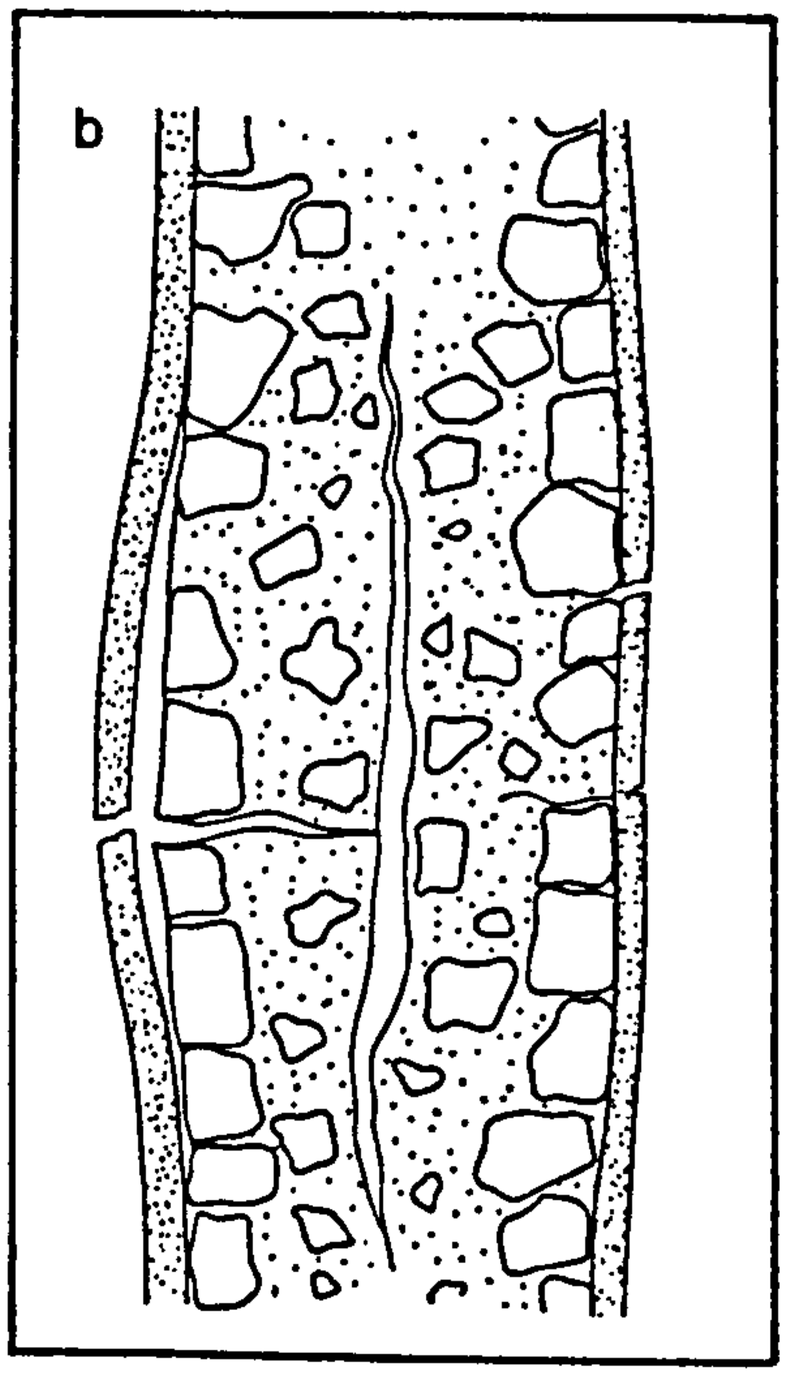
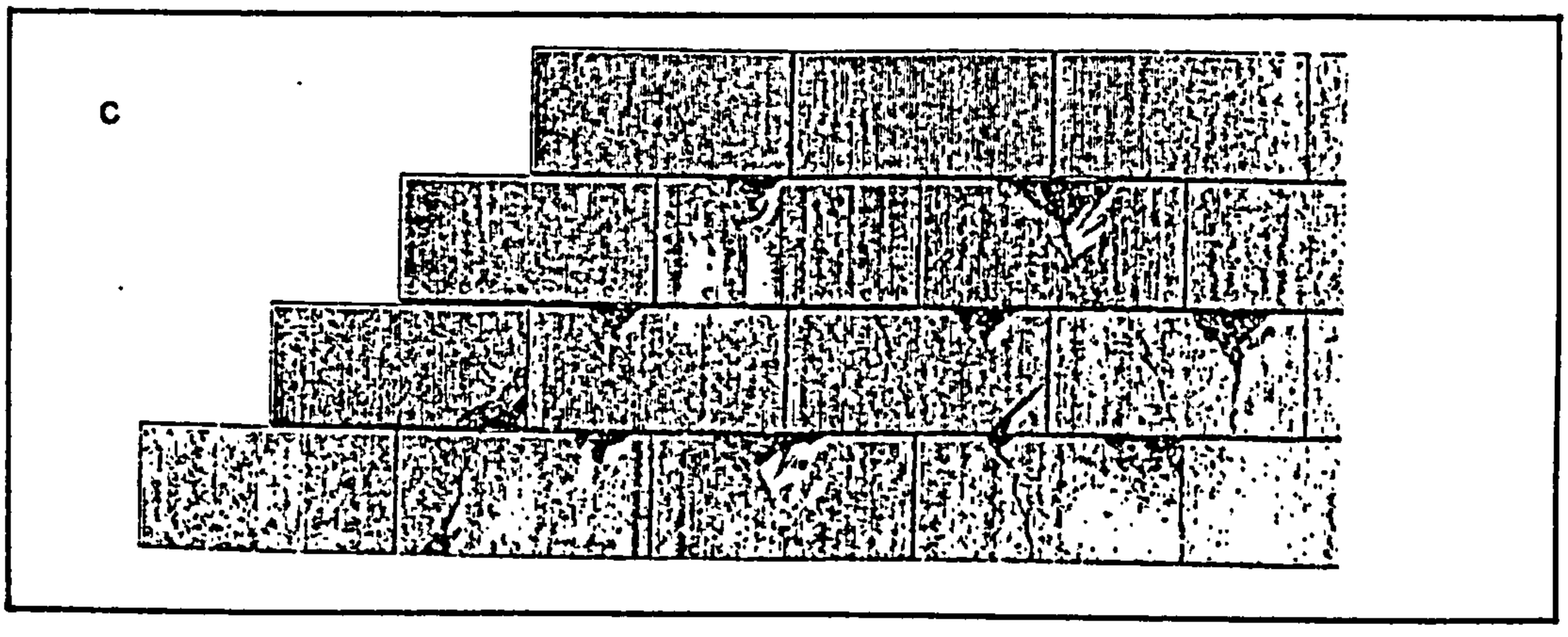


Fig. 1.10 Foundation / wall failure

a). Weakening of foundations causing cracking and separation of wall skins (FEILDEN, B. *Conservation of Historic Buildings*, London, Butterworth, 1982)

b). Differential settlement leading to local bulging of external masonry, and further weakening within the core (Ibid.)

c). Uneven pressure on walls creating cracking through stones and spalling arrises (HEYMAN, J. *The Stone Skeleton*, Cambridge, CUP, 1995. after Rondelet 1834.)



In the case of an historic site, with a long established structure, it is possible to point to a number of likely reasons for foundation failure. The immediate vicinity of the ancient site, in contrast to the monument itself, will probably have been subjected to an almost continuous succession of (more

or less dramatic) changes in exploitative nature. Such changes, the results of development, demolition and decay may have introduced influences on the stability of the soil. Such effects can be passed on, causing movements in adjacent structures. Alterations in local ground conditions, and therefore in foundations, may disturb the stability of the historic structure. For example, the balance may become disturbed in the direction of thrusts from roofs and vaults. Stresses are thereby imposed on the fabric which were never anticipated in the original design scheme. It is therefore essential in the maintenance of the historic building to establish a continual informed view of the adequacy of the foundation.

Investigation of Foundations

Modern methods of ground study are known as soil mechanics and owe their origins to Coulomb in the 18th century. This area of study concentrates on 'the nature of soils defined by the size of the particles and their geological origin.' (54) An immediate visual inspection will look for ground deformation as well as other obvious areas of weakness occurring close to vulnerable structures. These may include towers, bulging walls, and functioning buttresses (as opposed to the many decorative buttresses which were often introduced into a building's design for reasons of symmetry). Ground which slopes away from a building is clearly less able to provide the necessary abutment to resist the loading forces delivered from roofs, arches and towers, via the buttresses and walls. The causes of deterioration which attack the superstructure of a building, such as moisture ingress and attendant salt attack, (See Part 2.0 *The Agencies of Deterioration and Design in Limestones*) can also present a cause for concern in the decay of foundation material. The cycles of wetting and drying which precipitate salt crystallisation should therefore be the subject of examination.

A general foundation inspection should involve the collation of all available information, including plans of the building and where possible of adjacent buildings, as well as local archaeological investigations which may have been written up. This latter source of information may point out possible hazards such as ancient burial grounds, undercrofts, or other below ground structures belonging to earlier established sites which may be subject to collapse. Added to this information will be any new findings, the result of exploration. This may be merely from the digging of trial holes, or it may necessitate the drilling of bore holes in order to facilitate the extraction of soil core samples for analysis. Holes left following this action will need to be methodically plugged in order to keep out excess water, which might run the risk of altering the water table. The bearing capacity of the soil established, any structural intervention which may prove necessary may then proceed.

Remedial Action to Historic Foundations

In order to rectify inadequate foundations, either of two main courses of action can generally be called upon. These are foundation enlargement, or underpinning. Before intervention in any historic foundation, careful consideration should be given to the masonry structure above. If there is insufficient strength within the stonework, any interference below will merely exacerbate its poor condition. The effective enlargement of a foundation, in order to better resist the loads from above, will rely heavily on any new work being adequately bonded to the old. This can be implemented by a system of post-tensioning, which is a way of adding tensional strength to a material, usually concrete in the case of foundations. Traditionally, a steel wire lattice was used, but in modern work an anchorage point is established to which is secured a series of fixings. In the case of the central tower of York Minster, where a concrete collar was cast around the base of the main piers, 'a simple concrete retaining wall [was installed] to act as an anchorage for the tension bolts' (55) (See 3.3 *York Minster Restoration* (1966-70)). The newly extended foundation may not take up loads until some movement occurs in the superstructure. This can be achieved, however, by employing a system of expanding jacks, and compression pads. Once the loads are equal to those already existing, grout is poured into the voids in order to maintain established pressures.

Recognition of foundation inadequacy seems to have long concerned those charged with the care of buildings. Salzman refers to the Peterhouse Roll, which alludes to 'pynning' and 'underpynning' as early as 1375. (56) Underpinning can be defined as the removal of deficient footings and the substitution of new and larger ones. Care must be paid to the shifting of loads as short sections of the old foundation are removed. Again, by employing methods using flat-jacks, the loads may be controlled to equal those already present. Expanding grouts, poured into the voids after the loads are taken up will maintain them. It is worth considering at the time of underpinning, whether a damp proof membrane (DPM) should be inserted between the new concrete and the ancient masonry. Ordinary Portland Cement (OPC), contains calcium sulphate, introduced as a setting-time agent. Calcium sulphate may migrate into the pore structure of the stone and cause damage on crystallisation when drying. A massive acceleration of salt decay to the plinth course and surrounding areas occurred to York Minster following the restoration of the foundations. It is questionable whether a DPM should be introduced in such cases in order to prevent soluble salts from the Portland cement concrete migrating upwards into the masonry and causing extensive disruption to the surface of the stone.

Traditional Methods of Walling Construction

There are two main methods of stone walling, rubble and ashlar walling. This study is primarily concerned with the second category, but the first should be considered since there is a line of development essential to understanding the varying levels of workmanship found in buildings.

> 'Far and away the commonest type of masonry for our old stone buildings is rubblestone, bedded in mortar. This was not only the least expensive way of using stone, but with many varieties it was the only way. ' (57)

It may also assist in understanding the particular skills required to maintain such structures, as well as the deficiencies and confusion that exist in the trade of stonemasonry. In both types of wall, the stone is dressed, or worked on the exposed faces, which are referred to as 'skins'. The core, or infil, between the two skins of ashlar walling is itself comprised of an extremely crude assemblage of lime mortar and rubble, a feature that ought not be underestimated. In the case of the Romanesque Frieze on the west front of Lincoln Cathedral, (See 4.3 *The Romanesque Frieze: A Case Study in Policy Shaped by Practice)* structurally inferior stretches of stone are supported by a carefully constructed core which is essential to the equilibrium of the wall. The logic of construction applies to both techniques and may be no less refined in what is ostensibly cruder walling.

Rubble Walling

Rubble walling consists of random shaped stones, which would have been found naturally in or on the surface of the ground. Developing from this primitive method of walling came the idea of dressed rubble, forming a crude locking system which required less bonding material, ie mud or mortar, and a far more durable structure would have been constructed. Often, as in Saxon building, large quoin (corner) stones were utilised, with the infil merely relying on smaller and flatter stones. In all rubble walling methods long 'through' stones, known as 'bonders', serve to stitch the two outer skins of stone together, with the core being filled with dry rubble, or rubble mortar. There are many variations on the theme of building with rubble, and the following are a sample of those most often used, sometimes in the context of sophisticated medieval buildings.

- Random rubble walls are built from found stones, with no attempt to create courses. This is the least expensive method of building a stone wall and can be either dry, ie without a mortar joint, or jointed with mortar.
- Coursed rubble walls are built of roughly hewn stones which crudely form courses, with larger stones establishing a strengthening link across the smaller courses. These sometimes utilise larger stones at the quoins.
- Squared rubble walls use stones which are made roughly rectangular so that the fit is tighter and the joints smaller, making the wall stronger.
- Coursed square rubble takes the above process a stage further, establishing greater uniformity between the stones and consequently creating a neater and stronger structure.
- Polygonal walling is a vernacular feature, with shallow flat stones placed off the natural bedding plane, thus relying strongly on mortar adhesion. This style of walling is common in Kent where there is little sizeable stone to be found, and where it is known as 'Kentish rag'.

Ashlar Walling

Ashlar walling, is the system with which this study is primarily concerned, being successfully developed and adapted to Gothic construction:

> 'The word derives from the latin axis or assis, meaning originally a little plank or board: an example, not unique, of a masonry term originating in the practice of timber building, since the use of wood preceded that of stone. It is never applied to moulded work; it is just the plain facing.' (58)

Ashlar walling relies upon the sophisticated craft of stereotomy, which is literally the section-cutting of solids, in this instance the shaping of interlocking stones with the intention of forming a durable masonry structure. The stone to be used is referred to as a 'freestone', a term which implies that it can be satisfactorily cut in any direction irrespective of its bedding plane As a method of building, therefore, ashlar work is highly labour intensive, with that labour requiring also to be highly skilled, thus making it expensive. As a method of construction, even in medieval times, ashlar walling was employed only on the most prestigious of projects.

In a manner somewhat similar to rubble walling, ashlar walls are built of two skins of dressed stonework, with the cavity being filled with rubble and lime mortar as construction proceeds. Regular deep stones are placed so that they penetrate from the face well back into the core, providing a locking mechanism which helps to hold the wall together. Through stones, or bonders, may also be introduced, as with rubble walls. Three main types of ashlar wall may be outlined and described as follows:

- Plain ashlar 'is the term used for finely dressed stone which is worked to fit in the general face of the wall.' (59)
- Rusticated ashlar describe the type of ashlar where it projects from the face of the wall, with an angled margin forming the wall-line behind.
- Reticulated ashlar has a cleanly worked rebate around the face of the stone, thus appearing to separate the individual stones of the wall.

Medieval walling construction, as employed in Gothic cathedrals, is comprised of plain ashlar. As masonry abilities developed through the twelfth and thirteenth centuries, with stone cutting skills and building technology advancing simultaneously, stones were made to fit tighter together, reducing the threat of weakness in the joint. The ability to set-out the proposed construction beforehand in two dimensions developed alongside these hand-skills, helping to make joints narrower, creating a structure which bonded together and presented a steadily improved resistance to the elements (Fig. 1.11).

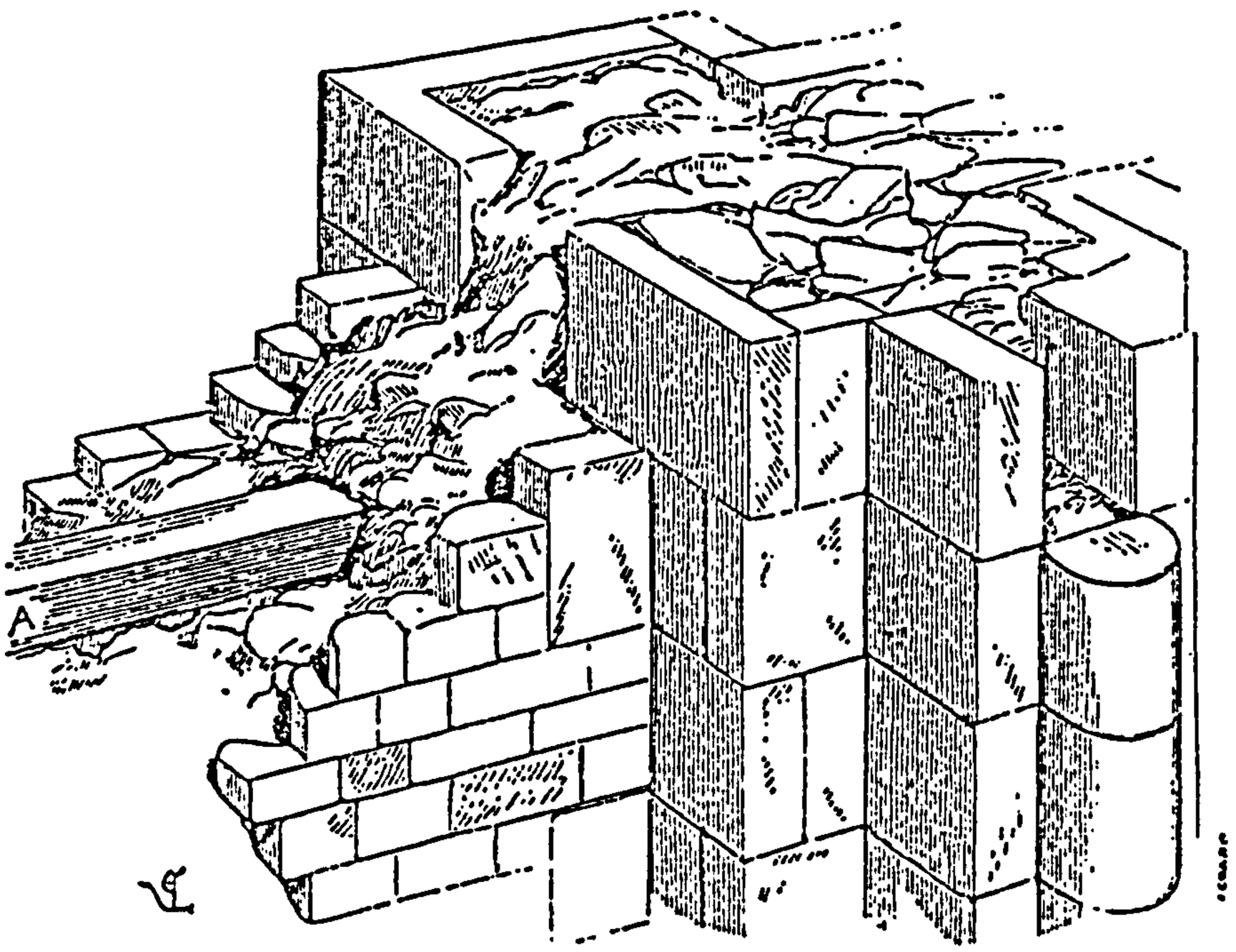


Fig 1.11 Well-bonded ashlar wall with compacted mortar and rubble corework. (VIOLLET-LE-DUC, E .E. *The Foundations of Architecture*, New York, Braziller, 1990.)

Masonry Joints

Mention should be made at this stage of masonry joints, as they form an inherent part of both the strengths and weaknesses of the wall, being the interface of what is essentially a modular structure. Traditionally the masonry joint is comprised of lime mortar and is weaker than the stone it separates, performing as a gasket around the stones rather than offering any adhesive properties. Cohesion is maintained strictly through the compressive properties of the structure: 'Thus the assumption implies that no tensile forces can be transmitted within a mass of masonry.' (60) Although the weak masonry joint may inhibit even the slightest possibility of tensile resistance in a stone wall, it does provide several significant benefits which effectively enhance the overall resilience of the wall. The masonry joint yields readily to the effects of cracking as the structure endures the stresses and strains of change around it, rather than diverting such stresses into the primary material, the stone itself. At the same time, the porous nature of the mortar joint encourages the collection of residual moisture in the wall, including inherent salt products, effectively luring it away from the stone. The porous lime mortar joint, the consistency of which for these reasons must be weaker than the stone, allows easy egress to the moisture, either by seepage or by evaporation. It can be understood that the mortar joint is eventually affected by constant filtering out of the polluted moisture from the structure and can be defined as sacrificial. Too much emphasis cannot be placed on regular maintenance of joints.

Common Symptoms of Failure in Walls

If a wall is built with good quality stones which are effectively bonded and bedded using a compatible mortar on a firm foundation, it should possess the ability to resist live and dead loads, and there ought to be no reason for it to fail. In cases where the equilibrium of a wall is disturbed due to a change in the nature of one or more of these factors, early attention is best given to arrest the problem and the threat of further deterioration can be reduced by being monitored. Some capacity to absorb movement is normal in a masonry wall and the extent of it is not as relevant as differential movement within the foundation, due to forces greater than it can withstand. The problems may be due to causes described earlier, such as changes in ground water, but an assessment will be more complex. The dangers of cracking are less severe than bulging, which may lead to collapse.

The danger presented by cracks is that they allow rain and air penetration, which can lead to further instability due to the eroding of the mortar core. It should be established initially whether the cracking is recent or historic and whether it is fundamental or local, ie. structural or superficial. Vertical cracks of parallel width are generally caused by climatic changes, for instance where a wider range of temperatures exist. Cracks that are of a varying width, however, can indicate some rotation in the wall, causing a curvature of the structure. Horizontal cracking along the bedding joint tends to suggest either the presence of an alien material in the joint such as an iron fixing, or

a sliding action in the structure. The latter indicates that the wall may be under some exertion other than a compressive, or vertical one, for which it was not designed (See Fig 1.10 p 32).

Potentially a far greater problem is the bulging of masonry walls where more fundamental structural issues are implied. This may point to a sudden change in conditions which the structure cannot endure for long. Shrinkage in materials may be involved, or a change in the ground conditions. Thermal movements between different materials may also be indicated, which could lead to separation of the two masonry skins of the wall. Cavities in a wall of any sort will disturb the equilibrium of loading, with the core becoming an ineffectual structural element of the wall, eventually encouraging further fracturing of the stonework. Thus a cycle of deterioration is established. Original or subsequent design deficiencies in a wall can invite water build-up, initially on the surface, but leading to eventual ingress and encouraging partial or total breakdown in materials. Structural movement of any kind may displace elements of a wall, once again leading to a deflection in the transmission of loads and to further damage.

It is advisable that a critical view of the complete structure is maintained when assessing a masonry wall and to test its efficiency on a continuing basis if possible. For instance, there is usually a logic to walls that is often simple to detect, and the ability to carry loads without risk should be confirmed. Cracks in masonry are not in themselves of great concern, but they can obstruct services within walls, such as doorways, gateways, or pipelines. It has been mentioned that moisture can penetrate cracks and create even greater problems in the long term. Bulges in walls may be relying solely on mortar for adhesion against gravity.

The Masonry Arch

The liberating architectural advancement in Gothic building was undoubtedly the pointed arch, eventually leading to the development of the flying buttress and the full realisation of the Gothic masonry vault. Whereas in the earlier style of the Romanesque period the arch was confined to the semi-circle, a limitation which severely restricted the span-to-height relationship, the advent of the pointed arch released the medieval builder from any such constraint. The semi-circular arch, where it was necessary to employ varied spans, as in the diagonal vault rib and the transverse rib, required the springing point to vary accordingly. This practice was known as 'stilting', and imposed enormous loads onto the structure, necessitating its masses to be substantial. The innovation of the pointed arch, around 1150 at Saint-Denis and Chartres, appeared to have been received with alacrity by English builders. Whereas in 1150 there are no recorded examples of the pointed arch in England, by the year 1220 (at the outset of the building of Salisbury Cathedral) the style was common throughout the country.

Structural Theory of Arches

It was the physicist and civil engineer Coulomb who first seriously sought to analyse the behaviour of structural elements, his principal objective being to establish the parameters within which they would safely function. As Heyman observes in this context, 'words like satisfactory and safe may appear to be clear, but they carry no numerical meaning.' (61) It is important at this stage to outline briefly how an arch can positively adapt itself to any minor shifting of its abutment. In principle, an arch may fail where a state of equilibrium is not maintained, for instance the upper portion may desire to move across the lower sections. With masonry voussoir arches this is highly unlikely to occur due to the dimensions, friction, weight, and interlocking action, as well as other physical characteristics of the material. Attention was given to this possibility in the building of Gothic churches and cathedrals, with what appear to be meaningless pinnacles being placed above the receiving points of flying buttresses. The intention was to compressively pre-stress the masonry in order to prevent sliding, creating in the flyer what may be described as the perfect prop. If the horizontal pressure at the crown of an arch is either dramatically increased or reduced, the line of thrust within the arch will be forced closer to the surface and the voussoir joints will be inclined to open up, buckling outward or inward, respectively. This mechanism of adjustment is known as 'hingeing' and subtle signs of the tendency give an indication of the performance of that part of the structure.

The Middle Third Rule

In 1675 the scientist and engineer Robert Hooke (1635-1702)[1] made a statement which explained the structural equilibrium of the arch: 'As hangs the flexible line, so but inverted will stand the rigid arch.' (62) This theory is represented most literally in the architecture of Gaudi, his forms seemingly fluid, though conforming to Hooke's definition of the inverted catenary. (FIG 1.12) This rule for stability is that the curve line of pressure must reside within the middle third of the intrados and the extrados, ie the inner and the outer contours of the arch, although this safety margin is contested by Fitchen who maintains that safety lies within the middle half:

> 'Thus if the line of pressure passes too close to the intrados of the arch at its haunch, the arch will crack and burst outward there. Again, if the buttress is too shallow a projection at the ground level, so that the line of pressure passes too close to the outside face at this point, the buttress is in danger of overturning by failing to prevent the arch from spreading at the springing.' (63)

These pressures are themselves determined by the horizontal and vertical forces and are a result of the total wedge action of the arch stones, and the weight of the masonry and other superimposed loads bearing down on the point at which the lateral thrust of the arch is functioning.

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[1] The seventeenth century scientist, Robert Hooke (1635-1702), developed a law relating to the resilience of solids, whereby the power of a spring was in proportion to its capacity to extend. This, he proved, was in accordance with the rule of nature, upon which all springing motions rely.

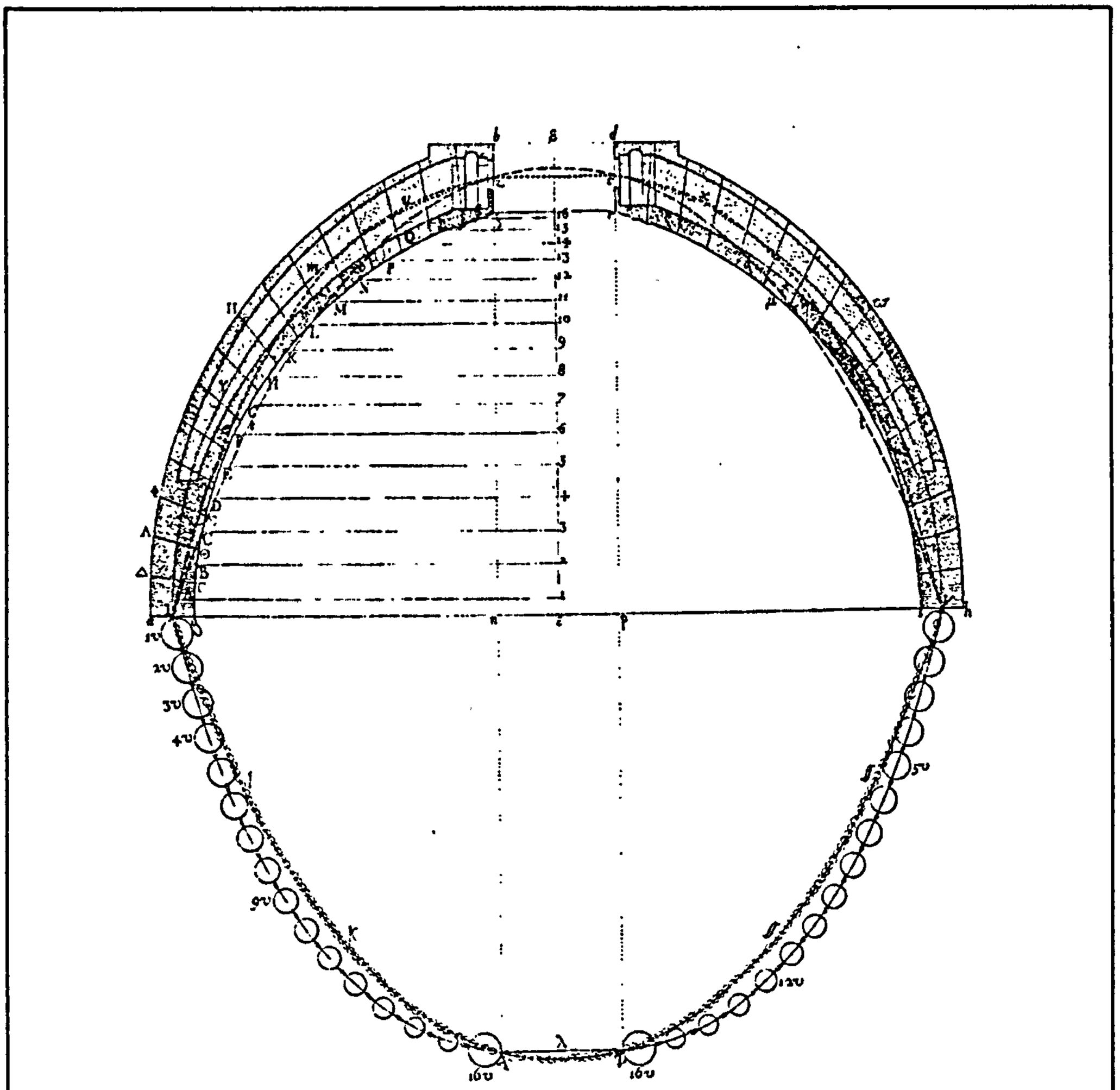

Fig 1.12 Hookes's inverted catenary (HEYMAN, J. *The Stone Skeleton*, Cambridge, CUP, 1995, after Poleni 1748)

Some Observations on the State of Arches

An arch is restrained by its abutment and held rigid by the horizontal force at the crown. In the case of flying buttresses the likelihood of slip is reduced by the weight of a pinnacle. Should the abutment move, as is virtually inevitable due to ground shrinkage, settlement, etc, the arch must spread to fit the redefined span. This distortion will create hinges and be manifested by cracking, which can be pointed up, leaving the arch to be regarded as a satisfactory and flexible structural element. It is accepted that arches comprising of stone voussoirs will resist any tendency to slide. Add to this the knowledge that the weak mortar joints between the voussoirs will not transmit tensile forces and that the stone itself is operating easily within its compressive strength, and a theory of arch action can be said to be established (Fig 1.13).

Medieval Masonry Vaulting

The single most destructive threat to a medieval building was always fire, recognition of this being attested by the pursuit of permanence in building construction. Stone was the material least likely to be destroyed by fire and was quickly adopted for the purpose. An immediate problem presented itself, however, in how to span the roof space. The most primitive notion of a vault is the extended, or tunnel arch, known as the barrel vault. This held intrinsic limitations, both structurally and aesthetically, bearing in mind the aims of achieving soaring height with optimum light. In order to achieve height of any magnitude, employing only the simple semi-circular arch, the amount of abutment required to contain the massive outward thrusts was prohibitive. The continuous arch of a barrel vault required a correspondingly continuous and thick wall to absorb the loads. This can be understood in reference to the middle third rule. At the same time, it would have been regarded as structurally unsafe to pierce the vault wall for windows, since this would have rendered the structure unstable. Therefore, the twin aims were at once defeated, leaving the demand for a more sophisticated method of spanning space.

In order to limit abutment it was necessary for the line of thrust to be delivered more directly to ground and this was achieved by means of the pointed arch. Just as related problems in arch construction were resolved through their distress, so the vault developed through a range of solutions. The barrel vault was followed by the simple groin vault, a three dimensional development of two parallel arches, employing the intersection of two extended semi-cylindrical arch tunnels. The domed ribbed vault advanced as more practical methods of vault construction were sought. The salient rib at the groin, brought with it a flexibility of thinking in the design of vault systems. 'The progress of refining the structure - of relating and unifying its component parts - developed rapidly.' (64) Still, the disadvantage remained that this system of vault could accommodate only square bays. A major link towards the mature Gothic vault came with the idea of an extra transverse rib, leading to the sexpartite vault (Fig 1.14). At this stage it became clear that loads could be concentrated and economically distributed to ground by a system known as the tas de charge (Fig 1.15). With walls and piers not now requiring to be so thick,

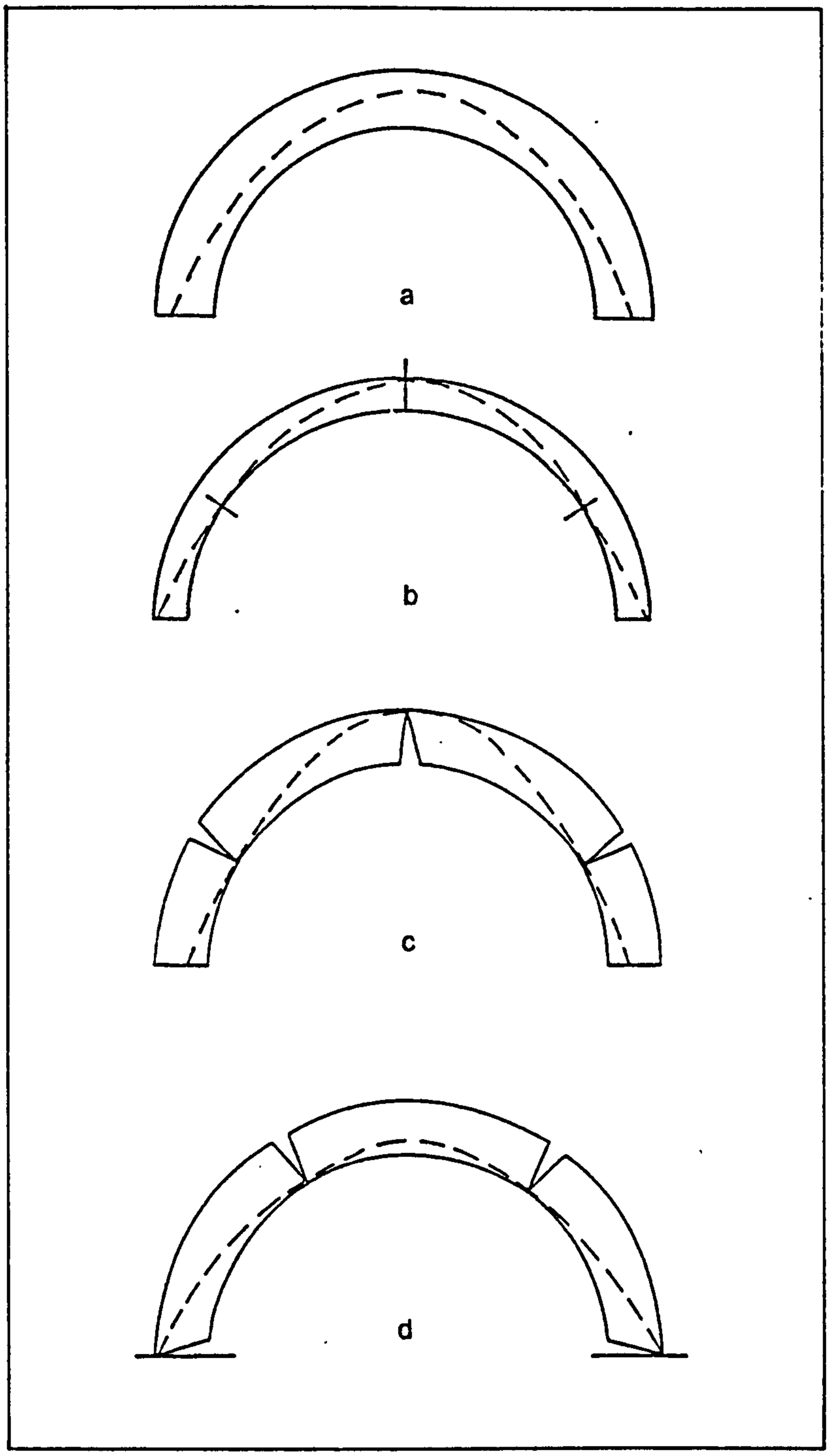

Fig 1.13 Arches illustrating the middle third rule, the line of thrust: a). passing safely through the middle third of the arch, b) outside that safe area. Failure is demonstrated by hinging in c) the line too close to the outer limit, and d) the line too close to the inner limit.

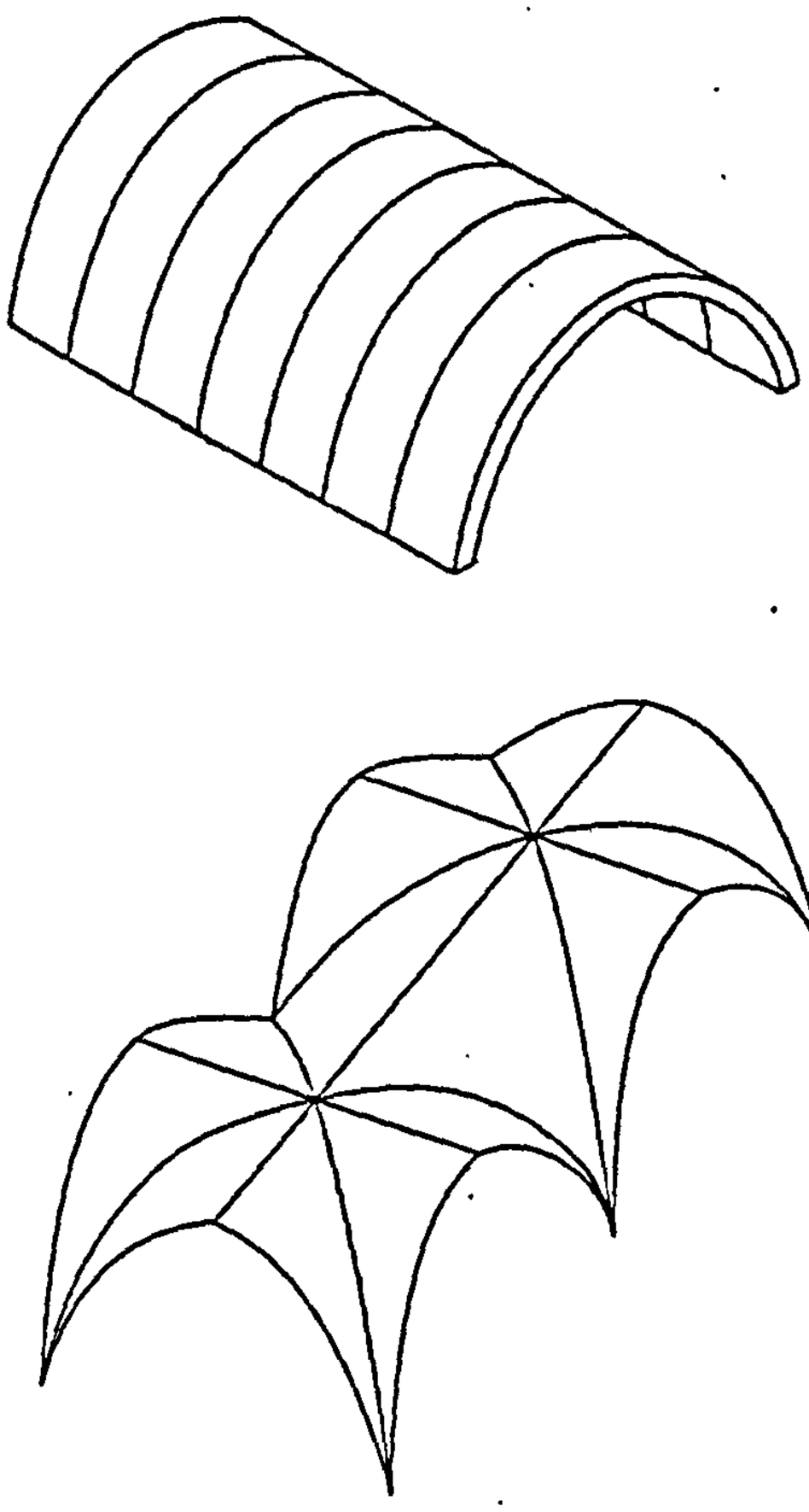

Fig 1.14 Vaults: a) barrel b) quadripartite c) sexpartite

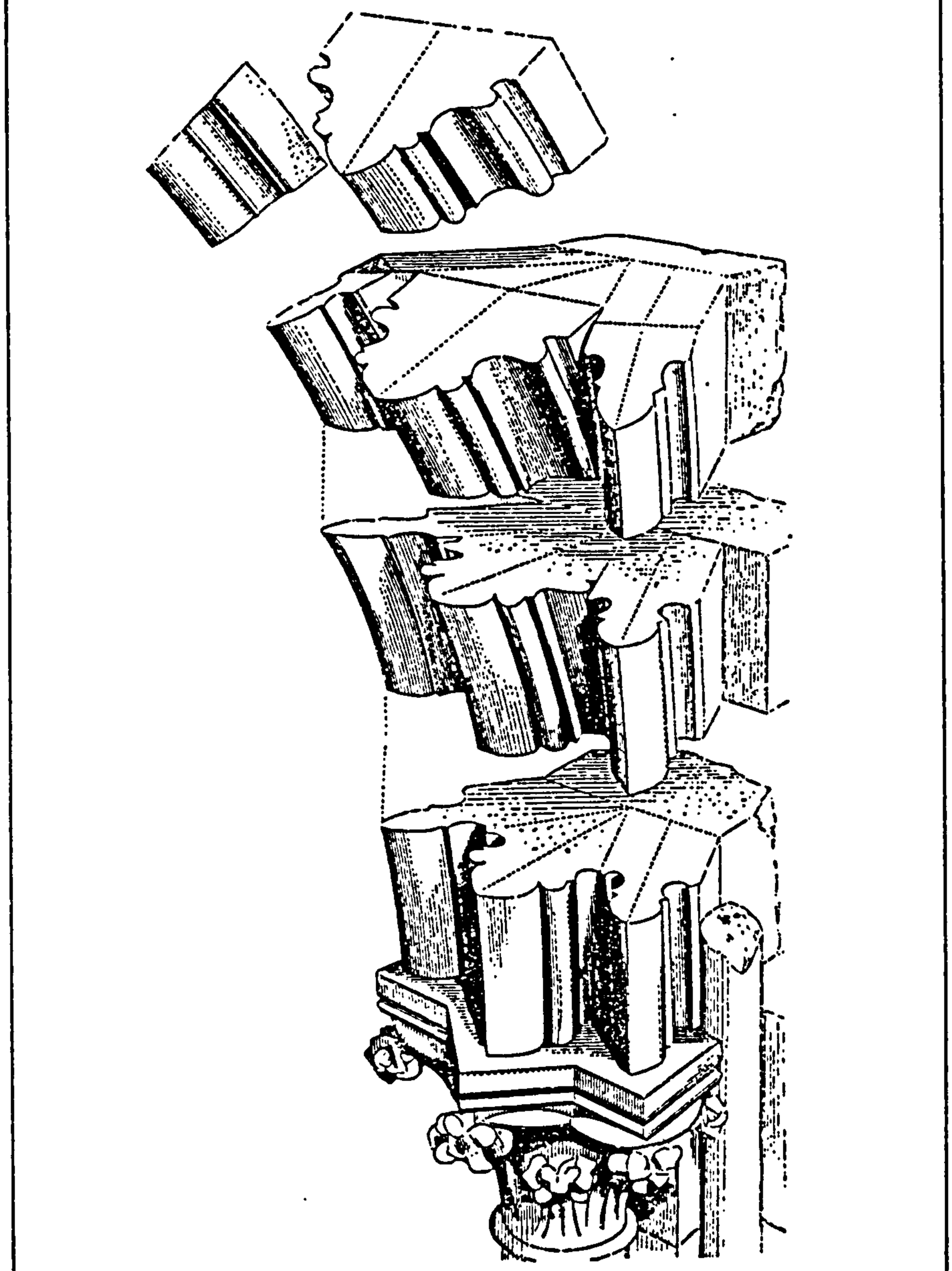

Fig 1.15 The tas de charge (VIOLLET-LE-DUC, E.E. *The Foundations of Architecture Selections From the Dictionnaire raisonne*, New York, Braziller, 1990.)

floor space could be better organised. At higher level, more light could be admitted with the welcome introduction of clerestory windows. In this way several needs were satisfied by a single discovery.

Vault Construction

In his comprehensive exploration of the construction of medieval vaults, Willis emphasises the success of the single-arc rib. Whilst the geometry employed was sometimes of a 'rude and practical' nature, often being 'very clumsily botched over', (65) he states, the Gothic vault works visually at its best with the single-arc rib. Willis describes the plan of the single-arc vault as being comprised of three essential and geometrically dependent features, of which any two would determine the third. These are a) the form of the ridge, b) the middle span of the spandrel, and c) the curvature of the ribs. Once the centres of the ribs were determined, according to the plan at impost level, 'we have no longer the liberty of disposing at pleasure both of the form of the ridge and the middle plan of the spandrel.' (66) The middle plan set, the rib curvature determined itself, with the vaulting surface becoming subordinate to the rib. This was in contrast to Roman vaults which were without ribs, the surface being the leading feature. In order to maintain the visual dominance of the rib, the vault surface tended to present an apparent independence of the ribs, immediately from its springing point of the abacus.

If the rib was not actually invented as an to aid vault erection, it must have quickly been seen as such. The need for heavy timber centering would have been greatly reduced, with the rib being built first on a light-weight framework and the infil, or web, being put in place once the mortar of each bay had initially gone off. 'When the masonry of these arches was set, the four compartments (cells) into which the vaulting bay (severy) was now divided, could be vaulted one at a time.' (67) The physical method of supporting the web, Bond suggests, utilised the 'cerce', an adjustable profile upon which the lightweight stones could be placed until the mortar had sufficiently gone off. Fitchen has further interesting ideas on how this may have been executed, rightly pointing out that the main problem would have occurred when removing the temporary timber falsework, the stone web possibly deforming under initial loading. Some of the most risible are illustrated (Fig 1.16).

It is certain that the rib simplified the planning and setting out of the vault. The main lines of the arches, once determined, would have allowed the fabrication of the web to occur from rib to rib, working across in drafts, compressively from bottom to crown. The ribs have a decorative value in that they covered the unsightly crease of the groin, as well as giving a look of increased rigidity. In actuality, as pointed out by Feilden, once additional backing mortars had been added to the vault, 'the rib lost its structural value and in time might fall away from the vault. Loose ribs are met fairly frequently in Gothic construction' (68)

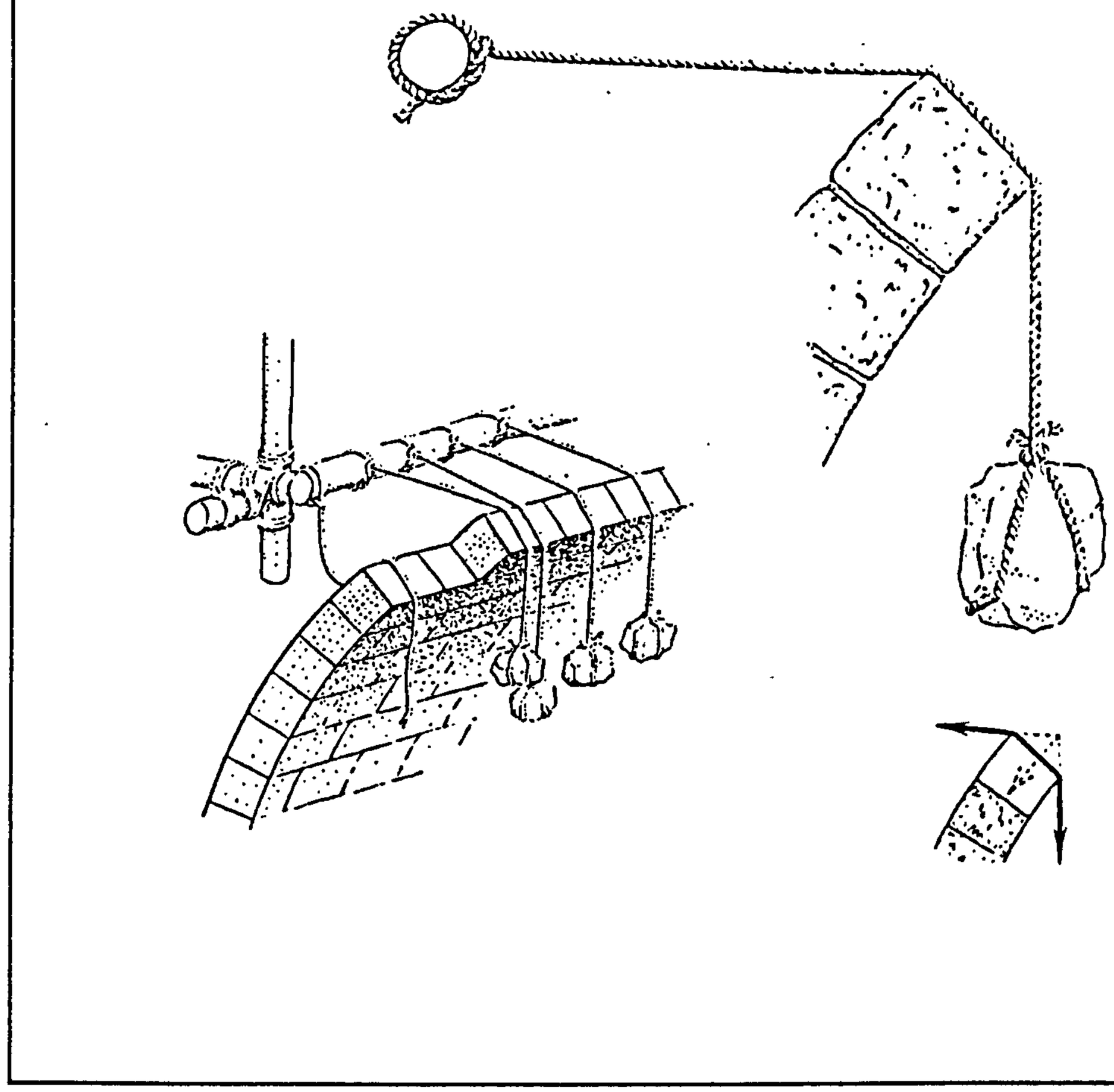

Fig 1.16 Unlikely theories about temporary vault web support (FITCHEN, J. *The Construction of Gothic Cathedrals*, Chicago, UCP, 1961.)

How Vaults Tend to Fail

As has been seen with the arch structure, it is the maintenance of abutment that ensures stability. Similarly in vault structures, movement in the deep supporting buttressing will effectively redefine the plan of the vault, and shift the line of thrust through the ribs, as occurs in arches. This will incline the imposed tensions in the vault to reduce, with visual signs of hinging starting to appear close to the crown of the vault. Where the underside of the vault is plastered, characteristic cracks will appear parallel to the wall, but away from it. The joint between the web and the walls may also be inclined to separate. Vault webs needed only to be constructed of light stone, their thick lime mortar joints being structurally weak. In cathedral naves there is a tendency for the structure to 'rack', away from the central tower towards the west, relying on the huge masses of the westwork to restrain such movements. These three tendencies are illustrated in Figures 1.17 and 1.18.

Outward Thrusts on Buttresses and Piers

In the same way that loads are transmitted through the voussoirs of an arch and the vault rib, so they are received within the safety of the middle third of the deep buttress or pier. This point is a determining factor in the physical depth of the buttress. At the same time it attests to the engineering command of the medieval builder, who strove to reduce mass in his constructions. Buttresses and attached piers can be described as the localised thickening of walls where necessary, their masses being kept to a minimum by being stepped outwards towards ground level. It was suggested by le Duc that in setting out a medieval building, the buttresses may have been constructed first, allowing their loads to be initially taken up by the ground. In this case, once prestressed, they would probably have been better capable of receiving the massive thrusts imposed by vaulting and flying buttresses. On the other hand, le Duc describes the inner independent piers as 'only rigid points of support', conceding that they were 'not absolutely indispensable.' He observes also that: 'The weight of the vaults rests far more upon the buttresses, because of the action of the thrust.' (69) The extra weight of a pinnacle placed on top of the buttress provided additional stability, countering the tendency where the thrusts are received in the upper masonry, to rotate, or slip. Further trimming of the mass of the buttress was then felt permissible, as well as larger openings in the main wall, recalling that the overall weights contained within masonry generally operate easily within the compressive resistances of the stone.

The Importance of Buttress Maintenance

It must be remembered that buttresses extend final support to a potentially moving structure, and their good condition must be maintained so that they remain stable and able to resist high winds. All the rules of caring for masonry walls apply especially to buttresses. Buttress maintenance starts at ground level, the fixity of buttresses relying on the firm support of the ground. In the case of internal piers, maintenance will usually be confined to monitoring, although some bending may occur. It is important to bear in mind the extra loads that pass through buttresses and piers, and the need to maintain cross-sectional integrity so that loads are received and transmitted evenly

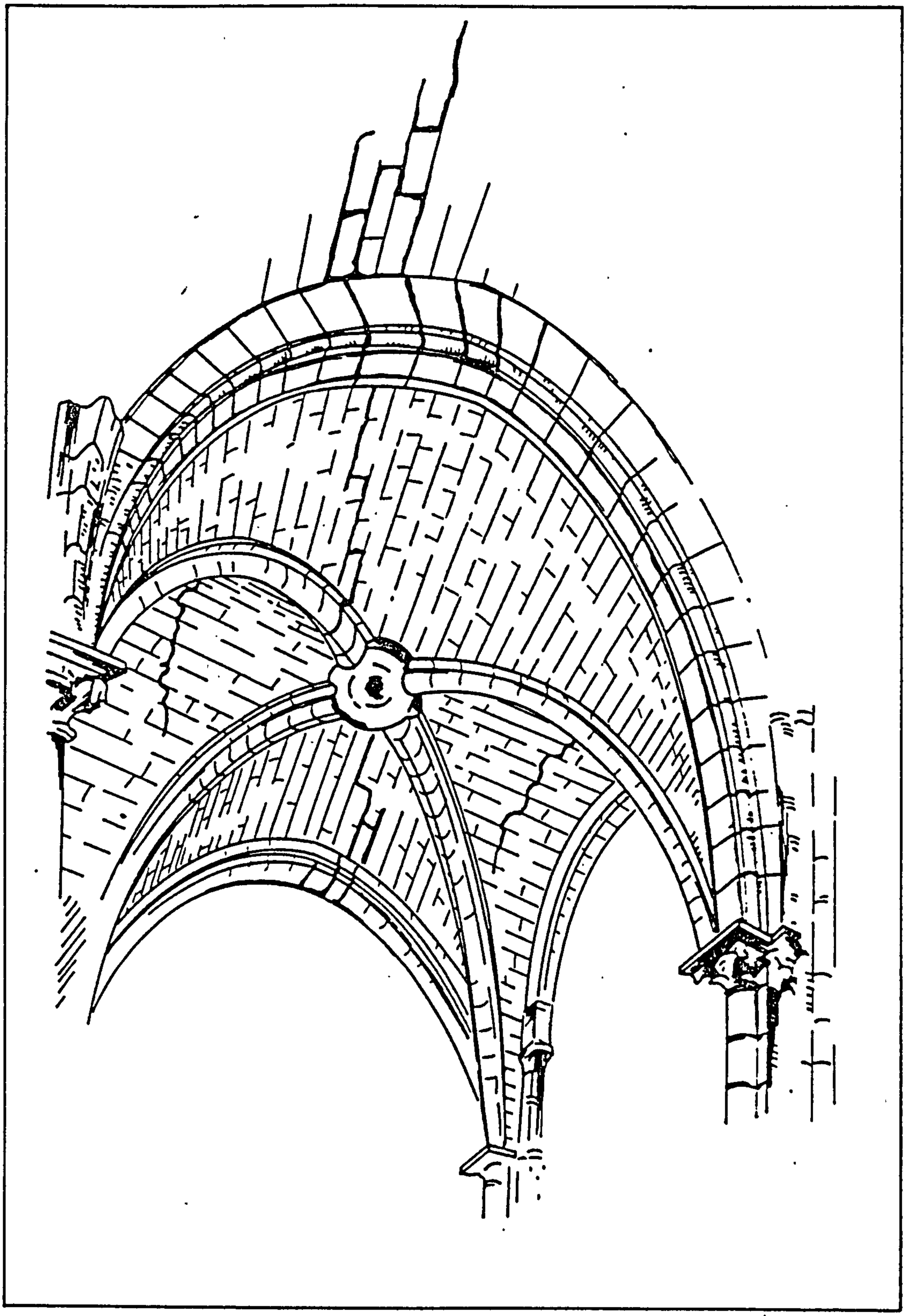

Fig 1.17 Typical cracks in Gothic vaults, with hinging cracks near the crown, cracks parallel to the wall ribs, and separation of the vault from the walls ((HEYMAN, J. *The Stone Skeleton*, Cambridge, CUP, 1995, after Pol Abraham1934)

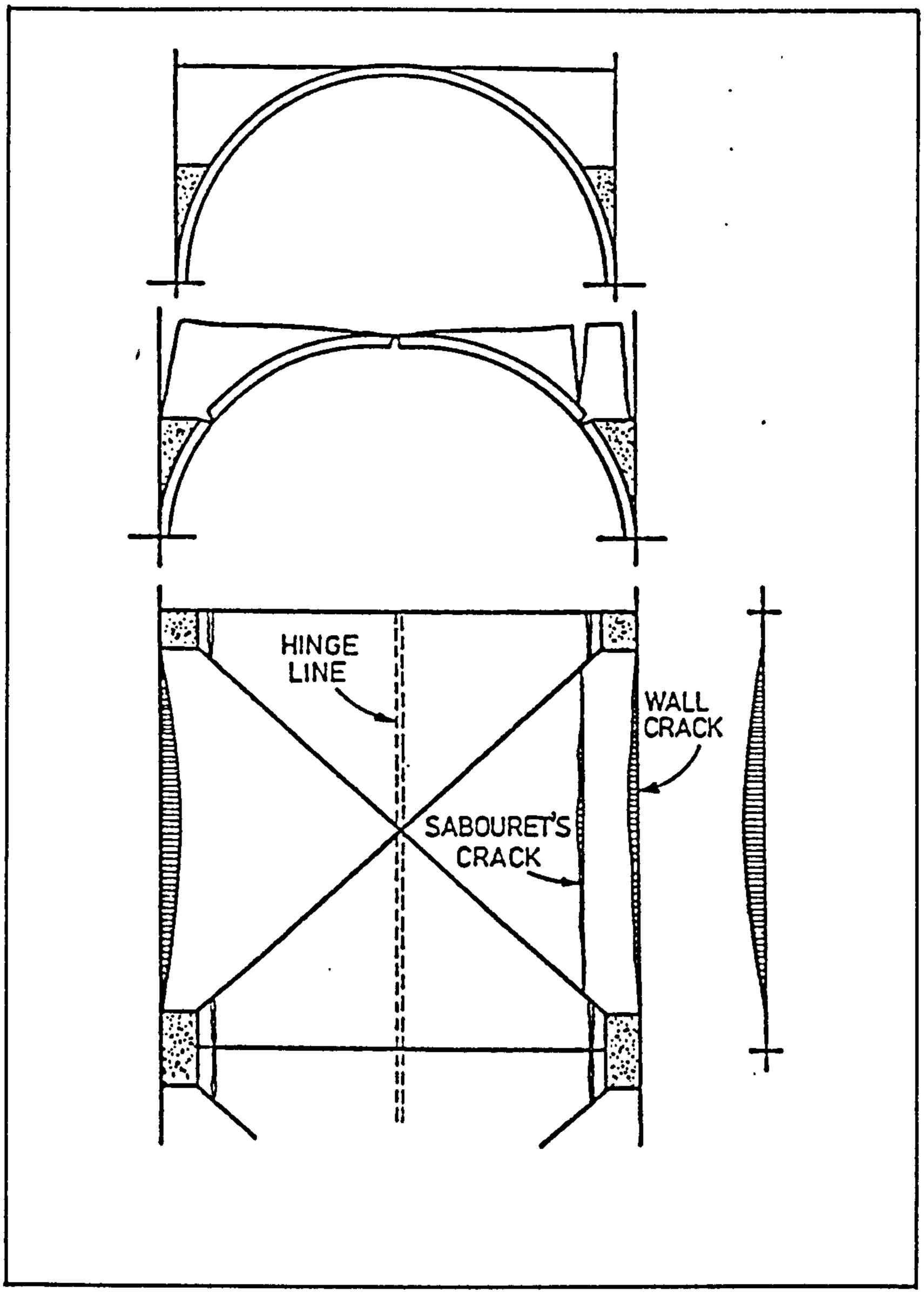

Fig 1.18 Crack patterns in one compartment of a quadripartite vault resulting from yielding of the buttressing system, initially identified by Sabouret in 1928. (HEYMAN, J. *The Stone Skeleton*, Cambridge, CUP, 1995, after Sabouret 1928)

through the mass of the masonry. If compressive forces reach near to the surface of the masonry, spalling will occur around the joint, and problems created by cracking of the external stonework may become critical. The outer buttresses are constantly racked by the high winds that hit the roofs and are likely to be subjected to deformation, and great danger lies in the wind loads counterbalancing the compressive dead loads above the point of abutment, since there is relatively little masonry, and consequently weight, to maintain stability. If this equilibrium is not maintained, due to freak winds of unprecedented velocity, or if the state of the buttress masonry is allowed to deteriorate to an advanced degree, insufficient resistance will be given to rotation, which will lead to collapse. Where masonry courses are allowed to vibrate loose, problems of moisture penetration will arise, eventually affecting the core, causing it to slump and entering into a cycle of decay. Uneven pressures placed on the outer masonry skin, due to poor bonding of stonework, or drifting of courses, may cause extensive cracking and will also lead to a self-perpetuating problem.[1] (Fig 1.19)

In the case of flying buttresses, which form a horizontal link to the upright buttress shafts and to the main walls of the cathedral, particular attention needs to be paid to the terminals at both ends. Due to their peculiar function, acting as flat arches (although not being able to rely on the middle third rule due to their shallowness and horizontality), the ends of these 'flyers' are most likely to develop tensile stresses. The symptoms of this will be the grinding out of the mortar from the joint, allowing stone to contact stone, water ingress and further damage. In the context of a rigid structural Gothic frame, the cross-members are seriously vulnerable to tensile stresses, with distortion most likely on the leeward side pier buttress close to the top (see 1.3 *Critical Areas of Tension in the Gothic Frame*). Here again, the threat of rotation exists due to the limited amount of masonry above it.

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[1] At Saint-Genevieve, Paris, masons spent a year opening up external masonry joints of piers with saws, attempting to divert loads back to the centre cores. This method was condemned at the time as bad practice and is frowned upon today by Heyman. Although he does not say why, it is likely that the reason for this criticism is due to the fact that the loads could not be diverted back all at once, but could only be reintroduced in a piecemeal manner. In this case, an extended series of unacceptable and uneven stresses was exerted on the external masonry walls of the piers. As those loads once again become rearranged, naturally seeking their own route to ground, further damage was likely to have occurred. Although the principle of what the masons were attempting was correct, no method could be relied upon to achieve it.

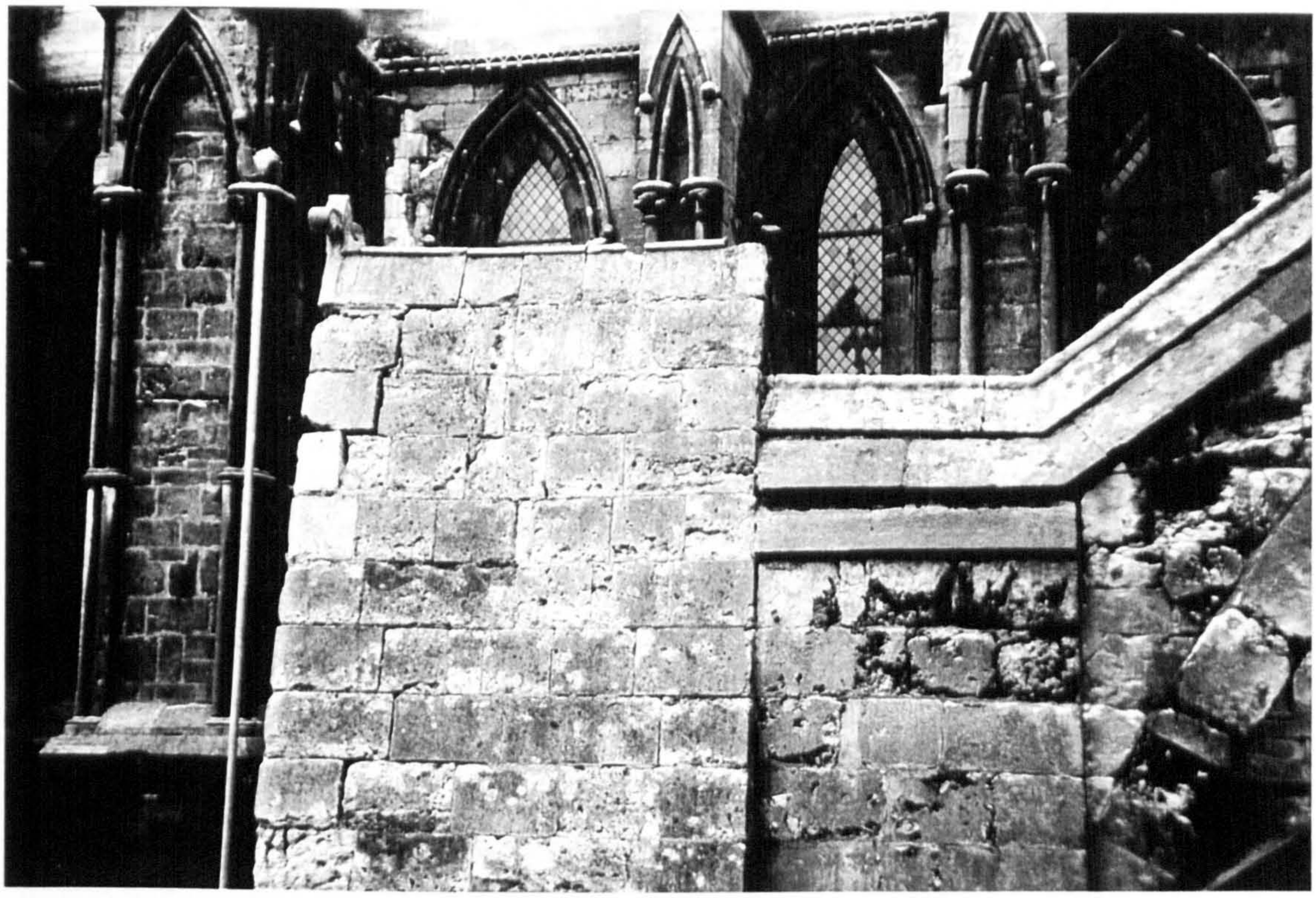

Fig 1.19 Failure occurs in buttress haunches due to tensile stresses produced by the action of high winds. Lincoln Cathedral north nave aisle.

1.3 Failure in Gothic Buildings

Not all cathedrals developed in a clear-cut and pristine manner, three dimensionally from the ground plan to elevation. Many were realised in a piecemeal fashion over a long period, together with the partial modifications of outmoded areas and the rebuilding of unsuccessful ventures. The resolving of constructional problems may have been worked out in a kind of relay, with previous efforts providing large scale models. Where construction did occur in a straightforward and logical progression, sequentially from one bay to the next, a comprehensive record of material performance, craft techniques, and engineering success was available for reference. Masonry construction has been described as having a 'forgiving nature', (70) and it can be interpreted that fairly crude geometrical solutions were capable of being repeated, and also transferred from one situation to another, even at different scales. Two points spring from this observation; firstly, contemporary models of design and technology were available not only throughout the land, but also on the continent, with designs developing empirically and with little advanced analysis; secondly, within such a liberal structural system, considerable movements and the consequent accommodation of anomalous forces were tolerable within a fairly wide margin.

The Gothic Frame

Systems of construction employed in Gothic cathedrals are not dissimilar to those used in modern independent scaffold structures, erected in individual box-like units. Each unit of the scaffold incorporates four stable uprights, or standards, with linking cross-members, and diagonal braces going in both directions to prevent lateral collapse. In the Gothic cathedral, the uprights may be represented by the piers and buttresses, the cross-members by arches, beams, and trusses, and the braces by lateral flying buttresses. Not to extend this analogy too far, whereas the scaffold may rely on bracing from the solid ground, overall stability is assured in masonry structures by the sheer weight of materials and the association of qualitative abutment. Structural performance is therefore reliant on a reasonable level of compression and a resistance to slipping in the case of weak mortar joints between masonry elements. Compression is maintained in the Gothic arch so long as the line of thrust, or centre of gravity, is contained within the middle third of its mass. This action is aided in piers where inclining forces meet them by the placing of extra weight in the guise of pinnacles on top of the pier extension, thus encouraging compressive forces to travel downwards rather than outwards (Fig 1.20). Large towers and pinnacles may cause a general racking tendency, for example in the case of timber roof structures, but are usually resisted by the transepts or other substantial structural mass, such as the westwork.

Structural Stability and Margins of Safety

Since the circumstances of buildings and their surrounding environments will be susceptible to change, some forces of tension within the masonry structure will inevitably appear and it is an essential characteristic of masonry structures that all parts are able to interact between forces and deflection, ie the stretching and contracting which occurs within the structural elements or the materials themselves. These actions were identified in a law devised by the 17th century

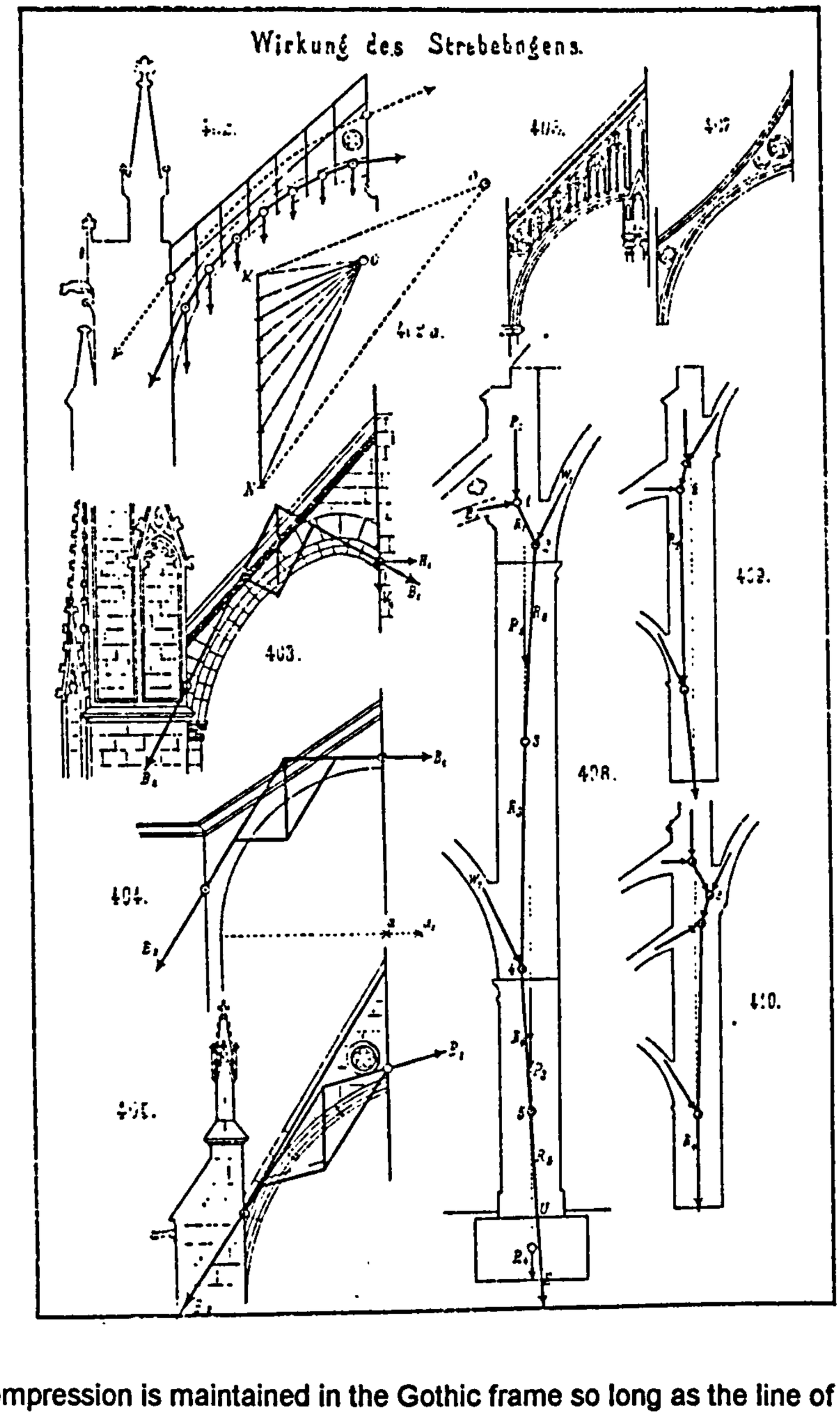

Fig 1.20 Compression is maintained in the Gothic frame so long as the line of thrust, or centre of gravity, is contained within the middle third of its mass. Where inclining forces meet, extra weight is provided by pinnacles placed on pier extensions, which encourages compressive forces to travel downwards rather than outwards ((HEYMAN, J. *The Stone Skeleton*, Cambridge, CUP, 1995, after Ungewitter 1901)

century engineer Hooke (1635-1702) in his simple dictum: *'ut tensio sic vis'*, (as the extension, so the force).[1] Recognition was given that structures and materials resisted the forces imposed on them. In the case of materials this rule operates at molecular level. With these actions in mind, Hooke 'set out to determine what might be the nature of the macroscopic relationship between forces and deflections in solids.' (71) It became clear that deflections were generally proportional to the load imposed and that certain solids used in construction returned to their original shape, a behaviour referred to as 'elasticity'. Those materials or solids that did not recover their shape entirely were described as possessing properties of 'plasticity'. Theorems based upon these characteristics were subsequently developed, and are useful to the engineer in analysing the behaviour of structures and calculating the distribution and magnitude of stresses and strains. The definitions of such commonly used terms are important and worth mentioning here, as they are the results of entirely different actions. *Stress* refers to a measure of depression received locally. The area receiving the pressure divided by the load will provide a stress reading. On the other hand, the term *strain* refers to the amount of stretching that occurs in a material. The margin of difference between the stretched material and its original length provides a measurement of strain.

Confronted by the fact that large Gothic buildings are subjected to live loads, combined with a continuity of changing environmental conditions, but do not generally collapse, it becomes obvious that masonry structures can accommodate a level of tensile forces. In an ideal situation, where masonry could be considered uniform, for instance, continuous or monolithic, a structure might be regarded as carrying exclusively compressive forces and being in equilibrium. In such circumstances, its condition would be capable of a reliable assessment, according to the principles of elasticity. This is not the case, since 'the individual stones within masonry are pressed against adjacent stones by compressive forces', (72) making it unable to maintain a monolithic identity due to the weakness of the mortar joint and an incapacity to transfer significant tensile forces. A cathedral is constantly subjected to changes, whether due to a sudden gale, the shift of a structural member, or in the event of radical maintenance intervention, and an assumption that masonry is stable as long it is static is unrealistic. The effects of shifting and lurching of architectural elements, will irrevocably alter the configuration of the structure, moving the emphasis of load-bearing, causing bending in some elements, and setting up unwelcome tensile forces.

At Salisbury Cathedral, a spectacular example of this is found in the main crossing piers (fig 1.21). Sir Christopher Wren, at one time the Surveyor of the Fabric at Salisbury, remarked generally in his report on the survey of the Cathedral: 'there is scarce any Gothic cathedral I have seen where the pillars do not yield and bend inwards from the weight of the aisle.' (73) Commenting on the incidence of bending in connection with the advancement of decay, William Harvey, one time

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[1] Robert Hooke, recognised that structures resisted the loads applied to them by mechanical forces, since they did not collapse, and deduced that there were equal forces pushing back and maintaining equilibrium. He described this as a natural law; ie that solids changed shape by compressing or stretching in direct response to the weights or forces applied.

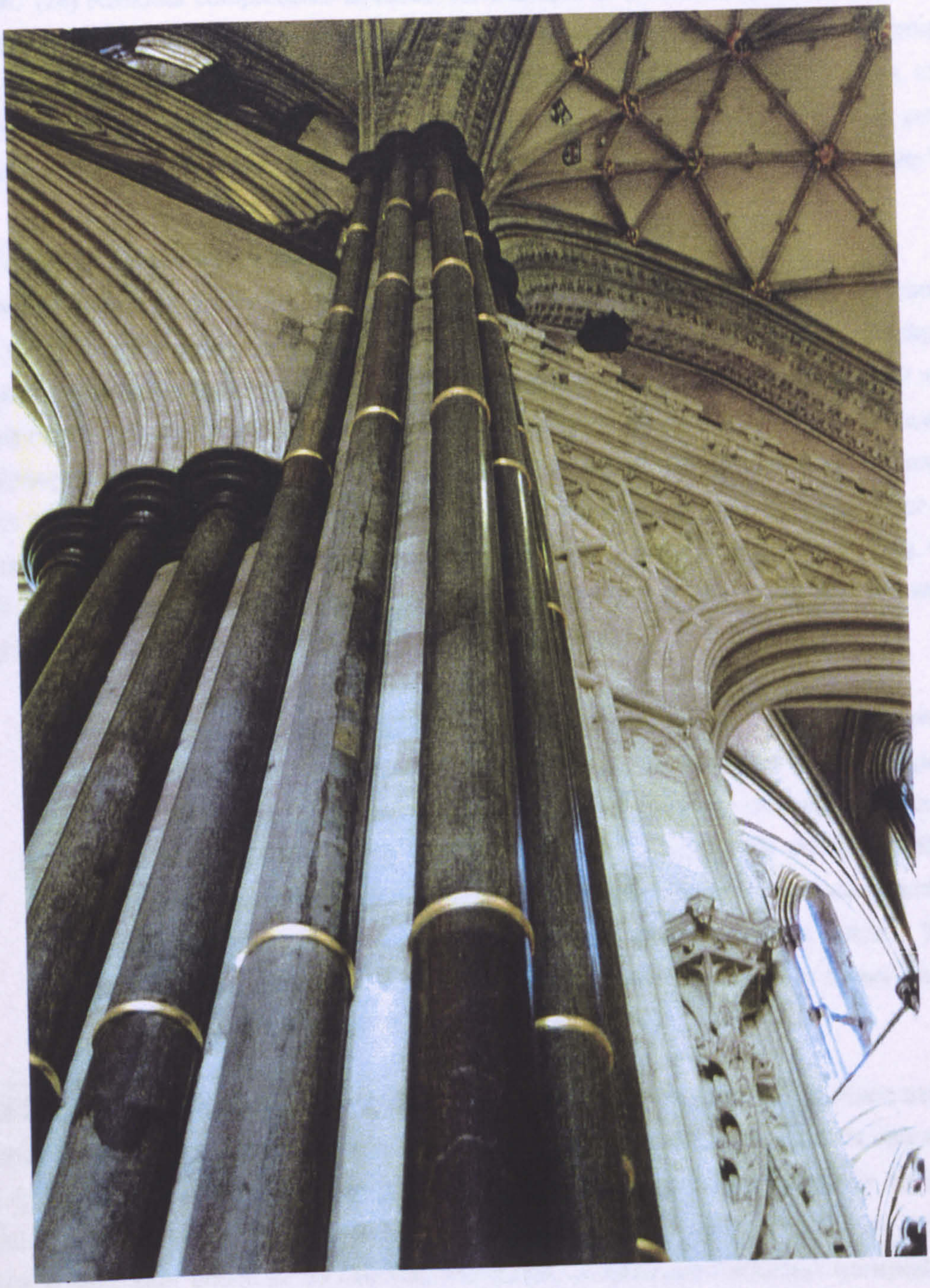

Fig 1.21 Salisbury Cathedral main crossing piers show the effects of shifting architectural elements altering the load bearing emphasis, causing bending in the structure.

architect of St Pauls Cathedral, warned 'that a curve accidentally produced in a part of a building which should be straight is a warning that further movements in the same direction are at least probable.' (74) Residual compressive stresses, for example of a column cluster or pier, added to by the tensile forces caused by bending, may result in irrevocable buckling. Such deformation as seen in figure 1.21 at Salisbury may exist in a state of precarious stability for many years, although it should be recognised that persistent bending may create a cycle of movement, with persistent deformation creating new norms. This insidious form of structural deterioration is known as 'creep'.

Critical Areas of Tension in the Gothic Frame

By viewing figure 1.22 it can be seen that critical points of tension in the sectional frame of a Gothic structure arise chiefly where unequal forces meet at the junctions of walls. Avoidance of damage due to tensile cracking is difficult, although speedy and thorough maintenance of masonry walls will help to ensure the movement of forces to the ground. Mortar joints provide the weak link, and pointing can act as a tell-tale on being checked for cracking. The efficiency of masonry walls depends on their homogenous state and voids in the rubble core, created by cracking or drifting, will force the outer ashlar skin to carry the majority of the load, and may result in cracking. General good order of the outer wall will be informative of the state of the inner core, and the wall in its entirety will be more capable of countering bending tendencies.

a. *Pier extensions*: Bending of the upper pier extension may be caused by massive wind loads against the steep roofs of cathedrals. Where such loads surpass the residual static compressive loads, and equilibrium is negated, cracking will occur.
b. *Junction of flying buttress to pier extension*: Much relies on the correct positioning of the flying buttress at this point, at the time of construction or during reconstruction. The pier extension, receiving the thrust from the vault, must be able to transmit the loads into the buttress, otherwise rotation will occur during high winds or heavy snow. This can be aided by the filling of the vault surcharge.[1]

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[1] In 1284 the vault of the choir of Beauvais Cathedral collapsed, the reasons for which have never been clearly established. Frankl has stated that: "The collapse at Beauvais was not caused by the height of the vault which stood over 150 feet above ground, but by inadequate foundations.' FRANKL, P. *Gothic Architecture*, Middlesex, Penguin, 1962. p101 The cause of failure put forward by Violet le Duc, later endorsed by Heyman, HEYMAN, J. *Beauvais Cathedral*: transaction of the Newcomen Society, London., XL 1967-68., was due to the integral positioning of twin colonettes into the pier extensions. Settlement, due to the drying and shrinkage of mortar, imposed too great a load on the monolithic columns, causing the increased point load to break the lintels upon which they stood. As the flying buttress then became loose and pressed outwards, a reduction in abutment occurred, allowing the vault to spread. A third theory extends on this, Robert Mark MARK, R. *Experiments in Gothic Structure*, MIT, 1982., lays the blame in part on the offset connection of pier extension and flying buttress, which cracked and caused rotation and collapse.

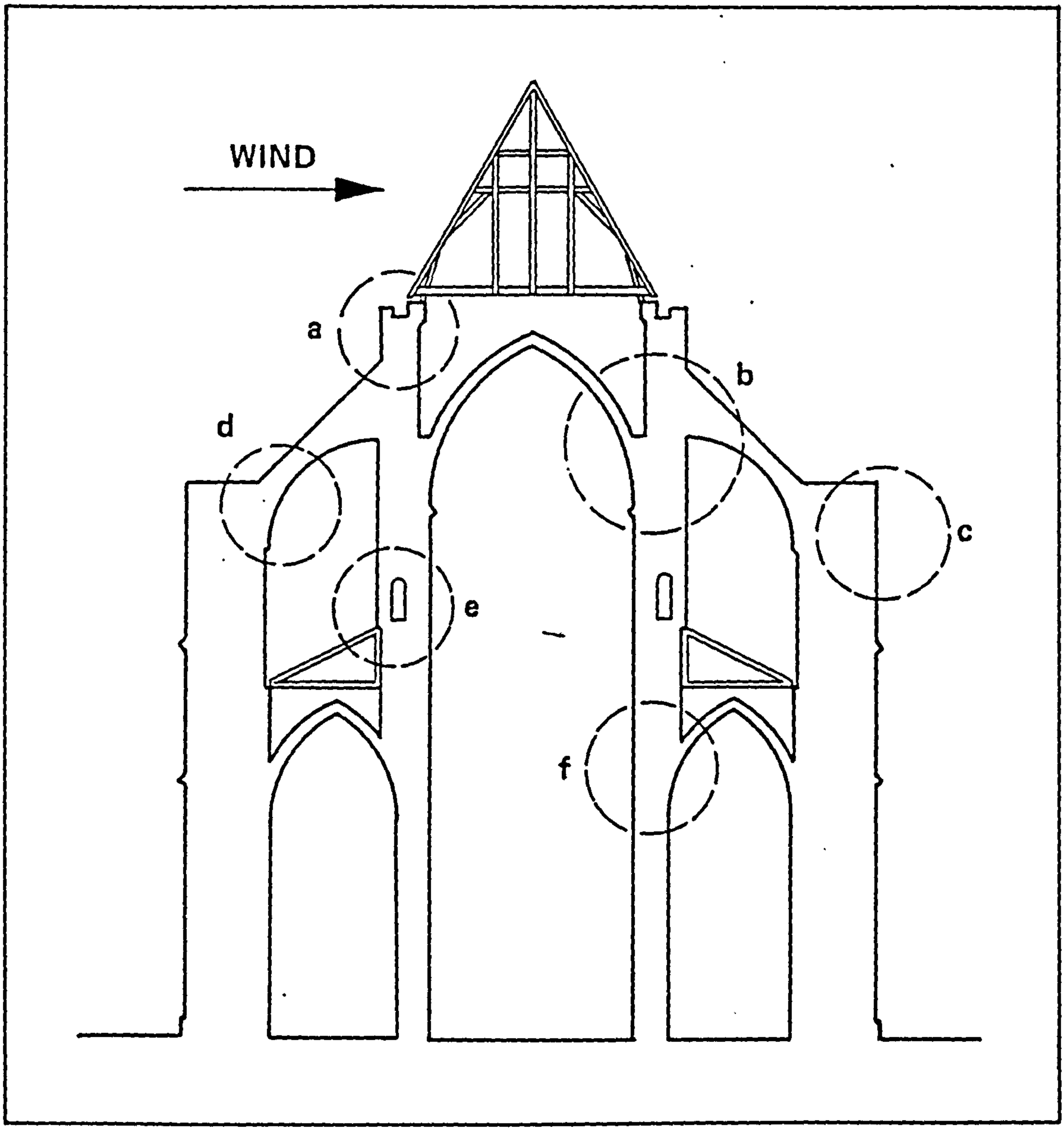

Fig 1.22 Critical areas of tension in the gothic frame (MARK, R. *Experiments in Gothic Structure*, MIT, 1982)

c. *Pier buttresses*: The rigid Gothic frame, during high wind loading, invariably receives heavy lateral vibrations, resulting in deformation and the stonework of the shoulders of the buttress shafts becoming loose.

d. *Flying buttresses*: The flat nature of flying buttresses often means that the arch operates outside of the catenary curve system, thereby not conforming to the middle third rule. Live wind actions combined with dead loads can develop tensile stresses at the terminals of the flying buttress, with mortar being ground out of the joints and cracking occurring.

e. *Passage openings*: These can be regarded as potential weaknesses in the masonry structure, since the ashlar might be abnormally thin and susceptible to cracking.

f. *Intersection of pier and pier extension*: The compressive forces bearing down from the pier extension to the pier are not in alignment and will tend to bend, although it may be adequately countered by the aisle vault.

Although some bending may in itself be tolerable, as it appears to be at Salisbury, it ought not to be viewed lightly where it is accompanied by fracturing of individual stones. This may indicate ominous movement of the masses within the building. Wren found the symptom of extensive cracking tolerable at St Pauls Cathedral, attributing it to settlement, although the symptoms were to persist for more than two hundred years, far exceeding Heyman's rule of settlement. In the event, a massive operation of injection grouting carried out earlier this century into the core work of the main piers was felt to have stemmed further deterioration. Calamity can be effected by relatively minor incidents, especially in conjunction with material deterioration, or poor design. In the words of William Harvey: 'Buildings can stand a most extraordinary amount of damage before they finally fall.' (74) However, in Gothic buildings, where the principles of construction are relatively simple, certain rules are unbreakable, particularly the maintenance of equilibrium of forces in action.

Heyman's Master 'Safe' Theorem

In all the above cases the distributions of forces may become affected and cannot be relied upon to return to their original routes, leaving the building to seek new ways of working. Those charged with the maintenance of historic masonry buildings need to be in a position to monitor the continued ability of the building to resist the elements and the sustained effects of changes, for instance during major repair works. A complete survey such as might be demanded during a crisis appeal is not always ideal for reasons associated with confidence in the structure and the business of fund-raising. Professor Heyman simplifies and adapts a 'plastic' system of analysis to the masonry structure which is practical to calculate. Three initial provisions are accepted, that masonry has a tremendous compressive strength, a lack of tensile strength, and no tendency to slip. Referring to the middle third rule, Heyman maintains that the actual line of thrust lying within masonry structures will also lie within the central third of the wall, irrespective of any reasonable

movement within the overall structure. If this line can still be established, 'then the structure can never collapse under the given loads,' (75) This relatively straightforward system of assessing margins of reliability, requiring only one position to be found, is termed by Heyman as the 'safe' theorem.

Failure in Gothic Buildings

In 1185, a total collapse of the vault occurred at Lincoln, ostensibly due to a sudden earthquake of great magnitude. Although it is true that earth tremors are a feature of the area, the coincidence is hard to swallow that the recently constructed vault, erected on piers never intended for the purpose, and only recently decentred, may have proved inadequate to the task. Heyman extends two principles in cases where construction has recently been completed; he maintains that if a building will stand for five minutes it will stand for five hundred years, a rule referred to as 'the five minute rule.' In the case of settlement, he suggests a generation rule, during which time any settlement ought to have manifested itself within the duration of an average life-span. This is not to state that buildings will never fail with the passing of time, due to changes that occur. Fundamental ground conditions change, sometimes dramatically and the original materials employed in construction do not generally improve with age, and it is generally the case that uncontrolled alterations that have taken place in large buildings are for the worse.

According to the simplicity of the 'safe' theorem any significant structural intervention might qualify a major building for some form of assessment and monitoring. It is often the mixed nature of repair and replacement, combined with much guesswork that evidently accompanies maintenance work that is responsible for increasing the complexity of the problem, and at the same time calls for monitoring. At York Minster in the late 1970s, one of the ten buttress shafts supporting the Chapter House was replaced with a reinforced concrete core, and merely cladded with stone, and at Lincoln in the early part of this century a great deal of reinforced concrete was buried within the medieval masonry structure (see 3.2 *Case Study: The Special Repair Programme* (1922-1932)). In the long term, what will be the effects of differential behaviour patterns? Again at Lincoln in the 1930s, a great deal of original stonework was replaced with Weldon stone, a far less dense material than the original Lincoln stone. Where small areas of Lincoln stone were retained, presumably due to its good health, many of these have now shattered irrevocably (Fig 1.23). After being subjected to certain stresses over a long period, could those stones on being released have attempted to recover their original shape (according to their properties of elasticity) and on being subjected to new stresses, have finally collapsed? In the long term, it may be valid to question whether such radical interventions are justified on the basis that the Gothic cathedral can no longer be assessed in its pure, or simple, state, ie as an unreinforced compressive masonry structure, within which some tensile forces will be tolerable.

In respect of the preservation of the structure, these relatively simple functions require maintenance and monitoring, as part of the active conservation of the building, and can be regarded as a primary issue. The ground will not resist the enormous loads required if its conditions alter dramatically, becoming either too saturated or dehydrated. Similarly, where pinnacles or buttresses are subjected over a long period to vibration due to the wind, the mortar may work its way out of the joint and introduce changes, causing the fixing system of dowels and cramps to become over-burdened and to fatigue, leading to collapse. The words of William Harvey ring clear as a reminder of hindsight: 'But while the fall is sudden, the maneuvering of the masses into the position for a fall may be extremely slow..' (76) Given the fact that the structure has stood for several hundred years, confirming the success of the engineering (unlike Beauvais), those particular actions upon which the design depends, and which create pressure due to the unleashing of tensile forces at anticipated points, need to be maintained so that small changes do not develop into serious structural issues and lead to major disruption.

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Part 2.0

The Weathering and Decay of Limestone

Part 2.0 The Weathering and Decay of Limestone

Introduction

This part of the study will examine how an understanding, or lack of it, of the processes of decay in a building limestone can produce both good and bad practices of construction, repair, and conservation. In a similar way that the fundamental principles of construction engineering are essential to the practice of structural repair, so a working knowledge of the nature of materials, including patterns of deterioration, is essential to their preservation. It is not always sufficient to have a specialist available with data on hand, for instance a scientist in the case of the presence of pollutants in stone. That information will need to be applied by someone from a completely independent discipline, who must be able to interpret the data for practical use. An understanding of limestone will begin with consideration of its genesis and inherent properties as a constructional element. This will be followed by a look at failure of this material in the context of building. The term conservation describes those activities that attempt to halt or slow down the processes of decay, although the inevitability of decay in natural materials is undeniable. Those very processes are identifiable to the geologist and geographer as the same processes of natural weathering which result in the formation of clay and soil:

> 'With or without acid rain, the gradual erosion of all buildings, built of natural stone or man-made materials, is a completely natural process. In attempting to stop, or even slow down weathering, the conservator is actually attempting to combat the forces which shaped the planet.' (1)

At this introductory stage it is necessary to state that some of the processes of decay in stones are not fully understood, but those mechanisms that are may be further complicated and their actions obscured by synergistic behaviour with other agencies. A good example of this is the case of Purbeck marble (which is rapidly disappearing from the exteriors of English cathedrals. Current research [1] is attempting to establish the causes of decay in Purbeck marble which will enable suitable treatments to be found. Purbeck details could be expected to deteriorate fairly rapidly externally, faced with all the rigours of weather and pollution. However, protected internal Purbeck decoration is often also in an advanced state of decay, while other contemporary limestones are perfectly sound. Sometimes, as well as obvious crumbling and splitting, Purbeck seems superficially intact but audibly rings hollow when tapped, giving the impression that decay is occurring within the stone. Possible causes range from the oxidation of sulphide minerals, dissolution of clay minerals, to micro biological activity. Until the causes of Purbeck deterioration are understood, the treatments which have so far been devised amount to no more than high quality cosmetic repairs.

Chemical, physical, and biological causes of limestone breakdown will be examined within the limitations of the conservation view, which responds to current understanding, a statement that

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[1] The BRE and EH and a number of cathedral architects are currently collaborating as part of a *Strategic Technical Research Programme*, to establish causes of decay in polishable limestones.

itself implies a need for continued research. Some attention will also be paid to man-made causes of deterioration, including past repair.

2.1 A Geological Outline

This geological outline will present a broad view of the evolution of rock material, which is defined as follows: 'Stone is a heterogeneous substance characterised by a wide range of mineral composition, texture and structure.' (2) Although this entire section will address the mechanisms and patterns of breakdown of the main stone type of which the fabric of Lincoln Cathedral is constructed, it is worth noting that there have been past stone replacements using other limestones, including some very minimal use of magnesian limestone, and some sandstone. Initial formations and subsequent erosion of igneous and metamorphic rock material contributes significantly to the sedimentation of limestones, providing its main inorganic component. This factor makes a general section of geological classification worthwhile. The main classification of stone used by geologists, fall into three convenient types, igneous, sedimentary, and metamorphic rocks.

Igneous Rocks

These are formed from molten material beneath the earth's surface. The material, known as magma, is driven by considerable pressure upward to the surface. As it travels, magma becomes infused into the fissures of other rock forms or, on reaching the surface, cools and becomes solidified to form what are known respectively, as intrusive and extrusive igneous rock forms. Intrusive rocks undergo continual attrition by erosive surface elements. This process, termed denudation, eventually reveals the underlying and more durable igneous constituent. 'The important rock-forming minerals can, in practice, be referred to comparatively few groups.' (3) In igneous rocks the following main minerals are classifiable; quartz, feldspar and feldspathoid, and ferromagnesian minerals. Mineral distribution and structure provide rocks with their characteristic colours and textures, and their unique behavioural properties on exposure to the weather. The main rocks of the igneous group are granite and basalt.

Sedimentary Rocks

The substance of sedimentary rocks is of secondary origin, being a combination of accumulated waste matter. Disintegrated material, released by the breakdown and denudation of earlier rock forms, becomes intermingled with sediments and organic detritus and deposited incoherently on the sea-bed. This collection is then sorted by the action of wind and water percolation. Interstitial pores are partially filled with mineral solution, which acts as a cementing agent. Compaction, by pressure exerted from shear weight serves to consolidate the accumulation into a coherent mass. The characteristics of sedimentary rocks, structure, texture and composition, are determined by the nature of the material accumulated, and the chemistry of the cement. Environmental conditions in which deposition has occurred, whether stable or unstable sedimentation, will have

determined the consistency of sorting. Stable conditions will have allowed evenly rounded particles to form regularly compacted sediments, whilst the random selection of angular grains which are forced together in turbulent conditions, may have an effect on the eventual consistency of the building stone and its quality.

Metamorphic Rocks

The action of metamorphosis, which sedimentary or igneous rock forms undergo in order to become metamorphic rocks, takes place beneath the earth's surface. Transformation is brought about by a combination of enormous pressures from overlaying material, agencies of extreme heat and the influence of chemically alert fluids. Change occurs to the rock in a solid state, without any melting or solution taking place to the original material, either wholly or in part. The volume of the original substance remains the same, no other material being added. The nature of the change is influenced solely by the chemistry of the original rock material and the conditions imposed upon it. Under such circumstances, limestones will convert into marbles, sandstones into quartzite and clays into slates, with igneous rock material converting to gneisses. The utilisation of these converted materials for building purposes is mainly limited to marbles and slates.

Sandstones: A Brief Description

The constituent sediments of sandstones are grains from eroded igneous material of greater resistance, such as quartz and to a lesser extent, feldspar and mica. Conversion into a relatively hard rock is completed by compaction and cementation. Cementing solutions in sandstones are extremely important as the grains are held in point contact, the matrix filling the gaps rather than being closely interlocked, as with igneous rocks. Cementing agents vary, the stones taking their name from the matrix. There are four main classifications, which vary in resistance to weathering.

- Siliceous sandstones have grains bonded together by silica, and are highly resistant to water and acidic gases.
- Ferruginous sandstones are cemented by oxides of iron, and are reasonably resistant to both water and atmospheric acids.
- Calcareous and dolomitic sandstones are cemented by calcite and dolomite, and both provide a good bonding agent, though are far less resistant to the natural atmospheric constituent of carbon dioxide than other matrices.
- Argillaceous sandstones, the least efficient of all sandstones, are cemented together by clay products. Due to the weak bonding between clay layers, these stones are highly susceptible to weathering erosion, moisture easily entering the clay and reducing bonding.

The characteristically deep bedding planes and wide jointing patterns of most sandstones indicate the undisturbed nature of their sedimentation, which may have been quite rapid. Deposition of rocks in shallow waters can be recognised by criss-cross, or current-bedding planes, evidence of

altering water currents and other swiftly changing conditions. Separate bedding planes perhaps represent extended periods during which no deposition occurred, or periods of erosion.

Limestones

These are made up of the tiny hard particles of the remnants of organisms, such as molluscs, the calcareous cases of crinoids (sea-lilies), skeletons and other organic detrital sediments, such as the remains of siliceous organisms. Carbonate rocks also include inorganic matter, such as calcite and aragonite crystals. Added to these may be quartz grains and particles of clay, with the occasional addition of iron compounds. These are deposited on the sea-bed in an incoherent manner. Eventually, through the process of water percolation, the deposits are sorted, compacted and cemented by a solution of calcium carbonate. The proportion of calcium carbonate is over 90%, against a small proportion of magnesium carbonate, and a silica content of around 5%. Those limestones which possess a larger proportion of substances other than carbonate adopt the prefix of that property, such as siliceous limestones, argillaceous limestones and magnesian limestones. Deposited at different times, limestones assume the nomenclature of their period. The most useful of the limestones for building purposes were laid down during the Jurassic period (195m.y - 135m.y.). These rocks form a diagonal belt across England, from the county of Yorkshire to the coast of Dorset. The rocks, which have settled in accumulated layers, are stratified into what are called 'beds'. (Fig 2.1) The bedding planes of the English Jurassic limestones range from a few cm (Collyweston and Stonesfield 'slates'), to the commonly sized beds of 30-60cm, and to the extreme beds of 6m (Clipsham). The two most important of the limestones originated by deposition are Oolitic and Dolomitic, Lincoln Cathedral is chiefly comprised of the former stone.

The name *oolitic* is taken from the Greek word 'oion', meaning egg. The physical characteristic of those stones known as oolitic is their composition of an accumulation of smooth, rounded grains. The nucleus of the oolith may be either organic or inorganic; a fragment of shell, a grain of sand, or a small chip of calcareous mud. The particle is gently buffeted along the sea-floor, in shallow waters, becoming coated in a solution of calcium carbonate and acquiring either a concentric, or radial structure. The action of agitation along the sea-bed, apart from aiding accretion, helps to grade the grains, ensuring a fine uniformity. Grains which go on to develop larger than a pea, are termed pisolitic. Pisolites and oolites may be assisted in their development by calcareous algae, which frequently surround particles and add to the coating. The formation of oolitic beds is currently occurring in the shallow waters of coastal Florida and the Bahamas.

Magnesian stones are sedimentary formations of the Permian era (250 m.y.) and are less common in Britain than oolitic stones. The outcrop occurs in a localised diagonal strip from Nottingham across to York. These rocks are classified as dolomitic and contain the double carbonate of calcium and magnesium $CaMg(CO_3)_2$. Whereas the calcareous limestones consist mainly of

Fig 2.1 Limestone beds clearly visible at Lincoln Cathedral quarry

calcite, the magnesian stones contain relatively little magnesium carbonate, over 90% of the mineral content being dolomite. Within its limited geographical span the magnesian limestones present a variable range of textures and colours. The textures can often be shelly with large pockets of crystal material, sometimes referred to as 'sugar', and their colour can range from rich yellow to grey. Within the main colour can appear dark flecks of iron oxide, whilst quartz grain impurities are quite common. White Mansfield contains approximately 37.4% quartz, leading to the stone being referred to as a dolomitic sandstone.

2.2 Properties of Limestone

The composition of stone, including its physical characteristics and performance, is the result of the circumstances of the process known as *diagenesis*. The conditions of sedimentation, including grading which occurred on the sea-bed, will have determined the homogeneity of the particles comprising the mass. Once the chemical and mechanical processes of sedimentation are complete, diagenesis describes the subsequent change to rock and includes cementation, lithifaction, and transformation into rock.

The performance value of limestone for building purposes depends on the reliability of its inherent properties. Central of these are as follows:

- Pore Structure and Moisture Content
- Factors Affecting Strength
- Hardness
- Natural Weaknesses

The following text will summarise the main properties of limestone which contribute to durability. These can be quantified by means of either indirect tests, which gain knowledge of the structural composition of the stone, or direct tests, which gauge a response to conditions that might naturally occur. Examples of the laboratory tests, developed by the Building Research Establishment (BRE) together with the standard tests of the American Society for Testing and Materials (ASTM) are given in Appendix A The ASTM Standard Tests for Compressive Strength and Modulus of Rupture.

Pore Structure and Moisture Content

One of the most significant factors in the durability of limestone is the amount of space within it which can accommodate moisture. The minute spaces are known as pores and the 'porosity is the volume of a stone's pore space expressed as a percentage of the stone's total volume.' (4) The porosity of stone can be measured and expressed as a percentage of space within the overall volume of the stone. This is useful and indicates the potential water content by absorption. Up to 2 % are low porosity stones, whereas up to 40% indicates a high porosity level, with around 10 to

25% being the common range of values. Porosity does not indicate the durability of the stone since it does not tell the size of the pores, but a stone with a greater proportion of small pores, or capillaries, can be assumed to be potentially less durable than a stone with fewer large pores. Capillarity is the rate at which water is drawn into the pores of the stone, and it is this property which largely controls the movement of water within the pore structure by evaporation and migration into adjacent materials. Capillarity is in effect the determining influence of the suction force. A higher rate of capillarity will ensure that destructive moisture-borne agents such as frost and pollution enter deeper into the stone's structure. Variable pore structures in the many materials combined in a building can create problems due to capillarity differences.

Moisture Travel and Evaporation

The movement of water, in the form of either liquid or vapour, about or through a material or assemblage of material units, eg. stone walls, is termed moisture travel. In individual stones the transmission of moisture is controlled by the action of capillarity and depends on the pore sizes and individual grain sizes. The travel of moisture in a stone wall occurs along the face of the wall in a downward direction, never creeping upward. Water passes easily along the more porous channels of lime mortar joints and may by-pass impervious areas across mortar renders, plaster work, or lichen and moss. The direction of moisture travel relies on the level of saturation. Some dense stones, Lincoln limestones for example, possess isolated pockets of oolites, often of coarser grain size and with larger interstices which will tend to hold moisture longer. Where stone walls possess stones of varying density and porosity, changes in saturation are impossible to predict. This may be further complicated by stones facing the weather and others facing away. As evaporation occurs in one stone or areas of it, water may be drawn from the stone adjacent to it.

The evacuation of water from stone under certain circumstances can have a deleterious influence. The ability of stone to lose moisture, either wholly or in part, is known as drying-out. This process is governed by the capillary nature of the stone and the prevailing conditions of the surrounding environment. Evaporation, defined as the transformation of moisture into vapour, occurs close to the surface of the stone. The atmospheric circumstances exercising an influence on this are temperature and humidity and the speed of air-flow over the surface plane. The surface acting as the drying plane may be inhibited by plant growth which may block the pores and prevent natural drying. The capillary network is comprised of the pores, and micropores of the stone. Capillary action, the rate at which water is allowed to move in or out of the pores, is determined by pore size. The smaller the pores, the tighter the pore network and the greater the capillarity. As evaporation occurs, the draw of moisture from further within the stone, which replaces lost moisture, is either aided or hindered according to the level of capillary suction. This is referred to as the 'capillary flow'. Residual moisture within stone, as the rate of evaporation falls, can be a major factor affecting decay, depending on the level of salt presence, or its liability to frost action. (See Appendix B Standard Tests for Porosity, Saturation Coefficient, Microporosity and Capillarity)

Factors Affecting Strength

It is very rare that an individual stone in a building is not functioning many times within its load bearing capacity. In fact, the very stability of a building structure relies upon the background of low compressive stress in order to provide a high level of compaction and a minimal risk of lateral movement. Heyman states three 'simplifying' assumptions, on the properties of stone, as a working premise:

> 'The three assumptions are: 1 that masonry has no tensile strength; 2 that stresses are so low that masonry has effectively an unlimited compressive strength, and 3 that sliding does not occur.' (5)

In fact, stones do possess very limited tensile properties and the compressive resistance of stone, although difficult to exceed, does have finite boundaries.

The transformation of the loose fragments of shell and skeletal remains deposited onto the sea-bed, into a consolidated mass of stone is known as lithifaction. The action is undertaken under enormous weight and pressure, compressing the particles until they are firmly consolidated and cemented together into laminated planes of stone. As a result of its sedimentary nature, limestones possess natural breaks in their mass, running both in parallel to sedimentation and vertical to it. Those that can be identified as laminations, are referred to as *bedding planes* and were caused by a temporary halt in the process of sedimentation. The breaks that run at right angles to the sedimentation process are known as *joints*, which are cracks that were normally caused by folding and faulting following lithifaction. Both characteristics are exploited by quarrymen during the process of extraction. Occasional joints, the result of marked movement in the masses of the land, sometimes created what are referred to as master joints, and intersect the bedding plane. Sediments were often laid in conditions where currents prevented the creation of strictly parallel layers; this is termed current, or cross bedding. The general mode of formation and the resulting compressive quality of the material represents its resistance to massive forces bearing down from above in the context of building construction.

Compressive Strength

This term can be defined as the load of a unit area under which stone fails by shearing or crushing. The resistant strength of limestone is at right angles to its natural bedding planes and is referred to, when in that position, as being 'naturally bedded'. The assumption that compressive stresses placed on masonry are so low that no danger of crushing exists requires clarification: 'This assumption is obviously 'unsafe', but it is not at all unrealistic.' (6) The low compressive stress exacted on stone will include the dead state of the structure, its own weight, plus any realistic superincumbent load placed upon it intrinsic to its construction, such as infil and mortar. In addition to this: 'Live loading will equally be carried by compressive forces.' (7) It might seem from this that the need for tests would appear to be irrelevant and none are officially performed in the UK,

although architects and builders often request the compressive strength of stone. A much quoted nineteenth century parameter calculated that a prism of average sedimentary stone would need to be 2 kilometres high before crushing occurred at its base (see Appendix A, The ASTM Standard Test for Compressive Strength).

Tensile Strength

The tensile strength of a stone can be defined as its resistance to tensile and shearing forces. Stone is a cemented assemblage of mineral grains, so its tensile strength is dependant on the grains and on the interface between them. Failure tends to be occur at the grain boundaries, individual grains tending to work loose and thereby creating fracture. 'Stability of the whole is assured, in fact, by the compaction under gravity of the various elements; a general state of compressive stress exists, but only feeble tensions can be resisted.' (8) Tests are carried out by ASTM, establishing resistances of rock to forces of rupture, expansion and flexure (see Appendix A The ASTM Standard Test Standard Test of Modulus of Rupture).

The assumption that stone possesses no resistance to tensile forces is not strictly true. Good masonry practice would indeed almost always recommend that advantage be taken of the compressive resistance of stone by being correctly placed on its natural bed. The ability of rocks to accommodate a limited degree of internal stress, caused by salt and frost crystallisation, is also due to a level of flexibility. 'Tensile strength is a very important parameter for estimates of a rock's resistance to expanding salts and freezing water'. (9) The tensile strength of stone is a most important factor, of which advantage was often taken by masons in the past. Projecting stone nibs, lintels and corbels rely solely on tensile counteraction, as do protruding gargoyles on churches and cathedrals.

Hardness

The hardness of rock can be defined as the resistance to permanent deformation and abrasion. Mineral hardness is measured relative to a standard scale known as Moh's scale. There are ten minerals on the scale, of which calcium carbonate is the third softest, lying between gypsum and fluorspar. Three particular qualities of relevant hardness can be considered in relation to limestones which are employed in the construction of the historic building, which are as follows:

- Scratch hardness can be tested on carbonate rocks with a knife blade, whereas on the mineral test it is necessary to find the next hardest mineral which will create a mark on the specimen.
- Impact hardness is defined as the resistance of the stone to sudden impact. This is expressed as the lowest height at which an object of a specific weight can be dropped on the specimen and cause a percussion mark.
- Abrasion hardness is defined as the resistance to abrasion, usually due to wear. In limestones the hardness of the granular component may have a limited influence on the rate of wear, the

strength of the cement bond and the density of the grains within it are of greater significance. Fine grained rather than coarse grained limestones are likely to offer greater abrasion resistance.

Inherent Weaknesses

Irregularities introduced at the time of sedimentation and during the subsequent complex processes of transformation into rock, create what is commonly understood as the 'character' of a stone. 'As a result of geological changes which took place during the time of their formation, sedimentary rocks may contain beds of different structure or of different composition.' (10) Certain of the 'characteristics' of a stone may alter to such an extent that the structure of a building becomes unsafe. Winkler speaks of the 'dormant residual stress' in stone, which may be subject to expansion in certain conditions. The physical change of state in the stone, which may take place in the natural outcrop or in the building, may result in the 'spontaneous or slow relief of 'locked-in' stresses'.(11) (See 1.3 *Failure in Gothic Buildings*) Such inherent defects in the building material may have been imperceptible to both quarryman, sawyer, and mason, becoming evident later during weathering on the building.

Vents and Shakes

Masons and quarrymen often refer to the defective nature of a stone as having vents and shakes, or possessing hard, or soft beds. Impurities of this sort can create long term mechanical problems, allowing water ingress and encouraging differential weathering, respectively. Schaffer, in defining such faults, writes: a 'type of natural defect which may have serious consequences is the presence of minute fissures in the stone.' (12) Faults of this nature may be attributed to earth movement at the time of deposition and during the process of diagenesis. Jefferson writes: 'Stresses and strains due to tectonic movement will fracture and shear the rock to a greater or lesser extent.' (13) Many microscopic ruptures may have subsequently been refilled with calcite solution, remaining structurally weak and difficult to detect. This physical separation would cause a displacement of the previously bonded shell fragments. Such weaknesses are distinguished as vents. On the other hand, Schaffer states: 'where the presence of a calcite vein has no harmful effect on the stone, the term 'shake' is commonly applied.' (14). These are described as veins which when weathering has occurred, are frequently seen standing in relief on limestones. [1]

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[1] In the experience of the writer, working in many parts of the country as a mason, these terms are used differently. Vents are most often referred to when describing openings between joints and may be considerably bigger than the strictly minute fissures described by Schaffer. They are thought to be generally created by stress beneath the ground. Shakes on the other hand are usually described as specific separations of the bedding planes, or cracks running into the stone where current bedding prevails. These are felt to be the result of a more recent source of disturbance, possibly from earth tremors or the effects of the use of explosives. Both vents and shakes are tested for by masons, using the ringing of a chisel on the stone surface. The description allocated to shakes by Schaffer, is usually defined as 'veins', by masons.

Impurities

Impurities occur within an otherwise homogeneous rock. These can come about due to variations in the materials initially deposited, or the lack of stability in the climatic conditions during sedimentation. Materials which become part of the rock may not possess similarly robust weathering characteristics to the main stone. Variations in deposition can create uneven weathering in several ways. For example clay components will be highly susceptible to swelling and separation by water, having a destructive effect on the rest of the stone. This may result in 'potholes' appearing in the stone, or 'furrows' along the bedding planes as the clay is fragmented away. Insolation, exposure to heat from the sun, will create zones of weakness due to the expansion and contraction differential. Microscopic flawing will provide water passageways and increase dissolution of the clay matter.

Individual deposits and pockets of iron, settled within the stone, will weather by oxidation once exposed to the air and moisture. Veins of iron-based matter will prevent uniform bonding and inhibit strength, also tending to reduce by oxidation. Some limestone beds possess a characteristic blue-heart, which comprises pyrite, the most common sulphide mineral. Pyrite on oxidation releases sulphur, which combined with moisture produces sulphurous acid. Burrows, in his study of the weathering of Lincolnshire limestone, speculates on this subject: 'Blue coloured stone should [also] be avoided as even though pyrite in its reduced state is not deleterious to the stone, its subsequent oxidation on exposure to the atmosphere will lead to the production of harmful soluble sulphate salts.' (15) Deep beds of Lincoln stone are found to be blue-hearted, as also occurs in Clipsham and Ancaster.

2.3 Factors of Decay

Introduction

As has already been suggested, the causes of decay in natural building stones and the action of what occurs as they decay are extremely complex and significant voids exist in knowledge of them, therefore the expectation that the processes of decay can be effectively stemmed for long may be unrealistic. It must be remembered that limestone is a natural material that embarks upon a continual process of deterioration immediately it is removed from the ground. Recognition of the causes of decay is, however, necessary in order to formulate some kind of defence against them. Whilst it is useful to separate the most salient factors of decay into individual categories, in few instances can agents be assumed to be working alone. Causes can overlap, sometimes by several others, and in many cases the principal bridging agent is moisture, without which frost would not occur, pollution would be rendered less harmful, and biological growth would not thrive (Fig 2.2). Buildings are subjected to enormous pressures from actual use as well as from the environmental elements. Popular historic buildings opened to the public can suffer from their own success, with often thousands of feet traversing floors and many hands touching monuments daily.

Winds that have picked up abrasive particles impact on buildings with tremendous velocity, inexorably wearing away historic detail. Acidic rain-water running across the face of walls can precipitate dissolution of the very material of which they are comprised, with soluble salts crystallising on drying and disrupting the surface of the stone. In the case of carvings, built into the wall to perform as masonry detail, there may be difficulty in distinguishing the effects of structural stress caused by the re-ordering of loads, from alien materials used in past repair. Erosion of the stonework caused by acid gases emitted by power stations, may be further exacerbated by plant growth on stonework which holds moisture next to it longer. On top of this, inadequate selection and the wrong-bedding of the original stones by the medieval builders, would create a cocktail of problems for those charged with their care In order to sensibly address such factors of decay, it is convenient to list them as follows:

- Physical
- Chemical
- Biological
- Man-made

In pursuing an understanding of the following categories of decay, an attempt must be made to interpret the usefulness to the practitioner of historic building conservation, and of how particular actions of destruction might direct defensive action. In cases where an historic architectural feature, such as a weathering moulding, is a contributor to the cause of decay, it may prove necessary to fall back to a secondary stage of addressing the problem, ie replacement. Initially,

Fig 2.2 Compound decay mechanisms. These photographs were taken within a period of forty years, showing a rapid rate of decay. Lincoln Cathedral Nettleyard. (Lincoln Cathedral Works Archive)

however, it is fundamental to this decision-making process to gain knowledge of the primary factors of decay.

Physical Aspects of Decay

Attrition

The symptoms of attrition, elements of the fabric worn down by external agencies, can most obviously be caused by the users of a building. Church and cathedral floors may have set in them important floor monuments and memorials, such as ledger stones, which can be seriously worn down by the traffic of feet, wheelchairs, or other objects. These stones can be further damaged by ill-informed cleaning processes, such as the careless use of mechanical vacuum cleaners and floor polishers. Internal monuments and sculptures often seem to invite what is ostensibly harmless tactile involvement from the public, yet each touch contributes to the long-term wearing down of the surface of the work. A difficulty lies in retaining the incidental nature of use of such premises, or cordoning-off areas in the same way as do museums and galleries.

Externally, air-born particles (aerosols) delivered forcefully by high winds can create much damage by abrasion to stone surfaces. Over a long period, this can result in loss of detail and can have knock-on effects, with water entering joints. Often, the effects of wind erosion are most evident at the extremities of the building. In the case of a cathedral, spires and pinnacles are often affected by high winds alone, with lime-mortar joints between stones risking being ground out due to vibrations set up in tall thin structures (see *5.2 Case Study: Replacement of Two South Transept Pinnacles*). As mortar is blown away, the heavy stones eventually contact one another, their surfaces continuing to grind together. Elements of decay are then permitted access into the joints and eventually into the core of the masonry where further damage occurs.

Fracturing

In the normal course of events in resisting live loads, such as the wind, rain, and snow, a major masonry structure such as a cathedral can be expected to move, with compressive stresses being converted into tensile forces. At specific points of tension (*see 1.2 Critical Areas of Tension in the Gothic Frame*) these movements occur as loads and are adjusted within the structure, and may be more exaggerated than elsewhere and some minor damage to stonework can be expected. (see fig 1.10c p32) Similarly, fractures may occur where ferrous metal fixings have been placed, such as for dowels, cramps, and for other reinforcements (Fig 2.3), or where natural weakness, such as clay beds, are eroded away by the weather. In themselves, minor cracks and fractures are acceptable in the masonry structure, and are only a cause for concern when accompanied by bulging of walls. Repeated fracturing, however, may indicate fundamental movements in the structural masses and may require close monitoring.

Fig 2.3 Fracturing caused by the insertion of iron ties within masonry. Lincoln Cathedral north nave clerestory.

Bedding of Stones

Correct bedding of stonework, with weight from above bearing down on the horizontal laminates of individual stone blocks, will maintain walls in a state of compression. Stones in this position, ie, the same as they were sedimentarily laid down, are referred to as being 'naturally bedded'. Apart from assisting to maintain structural stability, walls constructed and maintained in this manner are better able to resist the ingress of water. Where stones are required to be larger in area than natural bedding allows, they may have been placed in a wall at right angles to their bedding planes. In such cases, stones are referred to as 'face-bedded', where the plane runs in line with the face of the building, and 'end-bedded', where the plane runs at right angles to the face of the building. In both these states, stone is weaker than when naturally-bedded, and is less weather resistant, although the practice of selecting stones in such a way was common in the case of window mullions, columns, cornices, coping stones, and large scale sculptures.

Thermal Stresses

Air-temperature change, generally from heat of the sun in the day to loss of heat at night, has the effect of creating physical movement in all traditional building materials. This takes the form of expansion on heating, and contraction when cooling.[1] Such action is termed thermal movement and exercises a stress on materials, significant in the process of their decay. The amplitude of thermal action is determined by the reception of the solar properties to the surface and the capacity of the material to absorb the heat and, in effect, reduce the severity of it. This depends largely on the thickness and conductivity of the material and its coefficient of expansion. Light coloured materials with a glossy sheen will reflect the heat, so offering a less receiving surface. Dark matt surfaces will absorb the heat and suffer greater heat gain. Individual elements of a building never achieve a constant temperature, but may pass on the impact of heat reception by conductivity, thus reducing the sensitivity of localised areas of the building to thermal movement. The process of conduction ensures a flow to and from the building mass over a protracted time span. Late spring, summer and early autumn provide an overall heat gain, the rest of the year providing a net loss. 'Temperature differential across the block of stone is likely to be greatest in the early afternoon of a hot day.' (16) Buildings of a low thermal mass suffer a greater vulnerability

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[1] Stone moving through temperature changes, having once expanded, will not necessarily return to equilibrium. In an experiment, the BRE heated marble slabs to a temperature of 150°C, at which point they became warped, but on cooling they did not return fully to their original dimensions. Repeated heating showed a progressive deformation set. According to Schaffer: 'This permanent expansion, which is probably due to a slipping of the individual calcite crystals on one another, is believed to be the cause of the warping.' SCHAFFER, *The Weathering of Natural Building stones*, London, HMSO, 1932. p42. It was noted also, that the compressive strength of the marble, after 100 repetitions of heating and cooling, was found to be considerably reduced. A differential may be created between the surface and the mass of the stone by the concentration of heat from the sun. This is reversed at night as the surface becomes cooler than the interior (Unequal expansion causes the surface to develop hairline cracks which may become a problem, again, in combination with other agencies of decay).

to variation due to thermal movement, whereas buildings of a high thermal mass, such as a cathedral, are less sensitive to such variations.

For practical purposes it needs to be recognised that when rocks have undergone temperature change a series of stresses is set up in them due to conflicting directions of inner expansion and contraction. 'The coefficients of expansion of the rock forming minerals differ among themselves and many crystals have different linear coefficients of expansion in different directions.' (17) These pressures are sufficient to disrupt the structure of the stone and may eventually lead to the opening up of cracks, or micro-fractures. Such openings would then be vulnerable to the ingress of moisture, including soluble salts and potentially harmful chemicals, thus allowing combined effects to exact further decay (It should be pointed out that in the temperate climate of Britain, such stresses are not a major issue).

Frost Action

Water ceases contracting and begins to expand immediately below freezing point. As it converts to ice it expands suddenly by a rate of up to 10% of its volume, taking up whatever degree of available space is within its container, in the case of limestone this will be the pore space. This free space will determine the amount of expansion permissible before pressure is exerted; if it is less than 10% in the pore of a stone, a commensurate force will apply. Pore structure and saturation coefficient, the relation of its capacity to absorb water to its porosity, ie the total volume of voids, are important factors in the resistance of stone to disruption by frost. Where water is actually already held, whether the voids are full or partially so, is impossible to determine. The size and configuration of the pores are important factors in influencing frost attack in that they control the level of moisture content, and the gradient of moisture from the inner to the outer areas. The critical pore size is 5 microns, below which the term micropore is used. Outward drainage by hydraulic pressure is impractical at micropore level, and water is squeezed forward exerted by expansion, and damage occurs (see Appendix B Standard Test for Porosity, Saturation Coefficient, Microporosity and Capillarity).

Stones possessing a high level of micropores are therefore more vulnerable to frost damage, and fluctuations around freezing point may create greater physical disruption in stone than a single direct frost. Damage due to the action of frost is most likely to occur to stones which are already saturated, so irregular downfalls of rain followed by heavy frost are the conditions most likely to cause damage. In normal circumstances, those stones which are in the greatest position of exposure, or are likely to retain moisture over a longer period, are most susceptible to frost damage (Fig 2.4).

Fig 2.4 Frost damage. Lincoln Cathedral Chapter House flying buttress.

Chemical Factors of Decay

Introduction

Chemical weathering is caused by the interaction between constituents of the stone and components in the air or carried by moisture. The two main problems are the effects of soluble salts and the dissolution of limestone by acid deposition. Soluble salts rely on the porous properties of limestone and moisture travel within it. Limestone, calcium carbonate ($CaCO_3$), is only slightly soluble in water but highly reactive with acids. Rainwater and ambient moisture may form acid solvents through combinations with acid gases in the atmosphere. However, there is some crossover and perpetuation in the deterioration effects: some sulphates can be the products of both salt crystallisation and acid rain reaction; some acid reactions liberate more acid gases. Common factors in all types of chemical decay are moisture and temperature. To control rates of chemical decay would therefore require environmental conditions of particular relative humidity (RH), temperature, and exclusion of harmful atmospheric gases. This might be possible within a museum, to some degree inside a cathedral, but for external stonework, airborne pollutants, atmospheric moisture and temperature changes throughout the day and seasonally are impossible to negate.

Soluble Salts

Salt crystallisation is a major factor in the decay of limestones, with potential for enormous damage both at the surface and throughout the stone. In solution salts can migrate through the pore structure, but as water evaporates the salts crystallise out and take up more space, exerting pressure on pore walls. This damage is initially microscopic but repeated wetting and drying cycles will eventually cause stone to blister and crumble, destroying its structural integrity (Fig 2.5).

Soluble salt sources may be as follows:

- *Salts Inherent in the Stone:* Since the original process of sedimentation and the diagenetic processes of rock occurred in natural circumstances where salts exist, they form part of the rock make-up. The composition of 'the majority of florescences consist of sulphates of the alkali and alkaline earth metals, principally of sulphates of sodium, potassium and calcium'. (18) In oceanic conditions sodium chloride salts would have been present, although later they may have to some degree been flushed away by rain action. The sulphide mineral pyrite, on oxidation, produces sulphate salts, although the level is difficult to quantify. This inherent characteristic is evident in many of the local Lincolnshire limestones. The continual presence in rock, of sufficiently hygroscopic salts such as sodium, would have increased the cycle of erosion, since they exert a solvent influence on the calcium sulphate.

- *Salts Produced by Weathering:* These elements are the product of the interaction between components of the rock material with constituents in the atmosphere and are the result of a

Fig 2.5 Soluble salt damage. In this example the stone has 'peeled' back from its original profile by up to 10cm. Lincoln Cathedral north nave clerestory.

chemical reaction. Salts created by the process of chemical weathering can be described as secondary pollutants, where new products are formed. The primary pollutants are mainly those chemicals in the atmosphere.

- *Salts From Other Sources*: The introduction of soluble salts into building stone occurs from three other main sources, which are a) soil, b) mortars and grouts, and c) acid deposition. It has already been established that the earth bears salt products. The salts become soluble in ground-water, becoming mobilised and drawn into the stone by capillary pull.[1] Nitrates, chlorides, and sulphates of magnesium and calcium, common ingredients in soil, can become absorbed into the pores of the stone to produce salt action, manifested as crypto-florescence, or efflorescence. In the case of retaining walls, where the floor level within the building is lower, florescence may occur in the middle areas of the wall, according to the relationship of the outside ground level. Many materials used in association with the construction and subsequent repair of historic buildings can create salts. It is often extremely difficult to ensure that the use of Portland cement is restricted to the very minimum. Such cements can be strongly associated with florescence. The natural earth materials used to manufacture Portland cement can contain alkalis. Consequently, in reaction with the atmosphere, they tend to produce alkali salts.[2]

The Effects of Salts on Limestones

There are three terms used to describe characteristic damage exacted by salts on limestone, which are as follows:

- *Florescence:* Salt crystallisation can occur within the pore system of the stone, or appear on the surface. These symptoms are termed respectively: crypto-florescence and efflorescence, and collectively florescence (derived from the root 'flora' meaning to burst into flower). The occurrence of florescence depends upon the conditions of evaporation. Where evaporation occurs rapidly under hot circumstances, the internal moisture has no time to gravitate to the surface. In these conditions crypto-florescence will occur within the pores of the stone, with no visible signs on the surface. A more natural drying process which takes place under temperate conditions, with evaporation proceeding steadily, will result in the visible characteristics of

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[1] At Lincoln in the mid 1980s, a stock pile of limestone was purchased which had been under a railway embankment for a hundred years. The quality of the stone was examined by Geologist and Mason and deemed fit for use. However efflorescence became a problem, emerging after fixing.

[2] Where concrete underpinning of churches and cathedrals has been executed, there is a great danger that the residual salts will migrate into the stone. This is evident at York Minster where, following massive underpinning, salt migration became evident up to and beyond plinth level (See 1.2 *Remedial Action to Historic Foundations*). Pure lime mortars are more sympathetic, being chemically compatible to limestone and producing less salts. Pozzolanic, or 'Roman' cement mortars, have less of a likelihood of producing salts, although some substitutes for pozzolans, such as pulverised fly-ash may have a high sulphate content.

efflorescence, white powdery deposits. If periods of evaporation are sustained the inner moisture will take up vacated pore space and draw inner soluble salts to the surface (Fig 2.6).

- *Surface Skins:* Repeated surface evaporation can create a separation between the rapidly drying area and the rest of the stone body. Moisture will tend to gravitate towards the areas where evaporation occurs, with salts gathering at the interface. This may create pore blockage, further limiting the likelihood of deep evaporation. The evaporation differential between the surface and interior of the stone will then increase the likelihood of salt precipitation within the stone. Continuous salt precipitation at the surface may result in the formation of a hard crust.[1]

- *Exfoliation:* It is tempting to deduce that the crowding of salts behind the surface of the stone, due to the sieving action of the less pervious skin, creates exfoliation and forces the face to burst. However, often at the point of blistering there is little evidence of salt accumulation. A degree of conversion from calcium carbonate to calcium sulphate (gypsum) may take place on and around the surface, leading to a distortion of the original dimensions of the face of the stone. Schaffer questions this theory, which suggests an increase in volume, on the basis that 'it is necessary to assume that the calcium carbonate is converted *in situ* into gypsum, whereas the structure of the skins indicates that their conversion is not entirely due to direct conversion'. (19) The gypsum, Schaffer explains, is more likely to be the product of deposition. As an alternative idea, Schaffer proposes that due to the difference in the rates of thermal expansion between calcium carbonate and calcium sulphate, the latter being five times greater, lamination in the stone surface occurs. Thermal increase, causing expansion and at the same time evaporation, allows sulphate deposits to invade the micro-cracks of the surface. Subsequent patterns of repeated crystallisation and dissolution bring about a continued redefinition of the stone surface.

An example of exfoliation is associated with the jambs and mullions of windows, the stones of which are of a single depth. Dramatically opposing conditions can exist on the internal and external surfaces of the stone. The internal atmosphere, with low humidity and relatively high temperature, encourages a constant evaporation process, effectively drawing through the stone the salt laden moisture supplied by the natural conditions existing outside. The result is often seen as a flaking away of the surface skin on the internal face of the stone.

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[1] Experiments carried out by Burrows, S.J. *Mineralogical Changes Associated with the Weathering of Lincolnshire Limestone of Lincoln Cathedral*, MSc. Thesis, Leicester University, 1990., on Lincoln limestone samples confirm that surface crusts were a combination of calcium sulphate, dust (clay minerals) and soot, with a concentration of precipitated salts immediately beneath the surface skin. He observed that disruption of the surface appeared to be imminent and that these skins also tended to be less porous than the rest of the stone.

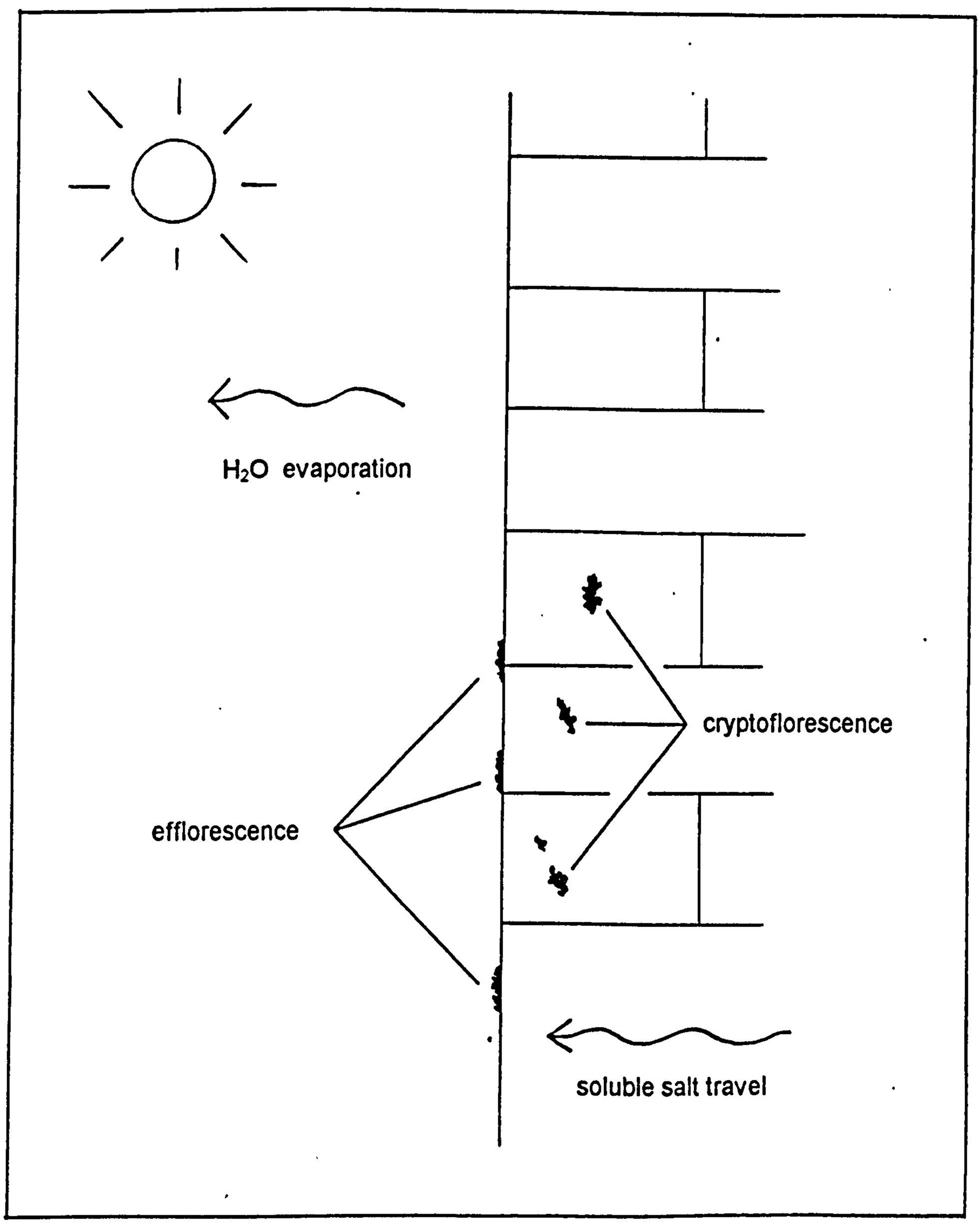

Fig 2.6 Diagram showing the actions of florescence. As moisture evaporates soluble salts crystallise either within the stone or on the surface.

Acid Deposition

Introduction

'The effect of air pollution on limestone is an extremely complex one which is exacerbated if the stones on the building have a long and varied history.' (20) The by-products of commercial and domestic activities which involve the combustion of fossil fuels are emitted as dusts, grit, soot, and gases. The routes by which such pollutants become aggressive agents towards stonework depend very much on weather conditions. Low winds, in anticyclone conditions, can have an adverse effect as can inversions of temperature which effectively hold pollution low to the ground. All chemical agents require the fundamental addition of moisture in order to precipitate reaction, thus forming a two-pronged level of attack as solvent and reactant.

The main agent in acid pollutant decay is sulphur dioxide. The gas dissolves in water to form sulphurous acid and may then follow two reaction paths both ultimately converting limestone to gypsum, which is approximately 200 times more soluble in water than the original limestone. Further erosion may then follow in several ways, some gypsum will be washed away by rain action or if the stone remains dry a surface skin can form. The gypsum traps particles of soot, dirt, etc, forming the familiar black crust (Fig 2.7). This in turn is hygroscopic, compounding the problems of soluble salts and further acid deposition and dissolution.

Dissolution of Limestone

Sulphur dioxide is the product of the combustion of fossil fuels, which in contact with rain produces a mild sulphurous acid, commonly referred to as acid rain.

> 'Some scientists have collected data indicating that acid precipitation is one of the most corrosive influences on modern civilisation, accelerating all we value - our architecture, agriculture and natural environment.' (21)

The effective transformation of water into an acid solvent is much enhanced by the addition of carbon dioxide, the mixture of which will have then formed a mild carbonic acid solution. Subsequent reaction with calcium carbonate will produce calcium bicarbonate, which is highly soluble. The effectiveness of the solvent is dependent on its acidity, the action being enhanced according to the saturation condition of the building stone. The lower the level of saturation, the more vigorous the solvent attack. Ambient temperatures also have an effect on the solvent efficiency; the warmer it is the higher the effect of acidity and the greater the solvent action as a form of erosion. The range and combinations of minerals and the physical structure of stone can result in an inconsistency in its weathering pattern. Dissolution of limestone requires the presence of moisture, or solvent. Those areas which hold moisture longer are subject to greater advancement in the process of dissolution. This is also applicable to the drying mechanism of the stone. The speedy riddance by the stone of the moisture from its surface and pores provides a protection against solvent completion. An open grained stone will lose its water quickly, whereas

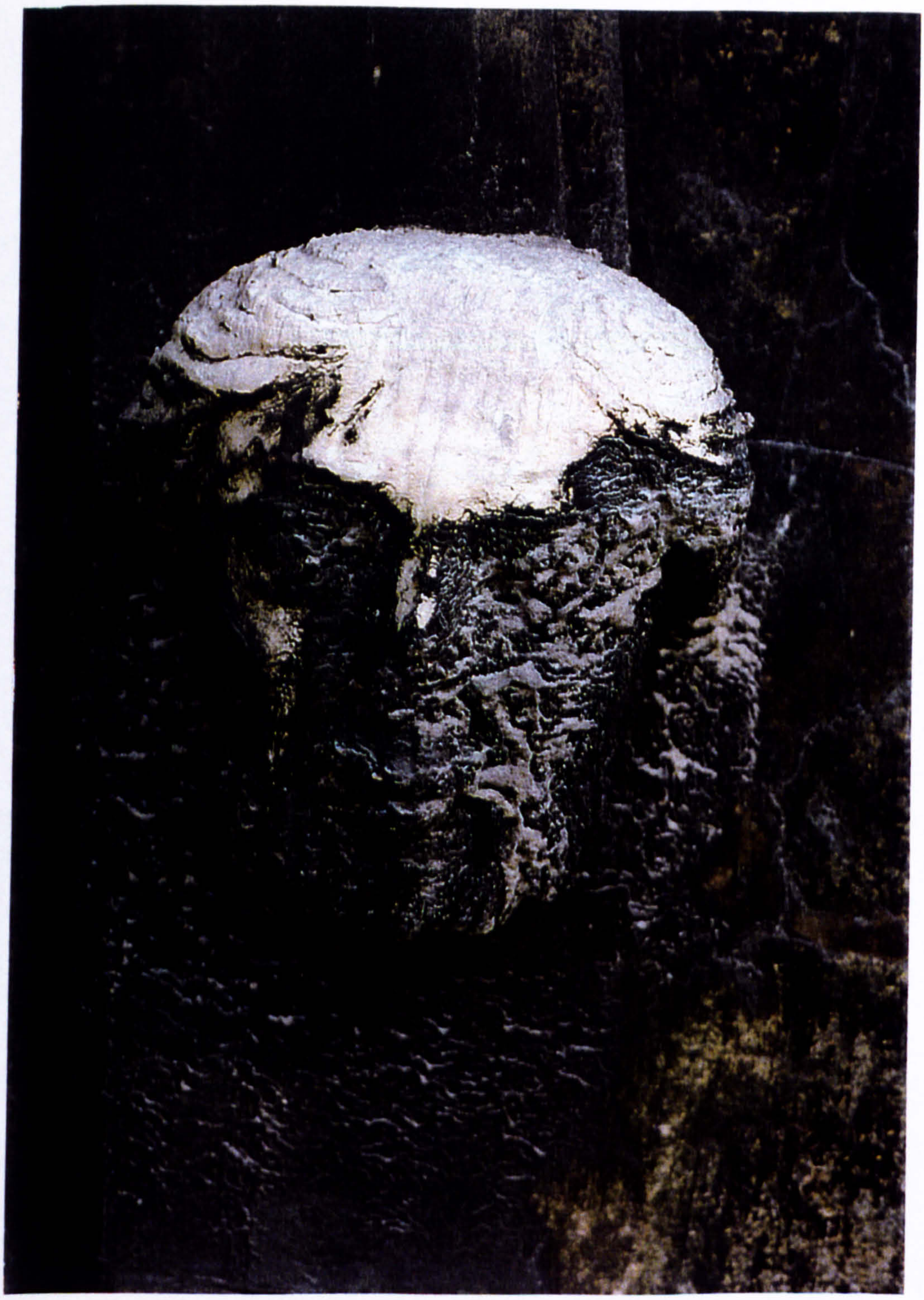

Fig 2.7 Typical build-up of black pollution crust on carved detail, showing rain-washed upper surface and thick encrustation beneath. Lincoln Cathedral west front.

close grained stones of a microporous nature, will remain damp over a longer period. Fine grained stones present a higher percentage of rock face to the elements and accept a greater chemical reaction. For these reasons they are likely to suffer a larger degree of disruption. Patterns of grain structure in sedimentary stones are not sufficiently consistent to be able to predict erosion levels, but generally the coarser grained areas will suffer less at the expense of finer grained areas.

The main constituents produced from the burning of fossil fuels are sulphur dioxide (SO_2), carbon dioxide (CO_2), and oxides of nitrogen (NO_x), which participate in the production of man-made ozone (O_2). Sulphur dioxide, and to a lesser extent Sulphur trioxide (SO_3), present a grave threat to building limestones. Even carbon dioxide, though less of a hazard, does form a mild acid solution which precipitates the dissolution of calcium carbonate. Nitrous oxide levels have recently risen due to the increase in motor vehicle use, though there is little research available on which to comment about damage incurred to building materials.

Sulphur Dioxide (SO_2)

Sulphur dioxide occurs naturally in significant quantities, but also as a by-product of the combustion of fuel. There is between 1% and 2% sulphur in coal in the form of pyrite or organic sulphur which, when burnt, oxidises to form sulphur dioxide. Approximately half of the sulphur remains in the ash or soot residue. Also, there is between 0.75% and 3.5% sulphur content in the oils (of the North African fields) commonly burned as fuels in Europe. Natural gas has a negligible sulphur content. Concentrations of atmospheric sulphur dioxide vary according to area, predictably dictated by usage of high sulphur fuel. On being emitted from the chimney, sulphur dioxide floats downwards towards the ground, some particles possibly becoming neutralised by the presence of alkaline products in the air. Highly hygroscopic, the sulphur dioxide quickly comes in contact with droplets of moisture, and dissolves as a weak sulphurous acid. The water may contain traces of iron, manganese or other metals, which serve to enhance the oxidation process. Travelling away from the source of the emission with the wind, the 'acidic' rain is eventually deposited on the stone.

The effects can be followed through the equations:

SO_2	+	H_2O	→	H_2SO_3
sulphur dioxide	+	atmospheric water	→	sulphurous acid
2. H_2SO_3	+	O_2	→	2. H_2SO_4
sulphurous acid	+	oxygen	→	sulphuric acid
Ca CO_3	+	H_2SO_4	→	$CaSO_4 + H_2O + CO_2$
limestone	+	sulphuric acid	→	Calcium sulphate (gypsum) + water + carbon dioxide

There are other possible chemical combinations and routes for sulphur dioxide to take, but all ultimately lead to the dissolution of limestone and its conversion into gypsum.

Carbon Dioxide (CO_2)

Carbon dioxide is a gas formed by the oxidation of carbonaceous matter, and is also a product of the combustion of fuel. In combination with water carbon dioxide can produce a mild carbonic acid, capable of dissolving calcium carbonate. It is a naturally balanced component of the atmosphere, breathed out by the animal and human population and generally assimilated by vegetation. The burning of fossil fuels has greatly contributed to the levels of carbon dioxide and is particularly concentrated in urban areas.

Nitrogen Oxides (NO_x) and Ozone (O_2)

Nitrogen Oxides levels in the atmosphere have increased substantially since the second world war, approximately doubling. This is largely due to the association of general prosperity and upward trends in the use of motor vehicles. Air quality data for No_x levels is not as thoroughly researched or recorded as for SO_2, although it is suggested that the combination of falling concentrations of SO_2 and rising emissions of NO_x may be critical to the built heritage. This synergism is known as the 'cocktail' effect, and may be a suitable case for monitoring in the future. The increase in the incidence of nitrogen dioxide is cause for concern, particularly considering its part played in the disturbance of the balance between nitrous oxide and ozone. 'Ozone is created in the upper atmosphere by the action of ultraviolet radiation on oxygen and diffuses down to ground level.' (22) Actions by man, causing chemical reactions to occur in the atmosphere, result in the daily manufacture of man-made ozone. Most important amongst these actions is the emission of nitrous oxide and hydrocarbons, the results of traffic. Low nitrous oxide levels are more or less equally negated by the ozone and while this balance is maintained, low ozone levels remain. However, nitrous oxide is further activated by the increasing sunlight of the day, and is replaced by a concentration of nitrogen dioxide (NO_2). The final result of this complex chain of reactions is the formation of ozone, which although not a primary pollutant is a highly active oxidising agent.

Summary

It is difficult to establish a complete picture regarding the condition of the atmosphere over Britain. Concentrated emissions of sulphur dioxide in urban areas have dropped dramatically over the past thirty years. However, this is balanced against the fact that statistics are available only in urban concentrations, which have decreased. This reflects a shift from the low and medium level domestic and industrial sources, toward centralised higher level emitters. The latter sources, rurally sited electricity power stations which are themselves fired by coal, are not difficult levels to establish. The Building Effects Research Group (BERG) report (23) states that the reduction of low and medium sources of emissions have decreased at a greater rate than the total level of sources. Is it to be concluded therefore that similar or higher annual outputs of acidity into the atmosphere, spread over a greater area rather than being concentrated over towns, is more acceptable?

Carbon dioxide levels remain high and are effected by ordinary domestic items such as central heating, fridges and the use of aerosol sprays. The burning of oil, coke and other fossil fuels, as well as the normal respiration of animals and humans, contribute to levels. Due to traffic congestion, such components are more plentiful in towns and cities and have the tendency to rise in conditions of fog and heavy rain. The levels of CO_2 have a significant effect on the levels of rainfall pH, which again raises the question of the long term significance of the dispersal of acidity and the types of deposition, whether wet or dry. The resistance or reaction to the effects of acid pollutants by limestone relies greatly on the circumstances of contact and may be greatly influenced by temperature, humidity, wind and rain.

The outstanding anomaly in the current trend of atmospheric acid gases is that of oxides of nitrogen which continue to rise dramatically with the continuing upward trend of motorised transport. The BERG report states that 'there has been no apparent trend in air concentrations of NOx at the relatively few sites where the measurements have been made over the past ten years or so.' (24) However, the report also makes only fleeting reference to the complex and ominous implications of synergism, the action of two or more pollutants together. The potential of even low concentrations of sulphur dioxide, creating weak sulphurous acid, mixed with a dilute nitrous acid solution, is deserving of further research. The complexities of such chemical reactions are intrinsically associated with the physical mechanisms of decay. The rate of absorption of individual stones, the incidence of moisture transfer, and reactions under thermal change, all occur simultaneously as salts are being manufactured within the stone due to acid reaction, in addition to residual salts from other sources. The aspect and orientation of stones, their capillary nature and the microclimate they exist within, the nature of their design and their general condition of repair, all play a significant role in how decay takes place or resistance is maintained.

Biological Factors of Decay

Introduction

Biological causes of decay are usually relatively minor compared with physical and chemical factors. Often their effects are more unsightly than physically damaging, for instance the 'greening' of masonry through algae growth. However, superficial damage may become severe given time or may serve as a catalyst for other agents of decay.

Lower and Higher Plants:

Bacteria, algae, lichens and mosses - these may all grow on limestones and attack the surface of the stone Some lichens secrete organic acids which can etch stone. Although it would appear that lower plant forms are negligible decay factors, some scientific opinion suggests that biological effects should not be too hastily dismissed. For instance, in the case of Purbeck marble it has been suggested that bacteria may play a role:

> 'The energy source for these bacteria can be sulphide minerals, which when broken down by the bacteria give rise to sulphates and sulphuric acid. Thus it is possible that the damage attributed to "acid rain", together with the secondary minerals which are said to be the result of such reactions, could also be caused by biochemical means within the stone as well as at the surface.' (25)

These lower plant forms can also create a hygroscopic layer over the stone, and prevent water from running off.

Plants with roots such as ivies can force out mortar joints allowing ingress of moisture and pollutants. Root growth can also lift stones, jacking up masonry and dislodging stones.

Animals

Most problematic are birds, especially pigeons. Their droppings are unsightly and contain ammonium salts, which contribute to soluble salt decay and at the same time provide a food source for bacteria. Nests also create hygroscopic areas, again attracting moisture, dirt, and pollutants to be held against the stonework.

Man-made Factors of Decay

Introduction

This category falls broadly into two different types, firstly the selection and use of limestone in a way that invites and accelerates decay through the physical and chemical factors already discussed. Secondly, by the addition of alien incompatible materials which introduce further decay mechanisms and deny the natural properties of limestones. This latter category is usually found in unsuitable previous repairs, often from relatively recent work programmes and is due largely to a lack of understanding of traditional masonry building techniques.

Selection, Design, and Craftsmanship

Two main types of clearly identifiable circumstances are worth describing, since these are both areas that may need to be taken on board as maintenance considerations. Firstly, with the design of inadequate architectural detail there is little that can be done even where replacement is approved, since this will normally be prescribed on a like-for-like basis. It may be sensible, and may even receive approval, to replace a moulding with a slightly modified weathering detail. Where poor choice of materials may have resulted in advanced decay and until that particular area of stonework becomes a candidate for replacement or repair, there is very little that can be done. Although symptoms may have been imposed on the structure either at the time of original construction, or some centuries later, it can at least be identified and subsequent repair should ensure that the same faults do not recur.

Inadequate Weathering Details

Whilst the analysis of architectural design is not a fundamental part of this study, certain occurrences cannot be ignored. This is particularly related to a primary function of architectural design, which is to cast water away from the roofs and walls of the building. Gothic mouldings, carvings, and sculptures inevitably took this necessity into account in their final design, with subtle runs guiding the water from the carved work, so that water was not trapped anywhere close to the building. Such elementary rules were not always followed, however, and the resulting damage can often testify to this. On the west façade of Lincoln Cathedral their are examples of bad practice in this respect, with large areas of flat weathering stones allowing water to pool, in some cases even being inclined to guide the water inwards to the fabric. In the early work of the eleventh and twelfth century it is possible to see examples of exceptionally poor weathering details, specifically over the Romanesque frieze. The influence of the weathering moulding[1] over the sculptures is to actually guide the water towards the carved face (Fig 2.8).

Choice and Selection of Building Stone

Inevitably, the choice of stone for building was dictated by its availability, since the logistics of transportation were often arduous and expensive. In most instances in Britain, with the exception of the south-east where stone needed to be imported, distance was not too great an issue. Many of the nations cathedrals, for instance, tend to lie within the catchment of the diagonal belt of limestone that extends from the river Humber across the country down as far west as Exeter. The choice of decorative limestones, such as Purbeck can almost be seen as an indulgence, its proliferation depending upon the resources available.

Often, the first beds of stone to be quarried had already been subjected to the rigours of the rain and frost, being the easiest won from the ground since they lie at the upper levels of the strata, and had been offered least protection from the overburden, which included layers of shale, loose stone, clay, and earth. Unfortunately, these were frequently the first beds of stone to be extracted for building purposes, therefore the first to be dressed and the first to be fixed in place as part of the substructure or plinth course, where resistance to frost and rising damp needed to be greatest. These stones could need to be quickly replaced.

The position of stone in the quarry is critical and will inform the experienced quarryman or mason of some of its most likely properties in relation to resisting the weather in the long term. For example, where a quarry is worked intermittently, but has not been quarried for some period of time, the stone nearest the face may need to be sacrificed, before stone of better condition can be reached. Where commercial firms are under pressure to show profit, this may not always be

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[1] The string course of the original eleventh century façade was not designed to protect sculpture, but was utilised when the Frieze was inserted. Even though it was placed in a plain ashlar wall, it has never properly performed its proper function as a weathering detail.

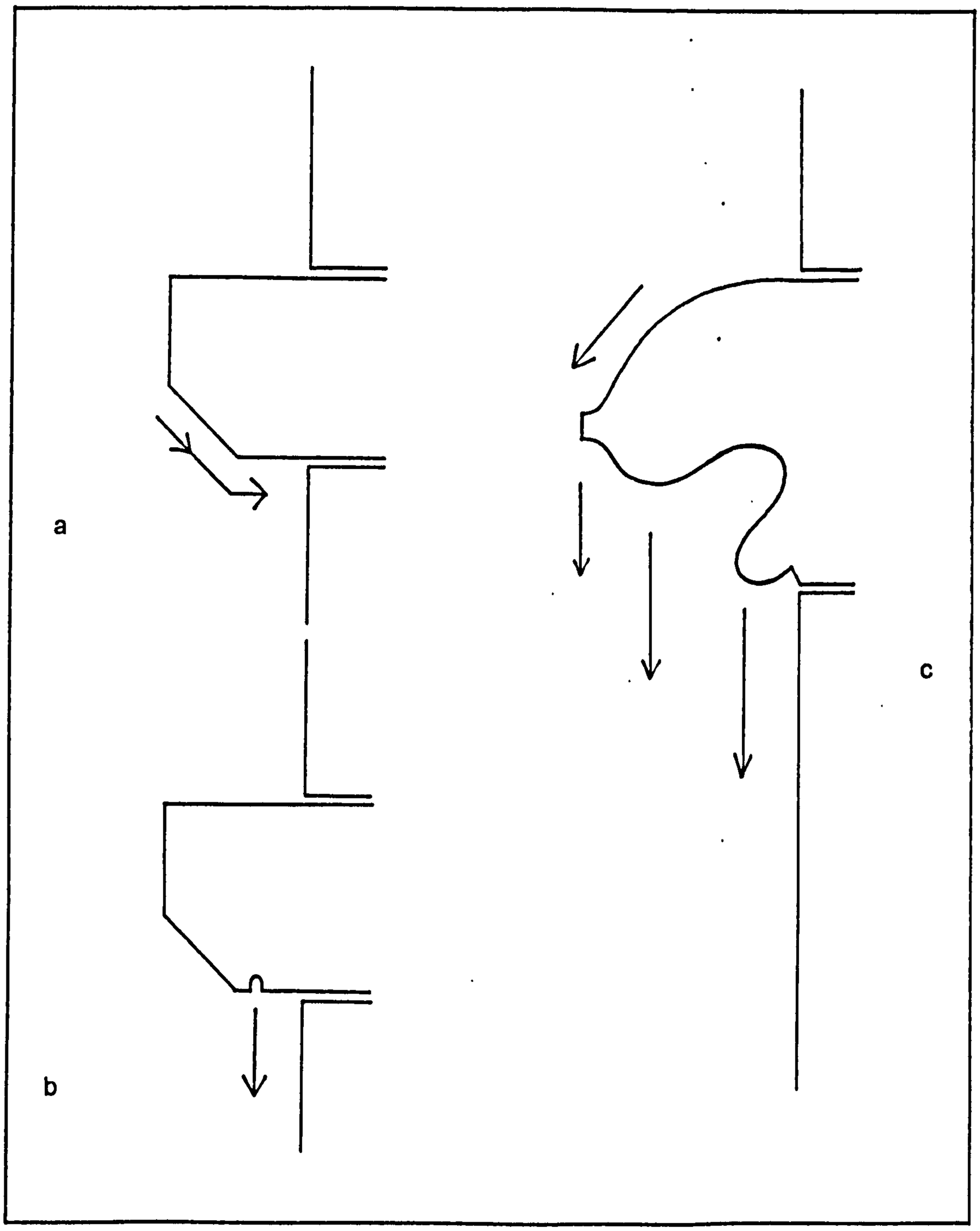

Fig 2.8 The efficacy of weathering features can have an affect on the stonework beneath:
a) a Romanesque string course possessing no 'drip' detail serves only to guide rainwater back onto the stone.
b) a simple drip detail would be more effective.
c) typical Gothic string courses and label mouldings were totally designed to cast water away from façades.

welcome advice, but it is worth bearing in mind that a well run quarry will suffer only a bare minimum of waste.[1] In medieval times, when wholesale earth-moving methods were relatively primitive, it is probable that stone for dimensioning would have been removed from hillsides or escarpments. Large scale excavations would have been avoided in this way, with stone being effectively mined rather than quarried. Lincoln is particularly likely to have yielded stone for building in this way, since both the Cathedral and the Castle are built on the immediate edge of the Lincoln ridge, a limestone outcrop. Phenomenal amounts of stone were originally required and as a result evidence could be expected in the landscapes, in the guise of hollows. Archaeologists have identified several shallow concaves in the Lincoln hillside, where stone was most likely removed for building purposes. It would still have been necessary for the quarrymen to have gone some distance into the ground to select material that had not been attacked by rain and frost. In the case of Lincoln, there would have been much to commend mining as a means of extraction, for instance a ready view of the beds would have been available for view and selection, so that unnecessary excavation and removal of spoil would have been kept to a minimum.

All stones vary greatly, but the variables within limestones are perhaps greater than sandstones or granites. Individual seams within a quarry cannot be subjected to any assumptions, being capable of differing dramatically in character within a small area. In some cases, even a single stone may yield widely varying characteristics from one end to the other. Selection of stone for particular purposes is as much a part of the skill of the mason as working it (Fig 2.9). The signs of quality in a stone are varied and the mason may require to knock off a good sized corner or two to inspect a block beyond its earthy covering. There may be pockets of clay, or loosely packed oolites in it.[2] Individual masons will have their own method of inspecting a block of stone, the most common being giving it a tap with a hammer. A resounding ring will indicate that the block is relatively free from vents or shakes. If the visual quality of the stone is consistent, with no dramatic changes in colour or shade, it is beginning to seem that the block is likely to be of good quality.

A skilled mason, or carver, will often wish to select his or her own stone for special purposes. Generally good quality categories of stone may be relied upon for ashlar or ordinary running mouldings, but in the case of select pieces of architectural carving or sculpture, the craftsperson may wish to assure himself that the stone is of exceptional quality and free from blemishes.

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[1] An economically run quarry will be able to find a use for most of the material produced, whether as good quality dimensional stone for sculpture and carving, construction purposes, for conservation work, general walling stone, rockery stone, to be sold at garden centres or for the burning of lime. Stone is a first rate, scarce building material and can easily be sold at competitive rates rather than being left to waste, to be ploughed back into the ground as back fill.

[2] Lincoln stone is an limestone of the inferior oolitic type, and is not regularly structured. A visual characteristic of the stone is small patches of coarse 'egg-like' areas, darker brown in colour. These are bands of oolites and are quite natural, but may possess a slight weathering difference in the long term.

Fig 2.9 Stone selection is an important part of the stonemason's skill, utilising appropriate beds of stone for specific purposes. Poor selection and wrong bedding direction has led to complete deterioration of this label moulding. South chancel window Ashby Puerorum Church, Lincs.

Close scrutiny and sound-testing is practically the only reliable method. Certain tests may provide a general indication of crushing ability, for example, or acid and frost resistance, but in the case of blocks to be used for exceptional purposes, the responsibility will in almost all circumstances reside with the craftsman, in most cases at his own request.

Stone Extraction, Handling, and Storage

The way that the block is extracted from the ground is of paramount importance to the way it is likely to perform later on the building (see Appendix C Case Study: Re-opening the Cathedral Quarry). If it is roughly torn from the ground using large items of plant machinery there may be a strong chance that the bedding planes of the stone will be ruptured, creating a diminution of strength and lessening its durability against rain and frost. This may not be visible to the eye at the time, nor can it be relied on that the mason will discover it during working the stone, or even fixing. However, it will be revealed some time shortly after the stone has been exposed to the weather, when it is more costly to replace. Similarly, the use of explosive powders is not conducive to good weathering resistance in the case of dimension stonework, since any amount of damage may have been incurred due to shock, again unseen at times of quarrying, working, and fixing. At every stage, stones increase in value as they are handled or moved through stages of workmanship. It is essential that care is exercised during handling, from when stone is being quarried to when it is in the mason's yard, the value not suffering during the process. Being dropped heavily at the quarry or from slings during lifting will administer a shock that may again be realised only later, at high cost. At each stage of being handled the stone appreciates in value, being of little value in the ground and immense value when worked. Batons, rollers, carpet or sacking as softening are best employed at every stage (see 5.2 *A Note on Handling New Stonework*).

Stone requires good storage at all times, being spaced apart by batons of timber, so that the air can freely circulate around it. This will help in the effort to prevent the occurrence of frost damage, keeping the surface of stones free from pools of water which may freeze. Loose sacking, or straw placed over the stone will stave off the collection of moisture. Where different types of stone are stored together, for example sandstone and limestone, it is worth remembering that sandstones will suffer if limewash is allowed to run across the surface. Therefore, whilst it is relatively safe for sandstones to be placed on top of limestones, the reverse is not a good idea, and it is advisable to keep different stones totally separate so that costly mistakes do not occur. Where a range of stone types and sizes is stored, their nature and bed height is best left clearly visible so that unnecessary handling is avoided.

Combinations of Stones

Masons have long been aware of the dangers of combining certain stones, such as limestone and sandstone, and even of the dangers of paring oolitic limestones with magnesian stones, the former attacking the latter. Reasons for this, following research by the BRE, were felt to be related to the pore-size differential and the transfer of soluble salts between stone types. Salts that have remained relatively stable in the limestone, having adjusted to the pore size, on being transferred in soluble form attempt on crystallisation to occupy too great a space in the magnesian stone pores, disrupting the structure of the stone. Mention was made in part 1.3 of the relationship of Weldon limestone, used in abundance as replacement material, to Lincoln limestone on the fabric of Lincoln Cathedral in the 1930s (see Fig 1.23 p61). Two theories exist, although neither has been proved, as to why the local stone has not survived the combination. The local masons feel that the porosity differential, where the more porous Weldon stone retains moisture longer, has an adverse effect on the relatively low porous adjacent Lincoln stone, resulting in poor performance during frosts. An alternative view relates to locked-in stresses, where eruption of the structure occurs on being released, after long periods (see 1.3 *Failure in Gothic Buildings*).

Incompatible Materials and Previous Repairs

The use of materials and techniques which are incompatible with historic masonry structures is a major cause of accelerated deterioration. Two main problems are the use of ferrous metal fixings and hard impermeable cement mortars. Often, such materials have been used in major campaigns of work and routinely over extended periods of time, so their influence on the building may be all pervasive. Also, although many fixings and areas of pointing may be visible and therefore easily detected, a considerable amount is likely to be hidden, manifesting problems which may be difficult to trace to source.

Ferrous Metal Fixings

Much reference will be made during this study of the perils of introducing ferrous metal fixings into the stonework structure, the oxide jacking of the metal exerting great pressure and causing significant damage. Ferrous metal oxidises when exposed to oxygen and water, the corrosion product of which is iron oxide (rust) and takes up additional space. Effectively, rusting iron exerts an unstoppable expansion force, sufficient to crack stonework and to lift entire structures. Where fixings are placed inside individual blocks of stone, expansion of iron is capable of cracking the block in two, since the stone is not capable of absorbing such rapid change.

Since Gothic builders habitually attempted to deny the limitations and rigidity of stone, alternative metal fixing arrangements were frequently employed in addition to the conventional masonry bed of stone on stone with a lime mortar joint between. In many instances, where stones were fixed close to the edge of the building or on to small beds, finials, sculpted heads, and even coping

stones, for example, this often required a dowel fixing, and was usually made of iron. Iron was a suitable dowelling material as far as strength, workability, and rigidity were concerned and was also available. However, the medieval builders appreciated its limitations and in order to prevent moisture seeping into the iron, a casing of lead was poured around it through pour holes made in the side of the stone. This helped to prevent damage to the stone due to iron oxidation, and the lead had the capacity to absorb some swelling if it occurred. In the long term, this method was often not efficacious since hairline fractures were inevitably created between the iron and the lead and would always encourage the seepage of moisture by capillarity. Once the lead had hardened, its ability to absorb any expansion of the iron was reduced and the adhesion between the lead and iron was further limited. Although the medieval builder realised that iron would be damaging if placed next to stone (where packing during masonry fixing was required, slate or shells were used between courses), these safe practices were not observed in more recent times. In the 1nineteenth century at Lincoln, thousands of flat iron wedges were placed between courses to 'tighten' up the masonry. Once 'oxide jacking' began to occur due to the rusting of the iron, tensions were introduced into the structure and much masonry was consequently destroyed (Fig 2.10).

Hard Cements and Mortars

Traditional masonry construction used lime mortars for bedding, pointing, and grouting, and an intimate knowledge and understanding of materials assured the medieval builder of their sympathy with the principal material of stone. Lime mortars acted not as adhesives to stones but as gaskets, permitting regular moisture intake and expulsion from within the core and the stones themselves. At the same time, during inevitable movements within the great masses of the structure, lime mortars provided little resistance but were resilient enough to remain in place without crumbling or cracking. Sacrificially weak mortar joints serve to draw pollutants and salts away from the stone, the joints being capable of being replaced to some extent. All of this helps the stonework to endure the rigours of changes in minor structural position, and the environment, including the weather and man-made pollution.

From the eighteenth century hard mortars were introduced which had the benefit of quick setting and ease of preparation. These first hydraulic cements, devised by Smeaton in 1756, are referred to as Roman cements due to their employment of additives based on pozzolana, volcanic ash from Italy, which provided a setting ability even under water. During the following century, further experiments went on to create Ordinary Portland Cements (OPC), which possessed similar properties; they were 'hydraulic' and easy to use. Portland cements were regularly in constructional use from around the last quarter of the nineteenth century. Where lime required burning, slaking and storage prior to use, and then much tending during construction, Portland cements were relatively simple to produce, store, and handle during work. They possessed disadvantages, however, which have been difficult to counter against their ease of use. Mortars made with Portland cements are potentially extremely hard and therefore offer resistance to minor

Fig 2.10 Iron wedges placed between masonry courses. Oxide jacking of the iron leads to structural disruption. Lincoln Cathedral Morning Chapel.

movements within a structure, and at such times it is either the mortar joint that cracks or the stone itself, where mortars are stronger than the stone. Moisture cannot easily pass through a Portland joint, since it may be almost impervious, therefore it will attempt to pass through the stone, often damaging the surface by depositing salts and pollutants into the stone, or making the stone too damp in freezing conditions. Where hard cements have been used for pointing, the stone can often be seen to have weathered back sacrificially rather than the joint (Fig 2.11). In cases where OPC has been used for grouts, the amount of damage may be incalculable and is irreversible. It is also impossible to monitor the state of a structure because once the grouting is entered into the core, the effects are hidden (see 3.2 *Case Study: The Special Repair Programme (1922-1932)*).

Fig 2.11 The use of Portland cement in pointing mortars can lead to extreme deterioration of the stone, due to moisture being unable to escape through the masonry joint. Lincoln City Medieval Wall.

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Part 3.0

Lincoln Cathedral: Its Pathology and Care

Part 3.0 Lincoln Cathedral: Its Pathology and Care

Introduction

It is likely that there has been a workforce serving Lincoln Cathedral since the days of its original construction. Early intentions to commission continuous maintenance are indicated by the establishing of a Works Chantry which 'was founded to pray for the souls of the benefactors' (1) around the beginning of the twelfth century. Some knowledge survives of the early masters, with documented evidence of land deals and property transactions confirming continuous working situations. The medieval masters would have had a close understanding of all major trade disciplines, including carpentry, glazing, plumbing, and smithying. They would have been responsible for securing a balance of labour throughout the project and would have been concerned with training as a means of meeting future building and maintenance needs.

Other changes have been inflicted on the building which are reflected in its current state, such as have at times been caused by major social and political upheavals, statements about which were symbolically exacted upon the medieval fabric. On other occasions the actions of repair themselves have taken a large toll on the ageing structure, and this section gives an account of certain factors of change, culminating in the major campaign of repair known as the Special Repair, which was initiated in 1922. The consequences of such a large-scale repair are being revealed even today during more modest conservation works. Areas of masonry have been effectively welded together by hard Portland grouts injected into the masonry at the time of the Special Repair, and are inhibiting simple routine replacement of ashlar. In the case of the Romanesque relief sculptures which are set into the west façade, hard grouting and reinforcement bars are endangering the safety of the sculptures.

During research into the Special Repair questions loomed ever larger of whether the treatment employed had taken account of the circumstances found. In most instances the answer has to be that this was not the case. Comparison with two similar repair programmes emphasises the lack of investigation and calculation at Lincoln, where recording when checked out with actual work, appears to have little integrity. There seems to have been no striving to encourage a combined search for the true conditions of the cathedral before work on a specific area, each wave of treatment being the same as that carried out on other areas. The Clerk of the Works was apparently given virtual freedom to carry out whatever repairs he felt justified in doing by Chapter. Some of the influences of the office of Clerk of the Works during the Special Repair survive still at Lincoln, and give a greater control over the administration of the budget and the quality of the work. Today this also serves to bring the works staff more closely into the decision-making arena, which helps to provide a more accurate set of circumstances regarding the state of the fabric.

3.1 A Legacy of Repair

Evidence exists on the fabric of Lincoln Cathedral to suggest that the best of skills were perhaps not always available and it is even conceivable that semi-skilled, self-trained, or even unskilled labour came to be employed to carry out vital maintenance work. By the early part of the 18th century the Cathedral had reached a point were it was suffering from advanced deterioration, with roofs, pinnacles and parapets in a state of near collapse. During 1728 Gibbs observed that 'the western towers at Lincoln were only the most threatened part of a building altogether dilapidated.' (2) It can be assumed that no serious or sustained programme of repair had been administered for some time before, and there may have been good reasons for that. From the late 15th until the late 17th century soaring inflation had laid the country low (Fig 3,1). Costs of labour and materials, in combination with confused attitudes following the Reformation, may not have been conducive to the restoration of ancient monuments.

About this time the Dean and Chapter resolved to rectify matters, even going so far as to submit a portion of their income towards urgent repairs to the fabric. Essential structural work was undertaken by Gibbs, who constructed two relieving arches under the towers to further support those added earlier which had not been bonded to the main masonry. The west front was in effect being pressured outwards under the massive weight of the west towers and perhaps the influence of 'racking' along the nave due to pressure from the central tower. Gibbs' suggestion to remove the spires was given short shrift by the local population, until 1807 when they were removed without ceremony. Other work carried out over the next century or so, was most likely in response to crises as they occurred. Evidence shows that the work hardly referred to traditional trade procedures, repairs to medieval masonry and timberwork were often ingenious, but makeshift, and would ultimately have required less effort had the correct disciplines been adopted. In 1743, Thomas Sympson, the Clerk of the Works 'took down the ancient image of St Hugh' (3) from its pinnacle on the south west corner. Sympson, a local retired schoolteacher and antiquarian, was more an enthusiast than informed in construction. Following reports that daylight could be seen through the joints of the same pinnacle in 1985, a scaffold was erected and evidence of substantial movement detected. Stones were discovered to have been placed so that they bridged courses, ignoring the bonding patterns of traditional construction. The correct placing of stones with their bedding plane running horizontal had been ignored, presumably through ignorance of this essential practice. Stones were randomly placed, often against their natural strength, simply in order to gain height from the shallower beds of Lincoln stone. Hundreds of iron wedges had been placed in between the joints and had jacked up the masonry, opening joints by several centimetres. In the roofs, timber repairs to the Angel Choir and St Hugh Choir roof structures, carried out during the same period, have been found to be elaborate though eccentric.

On the west façade thirty metres from the ground large areas of ashlar, put in during Pearson's time as Architect (1870 - 97), were recently found to be only around two inches (50mm) thick.

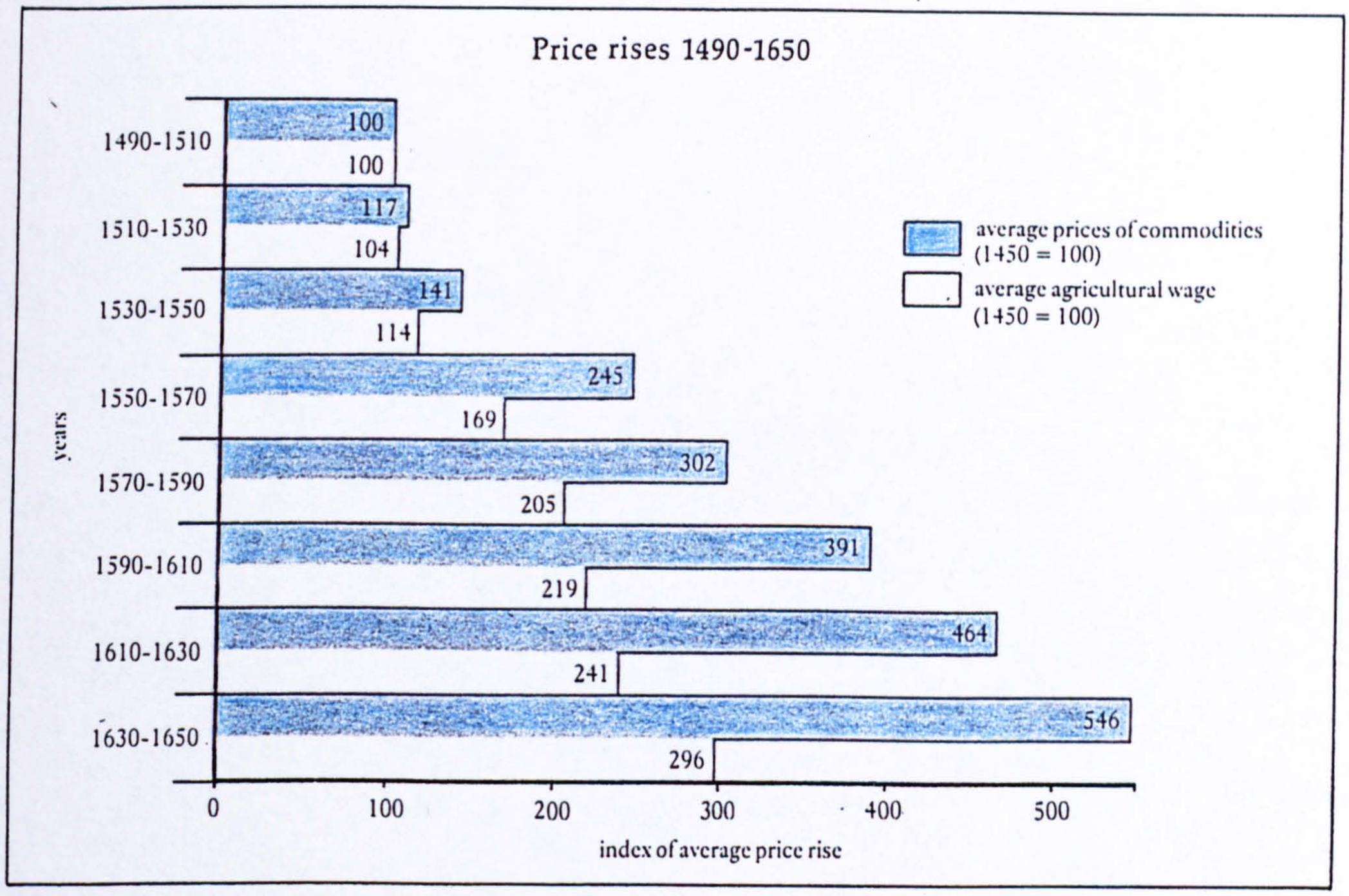

Fig 3.1 Inflation chart from the late 15th to the late 17th centuries. (BRIGGS, A. *A Social History of England*, Middlesex, Penguin, 1983.)

These stones look solid, but are perilously lacking in the ability to safely transfer loads, which is their principal function. The failure of such thin stones, often placed at right angles to their natural bedding plane, effectively reduces the bearing capacity of the wall, weakening its resistance against the forces bearing down from above. A similar repair, employing appropriate skills and supervision, would have effected a far more sympathetic and lasting repair. On a building the size of a cathedral, many areas may have been worked upon in such a manner, but current work programmes are only finding them by accident. Recording is therefore underlined at this point, being second nature in genuine conservation. Such poor practices would not then be rendered undetectable.

Changes in Use

It can easily be seen that a significant problem in maintenance lies not only in carrying out the work, nor even in funding, but in the ability to detect where problems are likely to arise. Some difficulty lies in justifying the continued upkeep of cathedrals and in finding real uses for their great spaces. Congregations, in the main, do not provide this and often naves or chapter houses are thrown open to civic use as concert halls, perhaps for degree awarding ceremonies, exhibition areas, venues for television programmes, and sundry other purposes. Functions such as these place demands on electrical circuits, increasing the risk of fire, and often need to be upgraded. The provision of heating facilities may involve large boilers being installed within the building, with intense sources of heat exacting untold stresses on medieval materials. Drainage must be capable of catering for large numbers and refreshment facilities in the guise of tea shops have become an accepted feature of English cathedrals. All these facilities require modifications to the fabric, creating new risk areas.

An example of damage by use was recently exemplified at the Parish Church of Wainfleet in Lincolnshire, where problems arose from the effects of dramatic 'dusting' which was causing discomfort to worshippers. The cause of this was eventually attributed to the heating system, a range of powerful oil-burning stoves which were ignited an hour before each Sunday service during winter. In the fenlands, the land even more moist than elsewhere, moisture and soluble earth salts were drawn in abundance through the stonework, crystallising as they reached the heated surface. As the face of the stone rapidly flaked away, a fine dust residue was left throughout the church. In encouraging its use, the church authorities were actually participating in its demise. It is alarming to hear of underfloor heating being installed, as at Canterbury Cathedral; a similar idea is still being considered at Lincoln.

As well as being at risk from changes in surrounding ground conditions, the natural elements, and atmospheric pollution, the fabric of the building is under constant threat from over-use, even from those who treasure its existence most. In the case of all public monuments it is conceivable that they can suffer from their own fund-raising success. At Hardwick Hall in Derbyshire, the National Trust recently closed the hall to the public for selected periods in order to reduce the threat of

stress to the structure in the guise of general wear from pedestrian traffic. At Lincoln, a small chapel was dedicated to counselling over cups of tea. The walls of that chapel, the Russell Chantry, are clad with a made-to-fit mural, painted by Duncan Grant in the 1950s, using water-soluble pigments. It has proved difficult to persuade people of the dangers of boiling kettles and using water-producing propane heaters, even following a much publicised and expensive conservation of the paintings.

In the case of a cathedral, limiting admittance to the public, even to obviate wear and tear, moves against the desired missionary course. Yet over-use is a major agent of deterioration in historic buildings. A report was recently produced by Jane Fawcett which revealed that abrasion was threatening to ruin many cathedral ledger stones and floor brasses. Her exhortations in 1991 that 'urgent action must be taken to protect the best floor areas before they are destroyed' (4) seems to have prompted little action other than research by the Building Research Establishment, who are attempting to devise a form of sacrificial protective coating. (5) In the case of interior statuary and sculpture, it is a lost cause to attempt to restrain hands from reaching out to them. Sculpture by its very nature invites tactile involvement, but the acids and oils from human touch may be unpredictable and complicate straightforward treatments such as cleaning and simple repair. Over long periods of time the actions of many hands fondling carvings can result in loss of surface detail.

A Note on Related Issues

In dealing with a structure the size of Lincoln Cathedral which is almost three hundred feet high and three and a half acres in area, the emphasis on regular survey (see 5.1 *Recording and Archive*) cannot be overstated. This may be the only reliable way of maintaining a view of the evolving pattern of change which buildings inevitably undergo, as well as identifying previous bad practice in terms of repair and caretaking. Often in the past, the quality of surveys may have been so perfunctory and superficial as to be of little serious use to those charged with the care of the fabric. This raises further questions which will be touched upon in the final part of this investigation, regarding the competence of professionals, such as surveyors and engineers, many of whom may have received little instruction in the essential nature of the historic building being surviewed. It is difficult to establish a reliable system of inspection; suffice it to say that the quinquennial survey provides only a guideline, within which the true picture of its condition may or may not be clearly expressed.

Where large restorations have been carried out on the skeletal structures of cathedrals, there may be scant knowledge provided of the whereabouts of what are now known to be inappropriate or harmful materials. At Lincoln, in respect of the current conservation programme of the Romanesque Frieze, it would be helpful to know precisely where previous repairs had been carried out during past campaigns, such as those of the 18th, 19th and early 20th centuries. Sometimes

repairs affect large areas of the fabric, and reinforcements must be presumed to be present in every area, and this again draws attention to the influence of accurate survey, best provided by the collation of many sources of information.

3.2 Case Study: The Special Repair Programme (1922 -1932)

By the first quarter of the present century pressing structural complications seriously questioned the continued stability of Lincoln Cathedral. A massive engineering campaign was launched under the auspices of what became known as the Special Repair Fund. This programme, carried out by a directly employed labour team, headed by Mr Robert Samuel Godfrey, the Clerk of the Works, began in 1922 and extended well into the next decade. The Architect of the day was Sir Charles Nicholson, who operated in joint consultation with the Engineer, Sir Francis Fox. The latter was engaged for his experience of work on foundations, and the operation of structural injection grouting. It was he who had prescribed and supervised the major engineering treatment at Winchester Cathedral, completed in 1912. He had also been notably involved in the construction of the Mersey Tunnel between 1880 and 1886.

Background to the Project

For many centuries strengthening work had been carried out to the west work of the Cathedral, commencing with two relieving arches inserted by the Norman builders; though never proving truly effective due to inadequate bonding. Matters did not improve until Gibbs in 1728 delayed the deterioration by inserting two further restraining arches, one under each of the west towers. Following this, between 1761 and 1783 'Essex had attempted to improve the stability of the towers by filling in some of the interior stairs and passageways.' (6) In 1912 Sir Charles Nicholson, reporting on the north west tower, commented that 'Although the main structure is sound the surface of the masonry is in a condition which requires attention, if not immediately, at any rate `before many years have passed.' (7)

It has been shown that the west towers had long been an area for concern, but this culminated in the early 1920s. During most of Nicholson's time as Architect, although reference was consistently made to the towers, no hint of impending failure was at any time implied. Nicholson's reports to the Dean and Chapter were noticeably relaxed, with comments such as: 'I have examined all parts of the structure; in particular I have carefully examined the three towers, and I have observed no indications of structural movement.' (8) following a period of little physical intervention to the fabric, the great war of 1914-18 only recently having ended, Nicholson reported of the west towers that there was 'no material change', and that 'the south west tower is in good repair.' As to the central tower, 'the tell-tales that have been placed over the cracks show no signs of movement, nor am I able to detect any such signs in the masonry over the four great arches.' (9) Such mellow observations did not presage a full-scale restoration and it was not until 1921 that specialist engineering expertise was considered necessary.

Within a short time of arriving, Fox drew attention to the elaborate iron fixings, including large straps which had been introduced into each of the west towers, dated in 1820 by the smith who forged them. It was later explained in a talk given by Godfrey that: 'several of these iron bands are broken in two; in some cases there is a distance of two inches between the broken ends which clearly shows spreading of the masonry.' (10) The iron work, it was then calculated, added a weight of some 6 tons to either tower, effectively accelerating the structural failure of the towers, During the latter quarter of the nineteenth century 'necessary strengthenings and restorations' (11) had been carried out to the west end of the building under the instructions of Pearson, Consulting Architect, who reported that the central tower was also showing signs of serious disrepair. Wrought ironwork, in the form of flat wedges, was at that time extensively and almost habitually inserted between the joints of stonework as a method of levelling up courses of masonry which had slumped due to earlier movement; in this case, particularly within the west towers and façade. The long-term results of this practice, throughout large areas of the fabric, has proved highly destructive to the masonry (see 2.3 *Ferrous Metal Fixings* and Fig 2.10, p102). It likely that this intrusion might itself have precipitated some movement in the towers and façade.

In his report of December 1918, Nicholson observes that the new appointment of Godfrey as Clerk of the Works and Surveyor is ' likely to work very well,' commenting in support of his intention to 'change methods' in working and to employ more personnel and install more equipment. According to Nicholson, this would better contend with maintenance, since 'arrears of repair work have lately been mounting up.'(12) Not long after Godfrey's appointment rather more alarm can be detected in reports regarding the state of the towers. Only about a year later, Nicholson's annual report to Chapter is much more serious, observing that the north west tower 'gives rise to considerable anxiety.' (13) In Godfrey's account of that time, presented in 1925 to the Rotarians, he suggested that there had been a continuity of progressive failure from the previous century, claiming that 'the tell-tales fixed one day were found to be broken in two the next,' (14)

Reports in this vein to Chapter caused an immediate reaction, with a plan of action being developed to include extensive pressure grouting with Portland cement, and the construction and insertion within the towers of concrete restraining beams. This was to be an engineering response, with no apparent attempt to include within it a contingency plan for reversibility. In 1921 Fox wrote to the Dean and Chapter with an introduction to the process: 'it is a means by which cement is forced, like molten metal, under air pressure into the otherwise unreachable parts of the thickest walls, 20 or more feet in width, and agglutinates, together into one compact mass, all the particles of stone, rendering the whole structure monolithic.' (15) In the event, many thousands of tons of Portland cement grout were ultimately 'blown' into the core of the masonry, to use Fox's own description, encasing several miles of phosphor bronze reinforcing bar.

The Scope of the Work

Throughout the entire duration of the Special Repair programme it is almost difficult to find an area of the Cathedral that did not come under the scrutiny of Godfrey and his army of grouters. The principal areas concentrated upon were the west end, including both towers, the main façade, and the two flanking chapels. Attention was given also to the central tower, the west transepts and the Galilee Porch. The restoration officially ended in 1932, but as Thomas Cocke explains: 'Embarrassingly, a fall of stone from the east end of the Angel Choir only three years later revealed that the east wall was falling outwards and that the great east window was in especial danger.' (16) This reinforcing programme eventually came to a halt in 1939, with attention turning after the war to the Chapter house buttresses, which had been of concern for some time (in fact only last receiving structural attention in the 1980s).

The work commenced with the north west tower, but quickly developed across the entire west front. As grouting continued, so cracks were perceived to open up almost simultaneously, dictating that the operation follow the symptoms. Ultimately, the core of the entire façade was grouted, the inner and outer masonry skins stitched together and joined to sixteen concrete ring beams which were inserted into both towers (Fig 3.2). Similarly, the central tower was drilled and grouted, and additional concrete beams placed within that tower (Fig 3.3), with strengthening work extending into both arms of the great transept. Reinforced concrete beams were placed along the north and south clerestory floors triangulating the three towers. The strengthening of the east end of the Cathedral, carried out in the mid 1930s, effectively resulted in the east end of the Cathedral being suspended over the Roman ditch, with two concrete supporting arms extending back along the choir clerestory. In effect, the attentions of the Special Repair covered practically all areas of the structure, from west end to east end, including the central tower and transepts, moving eventually to the Chapter House.

Technical Processes Employed

According to Godfrey, reporting to the Executive Committee of the Special Repair Fund, it was necessary that scaffolding should rise above the grouting operation, up to 40 feet (12.3m): 'This is to enable the surrounds to be carefully watched for any movement.' (17) The entire operation, including preparation of the masonry before grouting could take place, was powered by electrical air compressor, purchased specifically for the purpose.[1] In order to ensure continuity of work, the Dean and Chapter followed Godfrey's advice and increased the in-house works team. 'The whole of the work has been carried out by direct labour by local workmen; the leading men having been specially trained for the specific branch they are engaged upon.' (18)

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[1] A compressor room was purpose built within the Works Yard, with many metres of cast iron piping installed to supply compressed air throughout the Cathedral. A purpose bought compressor was installed and pumps to the present day 80 psi to the furthest point of the fabric.

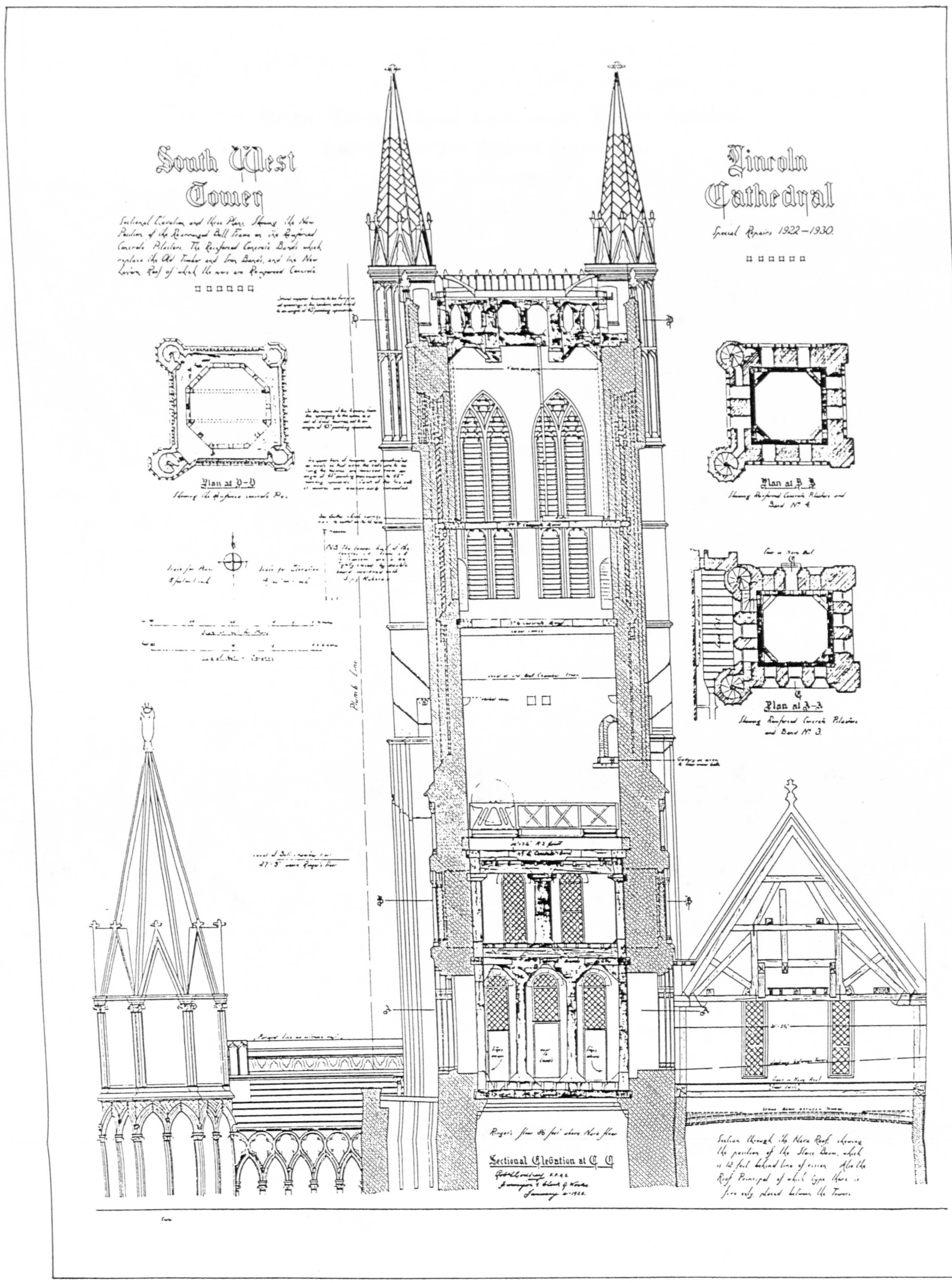
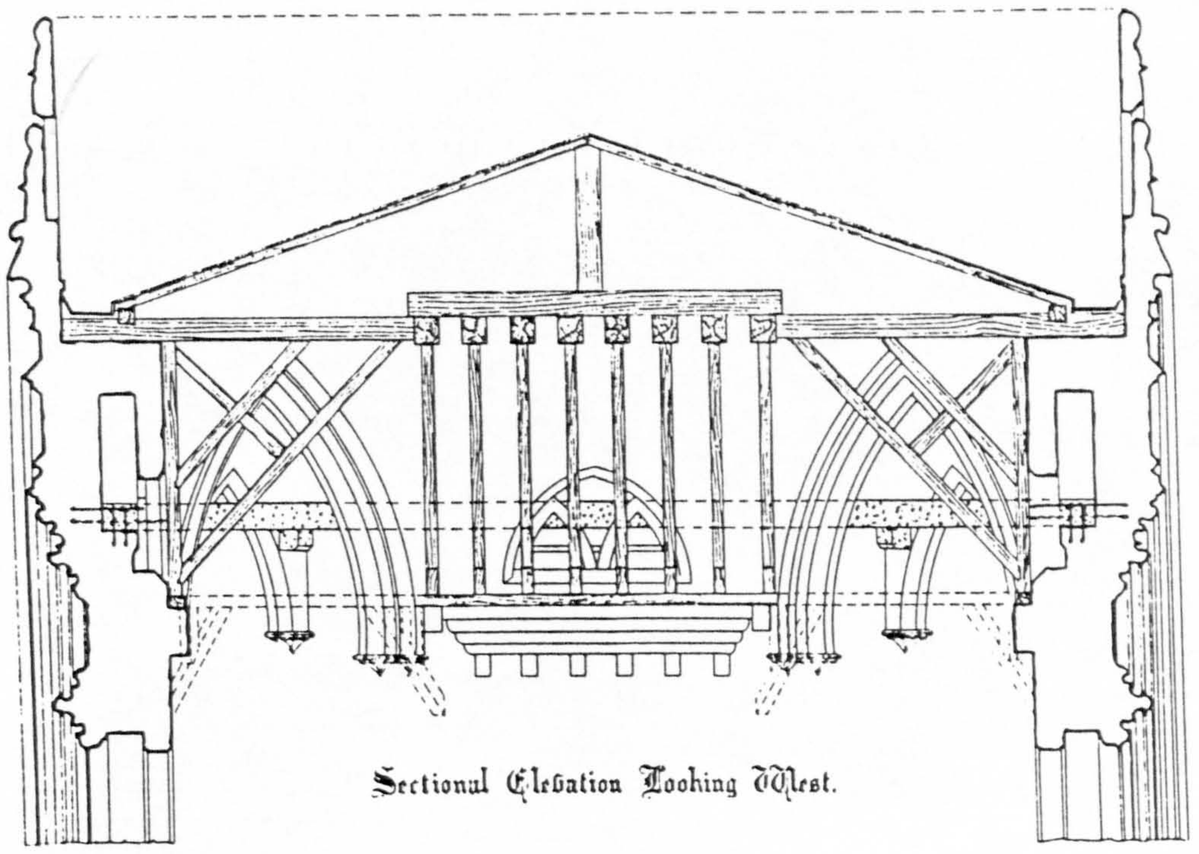


Fig 3.2 South West Tower Special Repairs. Sectional elevation and plans showing the position of the rearranged bell-frame placed on new concrete piers, and reinforced concrete bands which replaced old timber and iron bands. (Lincoln Cathedral Works Archive)

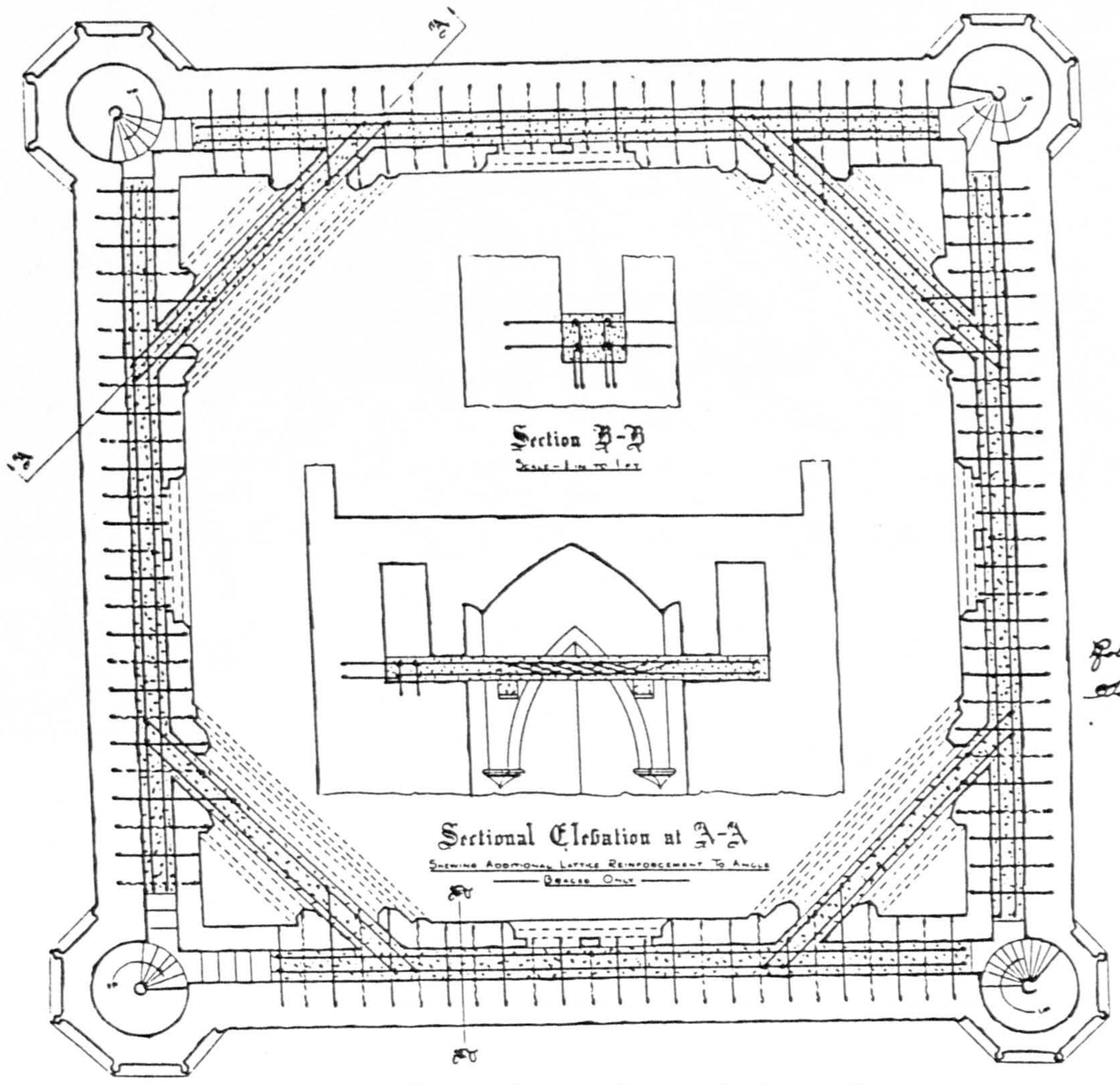
Centre Tower, (Special Repairs 1922-32) Lincoln Cathedral.

Detail of Number Four Reinforced Concrete Beam.

Scale — Four Feet to One Inch.



Sectional Elevation Looking West.



F.R.Godfrey. F.R.I.B.A.
Surveyor & Clerk of Works
September 19-1931

Plan of Tower Shewing Reinforced Concrete Beam.

Fig 3.3 Centre Tower Special Repairs. Detail of one of the six reinforced concrete beams.
(Lincoln Cathedral Works Archive)

The grouting process was to involve five stages, beginning with the selection of the area to be grouted. Once the area to be drilled was chosen, the drilling of holes commenced, their depth determined by the thickness of the wall. Drill bits were available that could be fixed to an air-powered rock-drill, specifically designed for horizontal work. This would create a hole from 6" (150mm) up to 20' (6.2m). All such work was carried out using air-powered tools, partly for speed, but also to reduce the impact of heavy hammering on the unstable masonry. As much dust as possible was blown out from within the bore hole using the air-line, before a jet of water was forced into it, again using the force of the compressed air. This dampened down the whole of the surrounding masonry, as well as providing tell-tales for any seepage of water. Once a leak was detected, it was immediately blocked up with clay or, in the case of larger fractures, a new insertion of masonry, lessening the danger of grout-runs defacing the building. Grout was then blown in 'until no more can be added.' (19) Figures 3.4 to 3.11 give a photographic account of the Special Repair techniques.

If a single stated principle of repair can be identified, it was to revitalise the core by grouting up weaknesses created by the slumping corework. These had occurred presumably due to the spreading masonry structure. Strengthening was to be effected by forcing a strongly adhesive grout (mix: 1:1 sand and Portland cement) into the interstices of the core. Extensive cramps and dowels, appropriately using non-ferrous metal,[1] were fixed into the fissures and across cracks, stitching the masonry together and making rigid the structure.

In Godfrey's Rotary Club paper, given on 16 November 1925, he claimed that the tower was hanging together 'trusting entirely to broken iron bands and bolts and broken wood tie-beams for support.' (20) To prevent the structure from spreading, six concrete ring beams were inserted at different levels into the tower, the top one forming the roof-plate. Each beam was calculated to resist a minimum strain of 800 tons. Similar constructions were also introduced into the central tower as well as in the main north and south transepts. Several arches within the central tower structure had spread and masonry had to be replaced in the conventional manner. A typical weekly record, all of which were meticulously kept, is entered on 9 July 1924 for the south west transept, showing entries of 149' of Delta bronze cramps, a total quantity of grout of 600 gallons, with sundry bags of broken stone for aggregate, and large quantities of sand and cement (Fig 3.12). Many records also note the vast quantity of broken bricks. Despite the introduction into the building of so much alien material, Godfrey remained adamant that the total weight within the building was not increased. 'Against this we have to calculate the hundreds of tons of debris old timbers and ironwork which we have removed from the building.'(21) No question during

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[1] In this case Delta metal, or phosphor bronze, which Godfrey proclaimed to have a tensile strength of 36 tons per square inch.

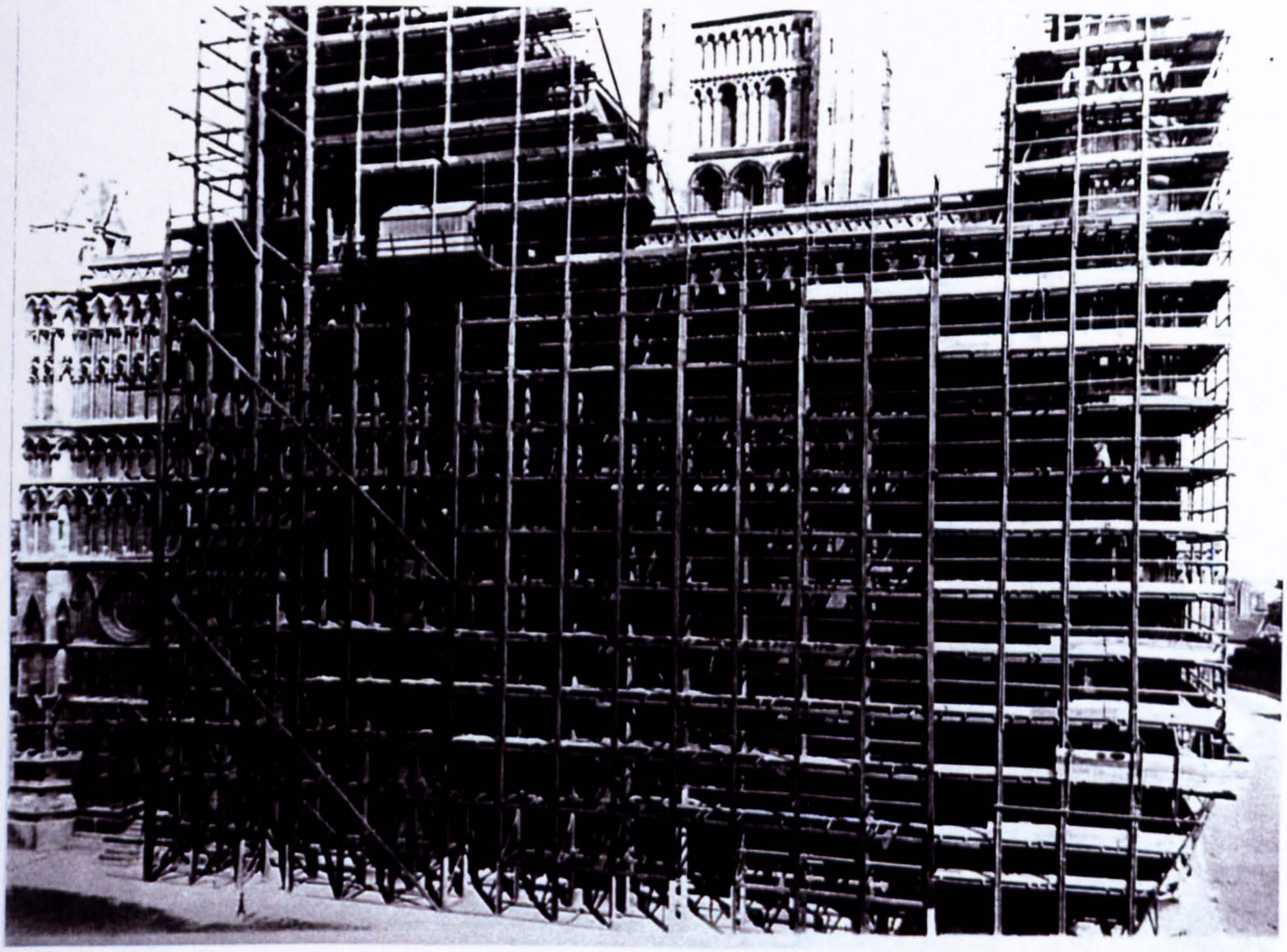

Fig 3.4 West Front Timber Scaffolding (Lincoln Cathedral Works Archive)

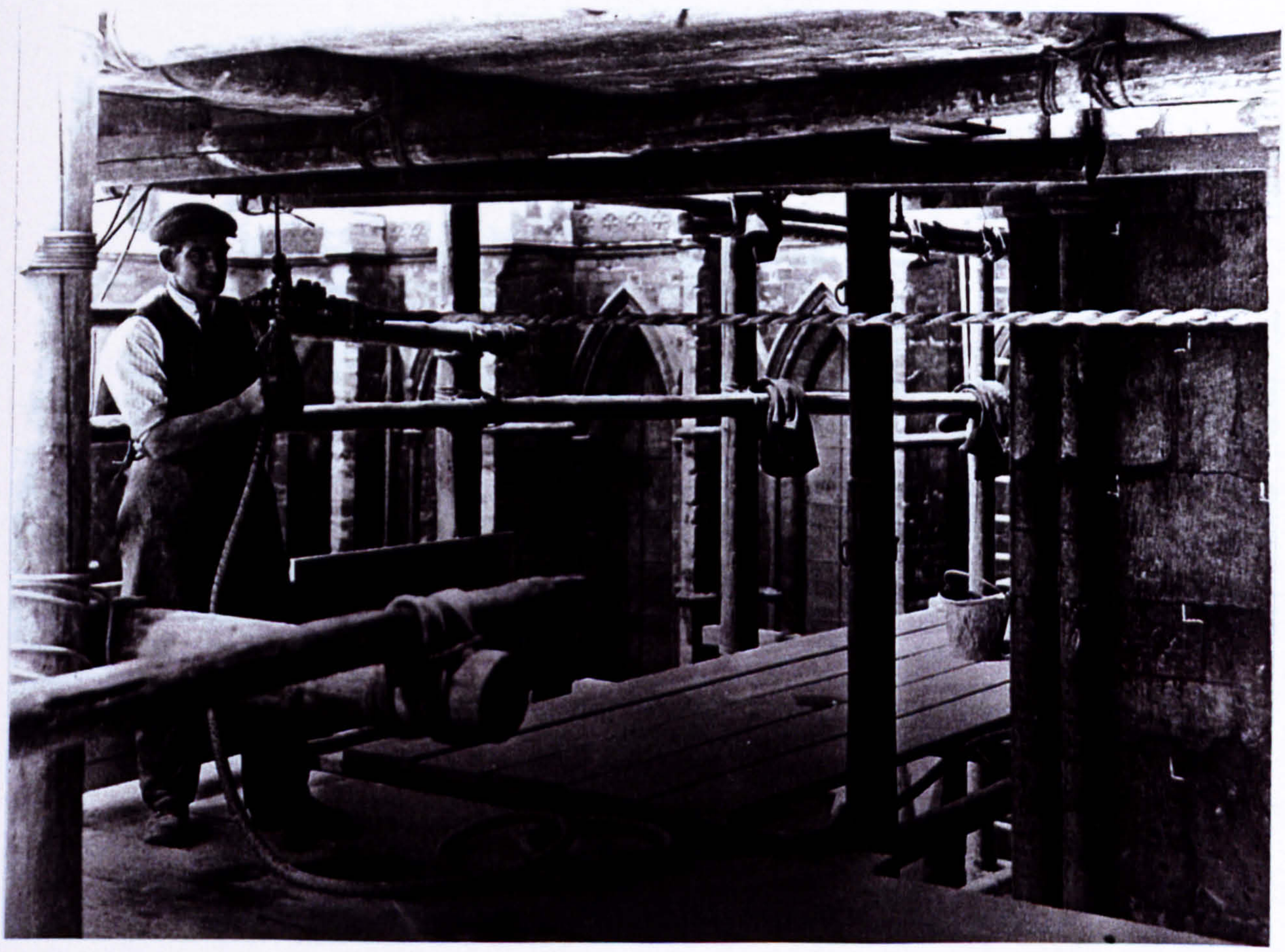

Fig 3.5 Specifically designed compressed air drill for horizontal work. Some of the drill bits were 12' (3.6m) in length (Lincoln Cathedral Works Archive)

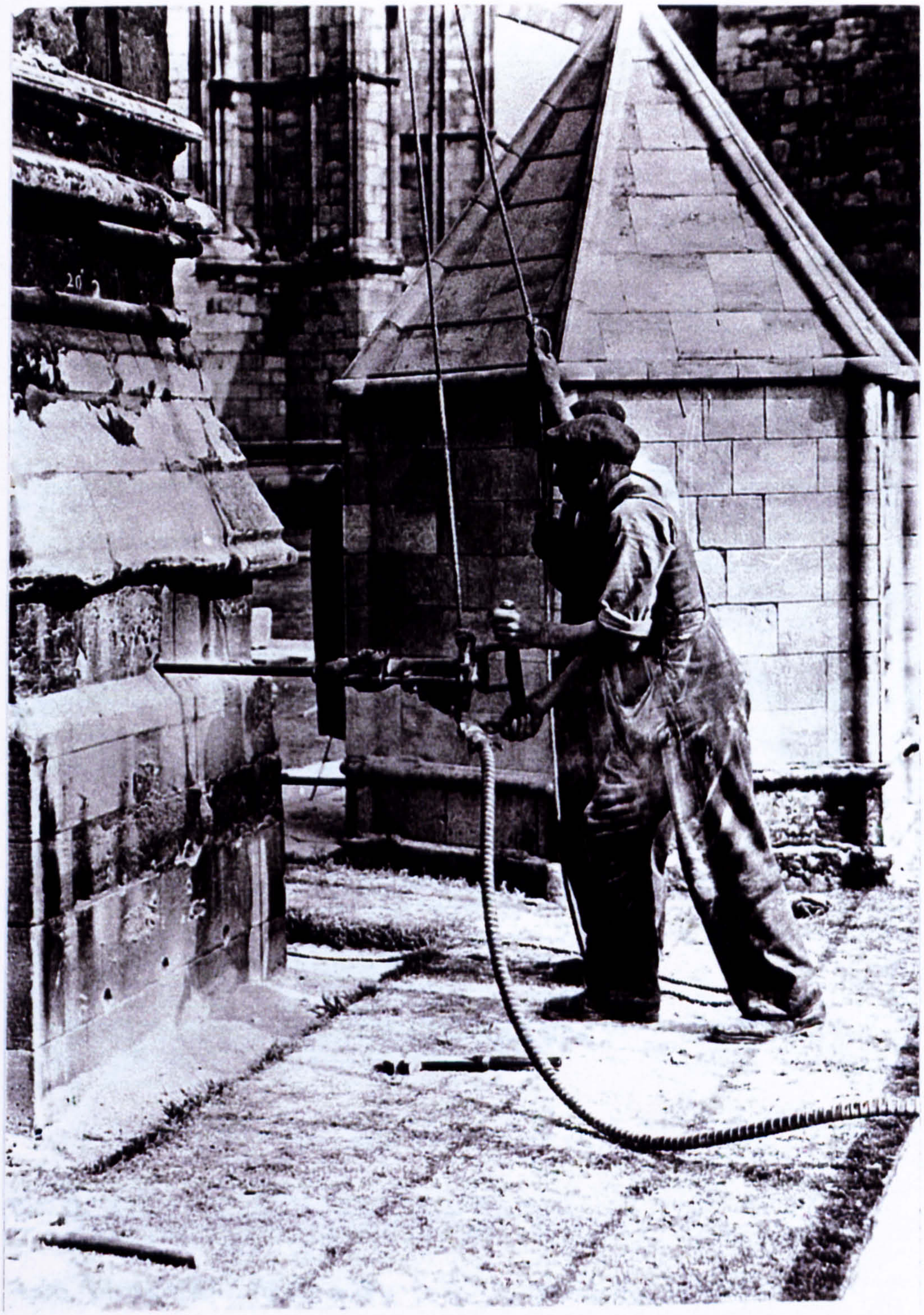

Fig 3.6 Drilling at the east end of the Cathedral - note quantity of holes (Lincoln Cathedral Works Archive)

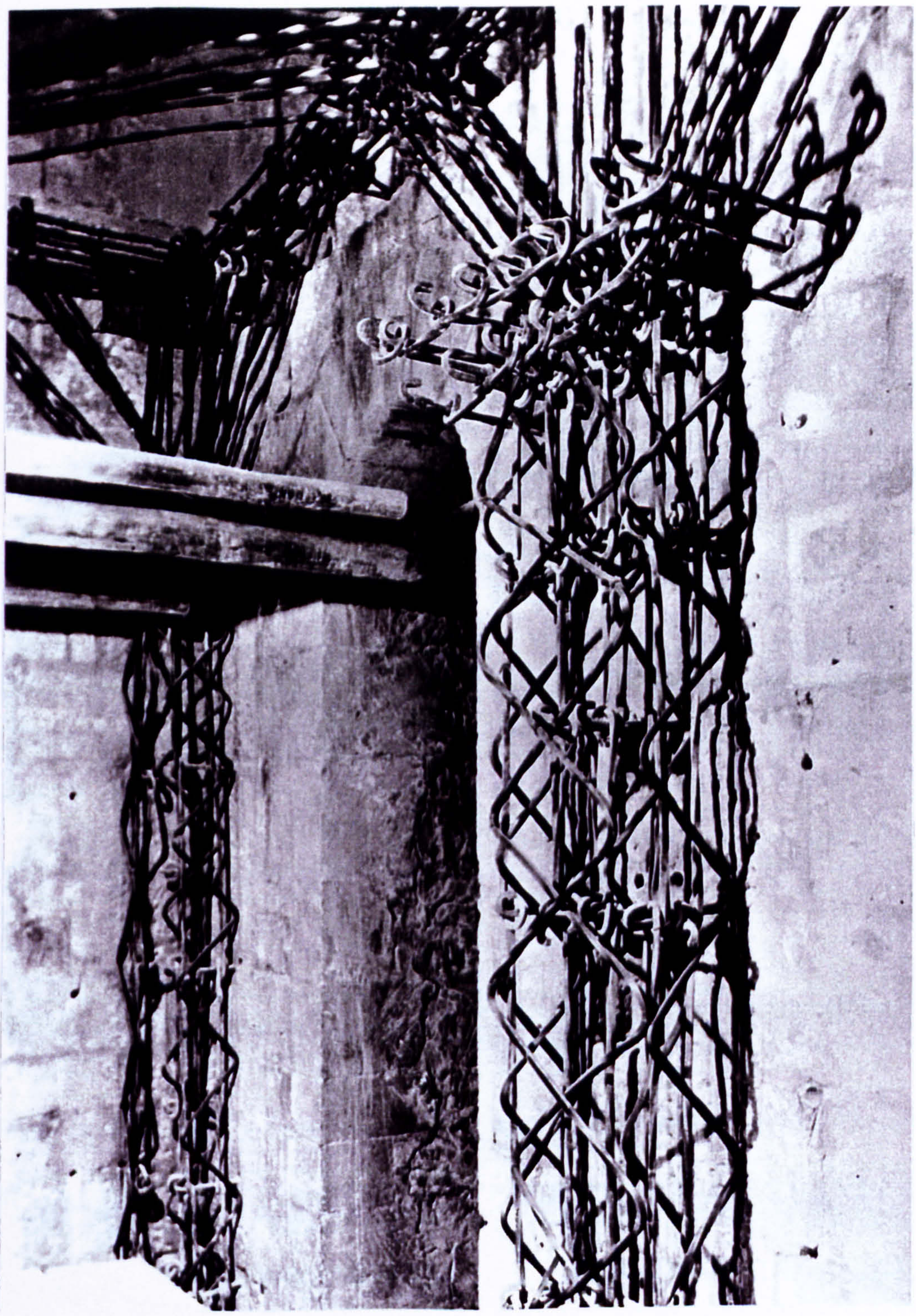

Fig 3.7 Reinforcement metalwork for the concrete pilasters in the South West Tower (Lincoln Cathedral Works Archive)

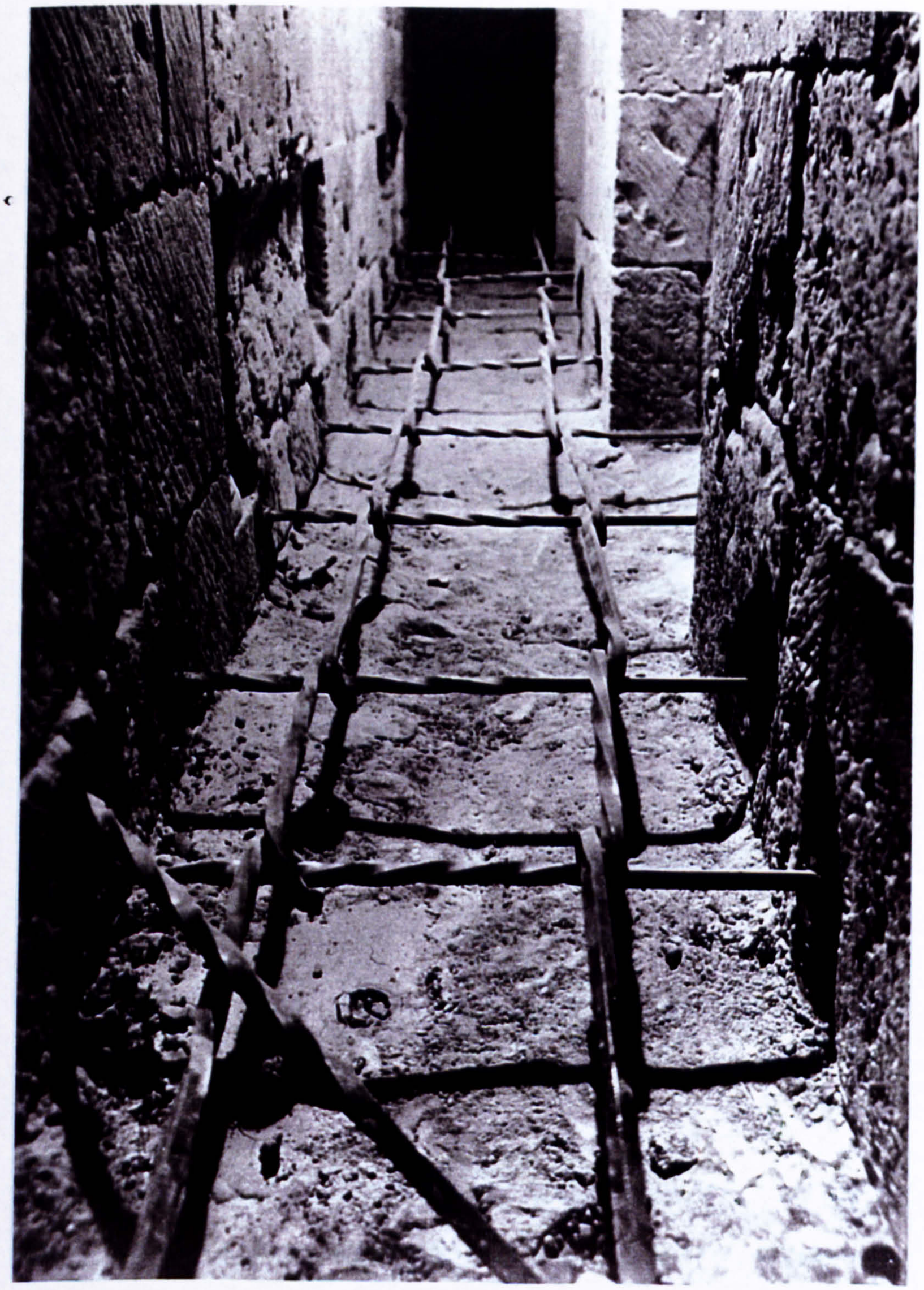

Fig 3.8 Reinforcement metalwork for concrete ring beam in South West Tower (Lincoln Cathedral Works Archive)

Fig 3.9 Compressed air grouting system, working from specially installed compressor for the Special Repair. This was capable of pumping at 100 psi at the furthest reaches of the building. (Lincoln Cathedral Works Archive)

Fig 3.10 Pressure grouting externally (Lincoln Cathedral Works Archive)

Fig 3.11 Pressure grouting internally (Lincoln Cathedral Works Archive)

WEEKLY REPORT No. 108.

Lincoln Cathedral

Jabl. S. Godfrey,
Surveyor & Clerk of Works.

Tel. 237.

Residence:
Priory Gate,
Minster Yard.

Surveyor's Office
26 Eastgate,
Lincoln.

THE SOUTH WEST TRANSEPT REPAIRS

July 9/24.

The following work has been completed during the past week:-

Machine Drilling

South Wall of S. W. Transept, 74'0" to 81'0" up.	No. 2	3'0"	-	6'0"
	" 14	1'8"	-	23'4"
West Wall do. do.	" 1	2'0"	-	2'0"
Total - 17 holes.			-	31'4"

Delta Bronze Cramps

5th Bay, West Wall of S. W. Transept, 59'0" to 70'0" up.	No. 4	2'9"	-	11'0"
6th Bay, do. do.	" 4	2'9"	-	11'0"
7th " do. do.	" 4	2'9"	-	11'0"
1st & 2nd Bays, West Wall of South West Transept, 59'0" to 72'0" up.	" 8	2'9"	-	22'0"
3rd & 4th Bays, do.	" 12	2'9"	-	33'0"
5th & 6th " do.	" 14	2'9"	-	38'6"
3rd Bay, from floor level to 71'0" up.	" 6	3'9"	-	22'6"
Total - 52 Cramps.			-	149'0"

The following materials were used in repairing crack between Vaulting and main wall on West side of South West Transept, 16 bags of broken stone, 6 bags of Cement and 13 bags of Sand.

Quantities of Grout

	Gallons
West Wall of S.W. Transept, 59'0" to 70'0" up.	160
do. 59'0" " 72'0" "	420
3rd Bay, West Wall of South West Transept, from floor level to 71'0" up.	20
Total -	600

Robt Godfrey

Clerk of Works

Fig 3.12 Special Repairs Weekly Report No 108 (Lincoln Cathedral Works Archive).

strengthening of the superstructure was raised about the effects that such upheaval was having on the foundations, the loads constantly moving from one area to another as work proceeded.

A mystifying point leading to the Special Repair project is the suddenness with which it was felt necessary to act. For over a decade, Charles Nicholson, a man ostensibly more qualified to assess the structure than Godfrey, had alluded to the poor state of the west-end masonry in his annual reports to Chapter, but with no sense of urgency or alarm. This may be due to reasons described by William Harvey in connection with architects who are perhaps familiar with a monument but at the same time are not aware of the secrets of its methods of building and their peculiar strengths and weaknesses.' (22) Harvey goes on to describe the necessities of persistent inquiry and research required to read symptoms. He concludes that 'No custodian of a famous building wishes to obtain the reputation of a scaremonger, and it is difficult for any person who has lived a long time in daily association with an apparently massive monument to make up his mind to the fact that the normal routine of minor patchings must be abandoned at a given moment, and a far-reaching scheme of major works substituted for it.' (23) In the case of Lincoln, it was only with the arrival of Godfrey that any sense of impending disaster was expressed. Within a very short space of time following his appointment a major disaster appeal was underway, with the services of one of the foremost structural Engineers of the day called upon. Nicholson appears then merely to have changed his responses to contend with the new perception of the condition of the structure.

A Question of Survey

Prior to the commencement of work, unlike at York forty years later, only relatively few conditions appear to have received planned research. One of these areas was the ground, upon which according to Godfrey, 'the Towers continued to settle.' (24) Such emphasis placed on the movement of the towers might have concentrated seriously on many trial hole investigations, but in the event this amounted to a small operation, with only two diggings carried out. These revealed a layer of rock on the north side of only around 9" (225mm) in depth, some 8' (2.2m) down. On the south side, the Norman foundation was only 2' (600mm) below the surface, itself built on seemingly firm Roman work. Anomalous findings such as these might have inspired a limited exploration of the escarpment, and have been more informative of ground conditions. In July 1922, Fox reported the findings to Chapter following the sinking of trial holes along the west green and wrote: 'The results of this investigation ... are very reassuring,' adding that 'there is no need (at all events at present) to undertake the somewhat difficult and expensive work of underpinning the Towers.' (25) It is commonly known locally that Eastgate, running parallel to the north of the Cathedral, is riddled with underground tunnels, any one of which would have provided a text-book illustration of the local ground strata. In Godfrey's reports to Chapter, this ground investigation warranted only a single page of superficial findings, once again with no reference to the causes of the problems.

Surprisingly uncritical of earlier workmanship, particularly in the work of Pearson, Godfrey pointed out that:

> 'repairs carried out at that time were practically all face work. It was certainly good work; but as the present method of making good the core of the walls was not then known, certain sections of the walls of the South West Tower are again splitting, and there are cracks to-day from 1 inch to 6 inches wide, running practically the full width from the South West corner of the West Front to the South West angle of the North West Tower.' (26)

Hindsight of seventy years informs us that Pearson's work was not always sound, often only appearing to be so. Whilst critical of placing wrought iron between courses, no great effort was made by Godfrey to find and remove it. Nor was thorough repointing carried out, the old pointing often only covering up these alien materials. Masonry areas fixed in Pearson's time have recently been replaced, providing an opportunity to inspect its thoroughness. A reduction of the outer skin of masonry, in some areas removed down to 2" (50mm), not only encouraged structural failure but denied succeeding caretakers evidence of the true condition of the fabric. Presumably the same skills of testing the quality of individual stones available in medieval times (and certainly available now) were also at Godfrey's disposal. This amounts to a non-destructive 'sounding' of the stone using the blunt end of a chisel. The difference is immediately apparent, a clear ring where there is depth with no fractures and a hollow 'clack' where there are fractures or no depth. Godfrey's remarks are either innocent or protective, but seem poor in judgement, perhaps lacking the qualification to make such assessments.

Aspects of Specification

That conditions were not clearly ascertained through comprehensive and informed survey prior to analysis and investigative trials for treatment is disturbing. As Harvey cautions with regard to the enlisting of outside expertise: 'It is quite natural also for the experts called in to wish to apply some specific remedy that has been proved effective in some other constructional works.' (27) At St Paul's, some years after the Special Repair at Lincoln, work being supervised by Harvey was inspected with a view that grouting should serve as the sole measure of repair, (28) but Harvey argued vociferously against it. Analysis at Lincoln, taking into account the behaviour of the whole structure, checking local tendencies to failure (see 1.3 *Failure in Gothic Buildings*), might not then have concluded that grouting was suitable as a single remedy. Examination of a range of available treatment options may then have produced a forecast of their effects, valuable in producing realistic limits on the operation.

In the event, the prescription of pressure grouting appears to have been open-ended, and through routine reports seems to unfold rather than to follow any comprehensive specification. In a letter from Nicholson to Godfrey in February 1922, (29) a reference is made to recommendations made by Fox to grout below ground, but in no record is this work referred to and does not appear to have ever been carried out. The original budget forecast of £50,000 was exceeded by a staggering figure of £138,000. There is little evidence of analysis of relevant areas of the fabric to be treated,

and such a lack of reference denied any opportunity for the monitoring of such a major intrusion. Any increase above the anticipated volume of grout and reinforcements forced into the medieval core was expressed by Godfrey as a measure of success. The following report is typical: 'Up to last Friday 312 gallons [of grout] has been blown into the walls of the Norman Transept abutting the Tower. This is a remarkable quantity, especially as at this point no cracks were visible to the naked eye.' (30) The danger of blocks being pushed out by sheer weight would have been extreme. In his Rotarian presentation, drawings ostensibly depicting accurate movements in the masses of the fabric amount to no more than diagrammatic outlines of fracturing (Fig 3.13). Lincoln stone, in heavy frost conditions for instance, does not fracture evenly along a bedding plane, but shatters in all directions and would be likely to react similarly on being subjected to pressure grouting of 45-50 psi. In no found written account of the work, by Architect, Engineer, or Clerk of Works, is there reference to this critical tendency.

Pressure grouting, developed primarily for tunnel building, as in the case of the Mersey tunnel or the London underground, relies on a continuous bearing of the weight from the ground above. Compressive medieval masonry structures, on the other hand, were never designed to resist the application of such random lateral pressures from within. Reports refer to 60 gallons of grout a day in a single area, at pressures sufficient to dislodge or damage the soundest masonry wall. Individual stones, having withstood the rigours of shifting loads within the west work for some six hundred years, were perhaps ill prepared for such forces, and shattered as the work proceeded, or are even today awaiting the slightest extra pressure to fail. At York Minster and Ely Cathedral, in similar circumstances only decades later, very low pressures and a reliance on the action of gravity were calculated to be a sufficient force to ensure that the grout penetrated the deepest voids of the core.

Lasting Effects on the Fabric

In total, Godfrey stated in a lecture to the Lincoln Engineering Society in 1931,

> 'we have forced into the walls and surrounds of the North West Tower 23,524 gallons of grout, equal to 3764 cubic feet of space, and weighs approximately 107 tons, and into the Transepts and the Centre Tower 12,682 gallons of grout.' (31)

By the following year, he stated that the drilling of 23 miles of holes, all made with the impact of power-hammer drills, with more than a thousand tons of cement encasing 31,516 Delta cramps, and a total of 13,547 new stones had been fixed into the fabric. By employing such irrevocable solutions to the fabric of the Cathedral, the Special Repair almost certainly averted possible partial collapse, but it must be stated that the methods employed in the context of a medieval construction were profoundly aggressive and can hardly have been without lasting cost to the fabric.

Fig 3.13 Elevation of North West Tower showing fracturing. Many drawings ostensibly depict the actual state of the fabric. However, such dramatic fracturing was not evident to the architect immediately prior to the appointment of the new Clerk of the Works. (Lincoln Cathedral Works Archive)

Hidden difficulties now exist, making some maintenance repairs hazardous. Not least, are the great lengths of reinforcement placed within the core which may deny the practical option of simple repair or replacement of masonry. What may otherwise have been a simple case of removal of eroded sculpture now poses great risk due to the ferocity of adhesion of the neat Portland grout. Hard and impervious barriers exist in the core of the masonry, and routes of moisture and soluble salts cannot be predicted, presenting problems for the future. A chest tomb repaired in 1993 was found to have been inadvertently filled with grout, the adhesion of the Portland cement to the stone and the advanced state of salt damage severely jeopardising the stonework as repairs were carried out. Referring to pressure grouting, John Harvey emphasises at length its 'dangers', concluding that 'In general it cannot be recommended as having anything in its favour, when compared to repair by traditional building.' (32) Certainly, the solution of transferring forces successfully to the ground, originally conceived by the medieval builders, has been severely interrupted. Any inherent hidden fail-safe methods that masonry structures normally possess cannot now be relied upon, but time will ultimately assess the newly imposed system with regard to its stability and survival.

3.3 Major Interventions and their Significance

The Special Repair Programme (1922-32) is perhaps the biggest maintenance intervention experienced by the Cathedral in its long life, and the positive and negative consequences may not yet be fully realised. In contrast, the current conservation of the Romanesque Frieze, although of perhaps equal significance in cultural terms, is at the opposite end of the physical scale (see 4.3 *The Lincoln Romanesque Frieze: A Case Study in Policy Shaped by Practice*). Both operations describe a point of reference in determining the pathology of the Cathedral, as macro and micro definitions, and both campaigns emphasise the value and fragility of the building. Some difficulty has existed in seeking to find a way to ensure the longevity of the building and at the same time preserve its traditions and historic value. There has been a considerable effort to do this by the Dean and Chapter of Lincoln during the 1980s and 90s, in resolving problems related to the Romanesque frieze, with effort made to absorb the current spectrum of conservation opinion. It is only a little over seventy years since the advisors to the Dean and Chapter of Lincoln responded to the lamentably poor structural state of the building. Much of the work taking place today is a consequence of the same concerns, but many current problems stem from the solutions employed during the 1920s and 30s. In view of the legislation now in place (Care of Cathedrals Measure 1990), it is certain that the technical, scientific, and ethical opinion of today would in similar circumstances influence a different course of action.

Assessment of the Special Repair and Comparison with Major Repairs at York and Ely

An absence of comprehensive proposals relating to the Special Repair programme has prevented a full analysis of the aims of the project, but there is some evidence to suggest that directions of the project were determined as new areas were surveyed and as practical work proceeded. From a

presentation to the Rotarians given by Godfrey in 1925, the most complete extant outline of the work, it appeared that structural problems could be described as 'live'; in other words, active. His suggestion however that ground settlement had still been occurring as recently as the 18th century, with the implication that this might be progressive, is clearly in opposition to the accepted structural theory that any interaction between soil conditions and masonry, other than unexpected changes in the former, will occur within a generation (see 1.3 *Failure in Gothic Buildings*). In the event, this was ruled out early in proceedings as being a cause of the movement.

Nowhere in the abundant reports to Chapter at this time, from the Engineer, Architect, or Clerk of Works is the cause of structural problems analytically addressed. Recent maintenance repair, even to the west front, has revealed the insertion of iron wedges in their thousands. The effects of these wedges on masonry has been mentioned earlier in this paper; suffice it here to say that the power of its destruction is virtually uncontainable. The symptoms of such a problem, undetected over a long period, cannot be dismissed as inconsistent with those presented to Chapter prior to the commencement of the project. It may have been that the iron wedges were used earlier as a remedy for an already existing weakness. Given the circumstances of an inherited engineering weakness, the symptoms of which were periodically stemmed, initially by the insertion of relieving arches in Norman times, a similar remedy developed by Gibbs in the 18th century. It may have been that with the device of tightening up slackening courses of masonry using wrought-iron wedges and the systematic replacement of damaged masonry, the cumulative conditions in the early 20th century were evasive of a single cause. Tolerable cracking in masonry can be described as the natural state of a masonry structure, but this may worsen until lateral forces from roofs can no longer be restrained. It may have been that Godfrey arrived at this critical point, alerting Chapter to the gravity of the situation, and had little option but to embark on his particular course of action. Questions still remain, however, about the constant application of the same solution to apparent problems throughout the building, and about the authenticity of such problems.

With no convincing analysis of the cause of the defects of the west work of the Cathedral apparent, it is difficult to be confident of how befitting the treatment was. It has been observed in Part 1.3 that a primary rule in the stability of masonry, and therefore in relation to repair, is that the entire structure should comply with a simple plastic theory of masonry, ie the compressive loads expected to be contained within the structure should reside within a safe limit in the mass of the masonry. In the words of Heyman, 'this theorem states that if it is possible to find a system of internal stresses in equilibrium with the external loading, and this system is satisfactory in the sense that there is no danger of crushing of the material, then there is a complete assurance that the structure as a whole is safe.' (33) Once the decision was made that major work should follow, the recently completed work at Winchester may have appeared to offer a panacea in the technique of pressure grouting with Portland cement.

Comparable to the Special Repair programme, though following half a century later, are the restoration works at York Minster and Ely Cathedral. Both programmes introduced systems of reinforcement and included injection grouting. Not withstanding the unfair advantage of hindsight, neither campaign of repair can be criticised for lack of preparatory investigation, or applying techniques that may not be appropriate. An analogy by Poul Beckman of Ove Arup Engineers, who were responsible for the work at York Minster, states that structural repairs, like 'medical treatment must be preceded by diagnosis.' (34)

York Minster Restoration (1966 - 1970)

Following the appointment of Bernard Feilden as Surveyor to the Fabric of York Minster in 1965, a thorough survey revealed apparently fresh cracking in the abutment of the main piers of the central tower and in the piers themselves, as well as in the choir. A second opinion by Ove Arup and Partners, Consulting Engineers, confirmed a 'live' situation. Here too, this refers to a condition whereby the structure was currently moving. Trial hole excavations were prescribed to establish ground conditions and a comprehensive ground survey was initiated. This involved examining all relevant known sources for useful information, including local archives, University departments, and local government planning offices etc. Movement in the foundations, due to changes in the water table, was clearly identified. At the same time it was established that the footings to the foundation were hopelessly inadequate, the walls having no corbelling feature onto the foundation. (see 1.2 *Foundation Failure*) A fund-raising appeal to support a programme of underpinning the central tower, together with extensive grouting of the superstructure and the insertion of concrete ring-beams, was launched in May 1967.

All identifiable structural movements in the Minster were analysed and several conspicuous areas were noted where significant settlement differentials had occurred. The most notable of these were found in the nave and in the main piers of the central tower, where a differential settlement of 4" (100mm) existed. It also became rapidly 'obvious that the east end was leaning out and that there were several distortions in the transepts adjoining the central tower.' (35) (Figs 3.14 and 3.15) A comprehensive and integrated study was put into motion, with factual measurements being tested against historic knowledge, with the science of soil mechanics completing the equation. Running concurrent with this three dimensional investigation (or *four* dimensional, according to Beckman, since 'time enters into the technical arguments very much and we cannot begin to understand what has happened to the structure without studying its history.' (36) was a regular consultation with the archaeologists, who had a regular attendance brief and an on-the-spot opportunity for investigation. Due to the precarious nature of the state of various parts of the structure, archaeology was secondary to the engineering imperative.

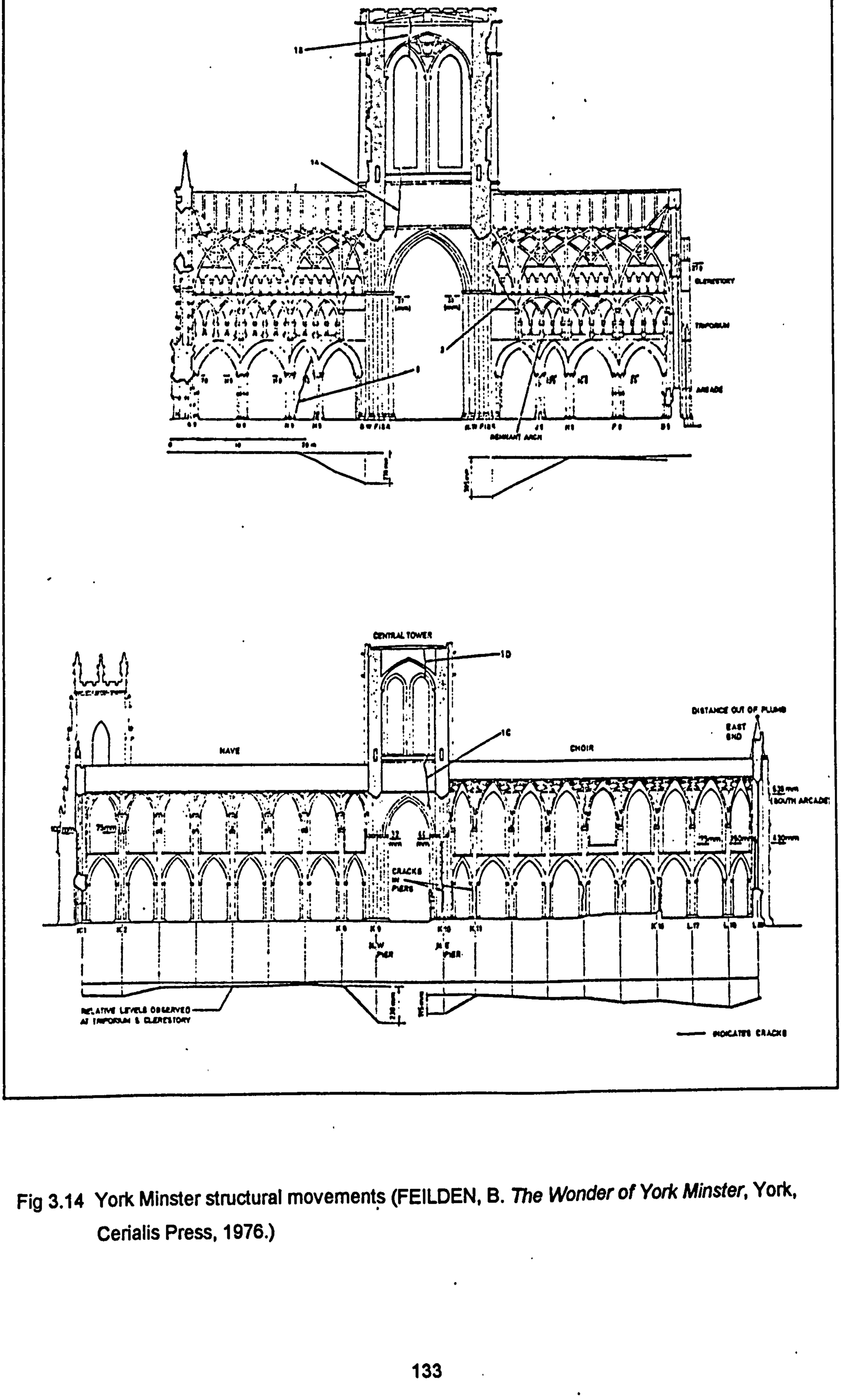

Fig 3.14 York Minster structural movements (FEILDEN, B. *The Wonder of York Minster*, York, Cerialis Press, 1976.)

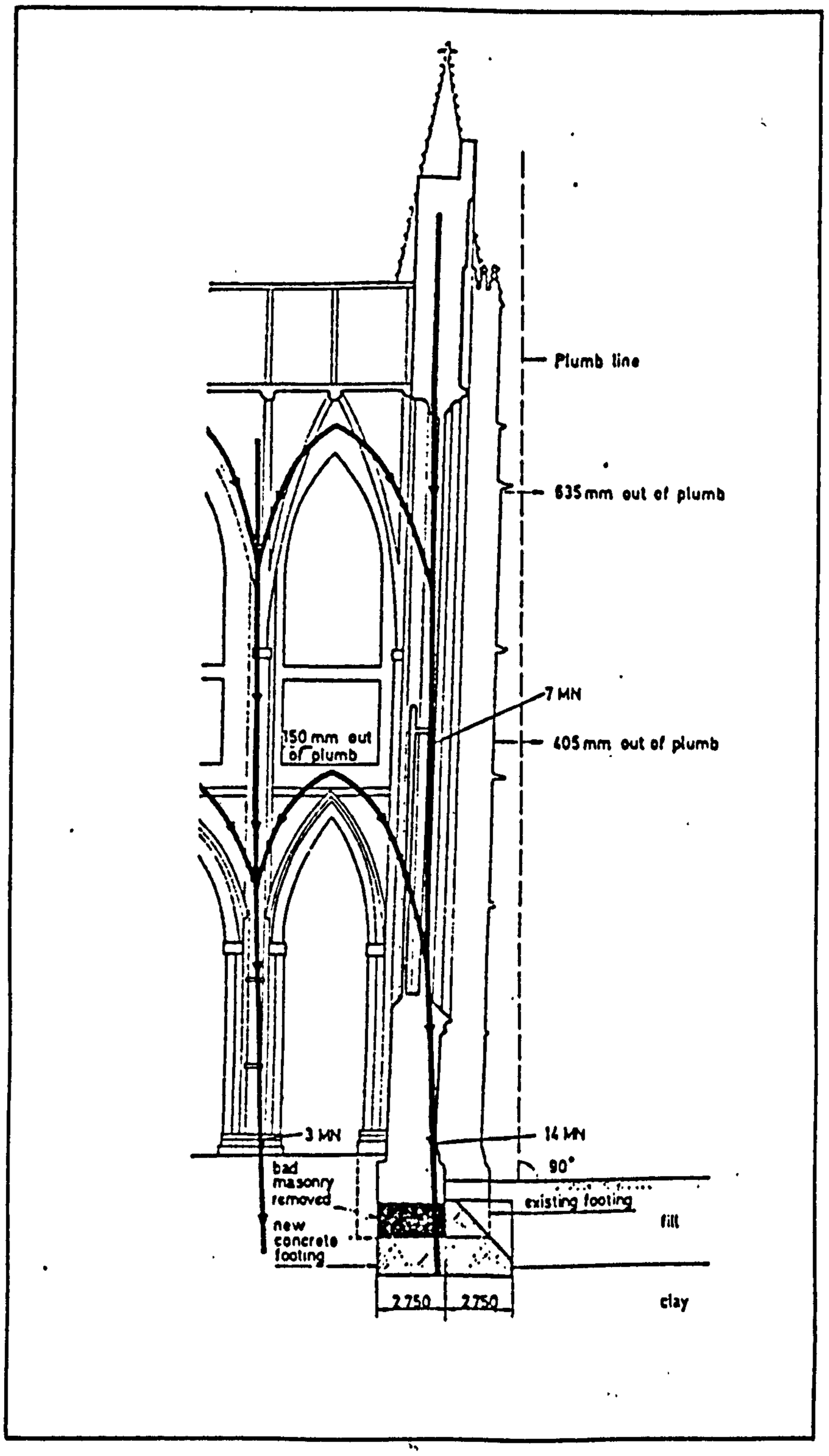

Fig 3.15 York Minster detail of east end structural movement (FEILDEN, B. *The Wonder of York Minster*, York, Cerialis Press, 1976.)

As soon as the complete study of conditions was made and all data collated and assimilated, a practical foundation modification was put forward by the engineering designers. Post-tensioned pads were installed to enlarge the foundation area, which served to eliminate eccentricity of loading. An ingenious system of hydraulic jacks was then permanently positioned between the stonework and the new foundation to further discourage movement, as well as serving to reduce dangerous pressures on the soil and making movement even less likely. As each individual pier foundation was being excavated, precarious stitching and grouting of the superstructure was carried out, the intervention below having inevitably exacerbated the previously created fissures in the masonry. Other areas of the Minster were simultaneously assessed for disturbance and damage, with trial holes dug at both the east and west ends. At all times, the Architect, Engineer, Archaeologist, main Contractor, and responsible Clergy, communicated vigorously to the benefit of the operation, at the same time maintaining the daily life and future security of the Minster.

Ely Cathedral: Repairs to the West Tower (1973 -1974)

The principle employed to make safe the west tower at Ely was one of partial 'conversion', as described by Heyman, the Consulting Engineer, 'into reinforced concrete by drilling, 'stitching' and grouting with neat cement.' (37) It was established that the core of the masonry had weakened and that its value should be restored so that it would once again function by absorbing its share of the imposed loads, becoming a valid part of the assessment of the total masonry structure. In the context of Gothic building, this latter state can be described as 'a two-skin wall with rubble fill.' (38) Internal cavities, such as those created by the slumping corework, were not part of the original plan and possessed no integral safety feature, such as might be offered by relieving arches over window openings. If the 'safe theorem' stipulates that forces should reside within masonry, then the core requires to be an equal part of the wall receiving them, and does not simply pass them on to the outer skins of ashlar. A significant underlying statement here is that the traditional masonry wall, consisting of two skins of dressed ashlar with a lime mortar and rubble core, performs as a single entity, retaining the integrity of its shape, or geometry. Most masonry repair is a process of rectifying situations that have deviated from this state.

As at York, it was ascertained that the considerable historical problems of settlement were due to the unreliability of the water-table. Records showed a variety of subterranean surfaces upon which the structure stood, such as a thin wedge of sandstone upon which the Norman and some Early English footings bear, although tests indicated that no movement had occurred at foundation level for some centuries. Under this slip of stone, only approximately 1m in depth, lay a 'stiff laminated dark grey clay.' (39) It is upon this material that the entire structure depended. Previous reinforcements, although adequately thought out in principle by Scott, were apparently largely responsible for the magnitude of fracturing, due to the ferrous nature of his choice of materials, and it was decided to replace them. Figures 3.16 and 3.17 demonstrate the level of preparation and calculation associated with this proposal, and the principle of stitching used. This followed

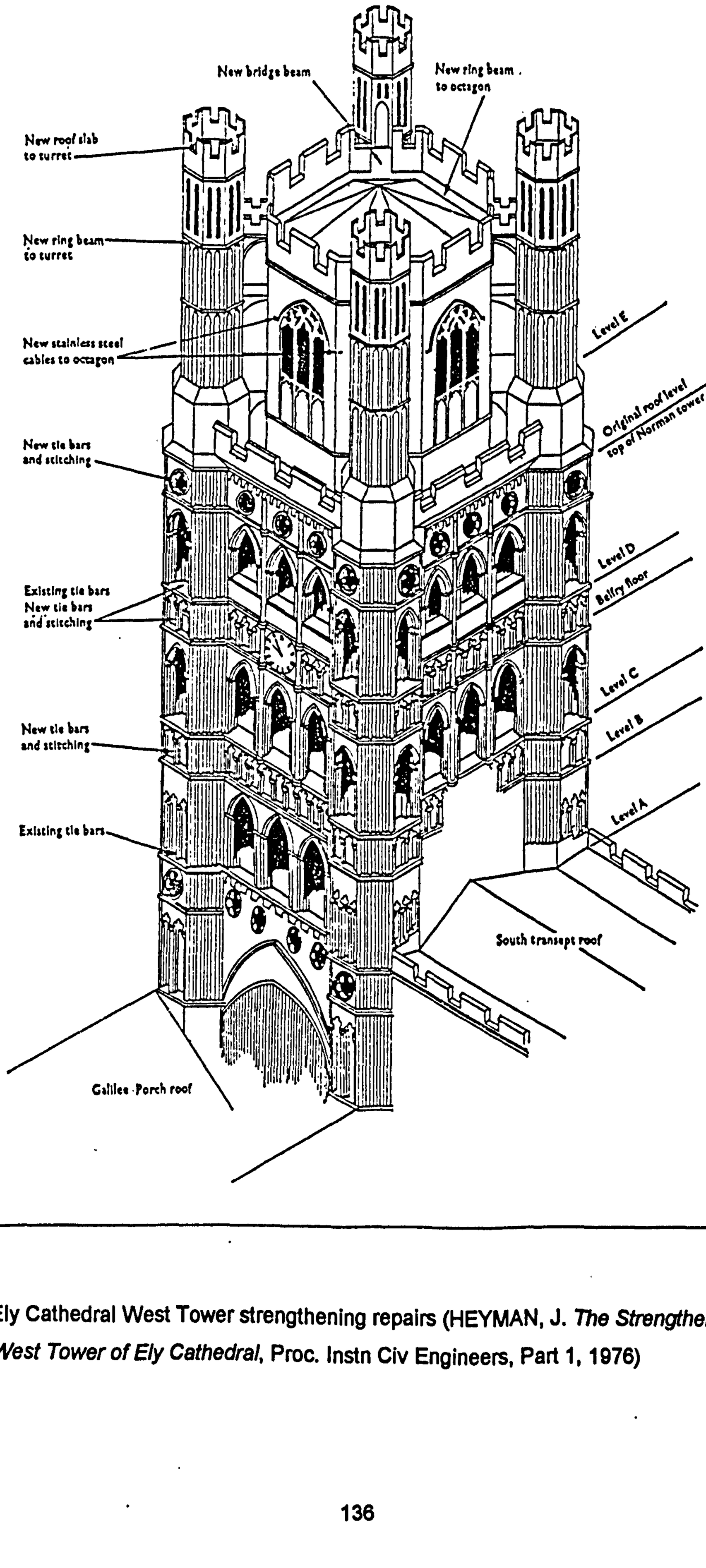

Fig 3.16 Ely Cathedral West Tower strengthening repairs (HEYMAN, J. *The Strengthening of the West Tower of Ely Cathedral*, Proc. Instn Civ Engineers, Part 1, 1976)

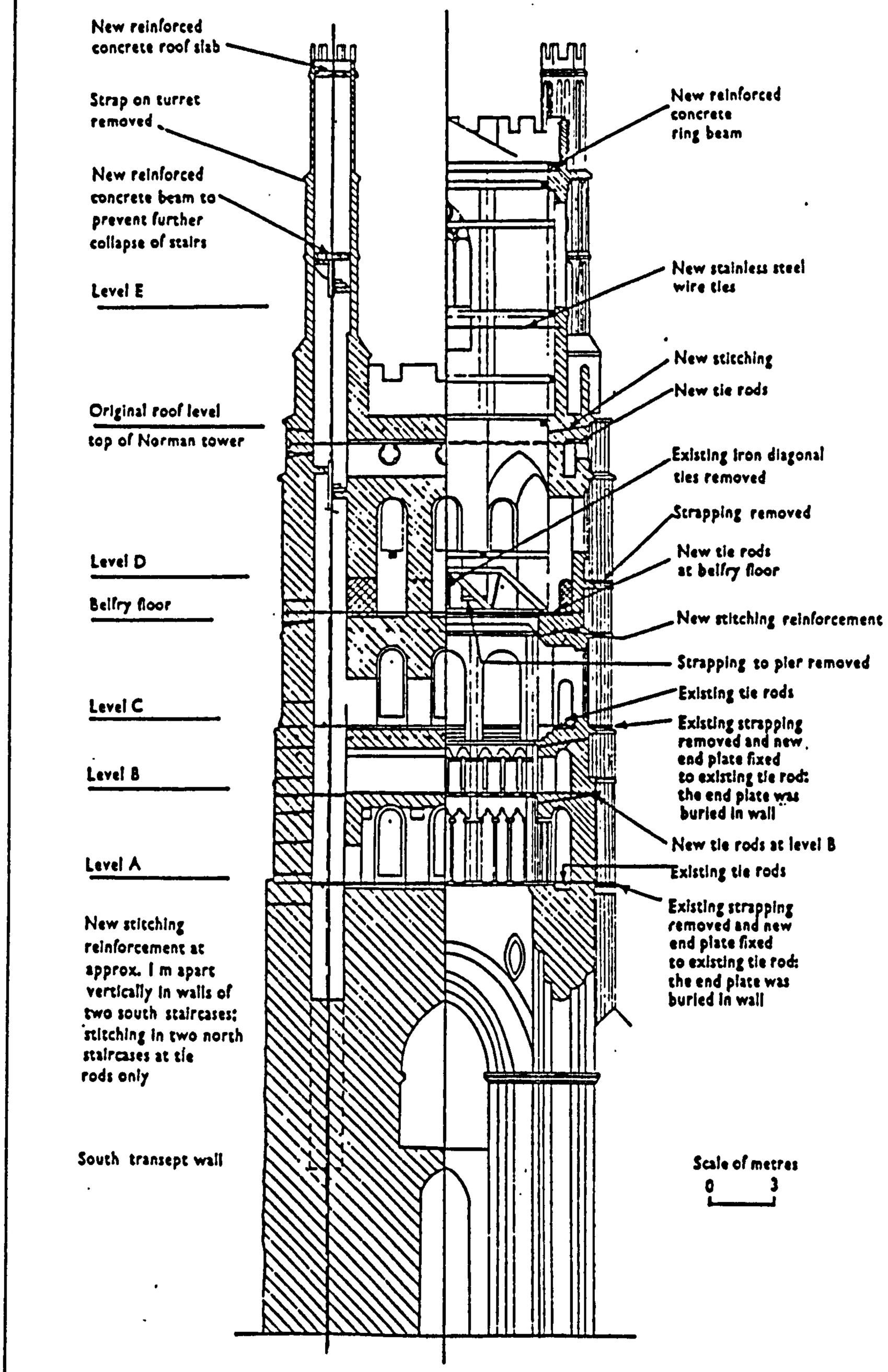

Fig 3.17 Sectional elevation of Ely Cathedral West Tower strengthening repairs (HEYMAN, J. *The Strengthening of the West Tower of Ely Cathedal*, Proc. Instn Civ Engineers, Part 1, 1976)

Scott's system, extending on it and differing from it in three ways. Firstly, stainless steel bar (austenitic 18/8 type to Grade AISI 304) replaced the wrought ironwork that had caused such damage. Secondly, where Scott had anchored from only the interior ashlar skin, these were extended to include the external courses, further maintaining the geometrical shape of the structure. In some instances, tie-bars passed dangerously through turret passageways [1] and these were moved. Thirdly, the new tie-bars were post-tensioned and grouted with neat Portland cement prior to the tightening of the locking nuts over plates braced against the outer walls. The main aim of the work, and its ultimate achievement, was to encourage a system of uniformity in the distribution of forces delivered to the ground. With the shape of the structure assured by an improved and subtle enhancement of Scott's stitched ring beam system, a safe delivery of forces to the stiff clay under the foundations would be maintained in equilibrium.

A Brief Appraisal

A characteristic of the York programme of work was its affinity with local traditions of maintenance of the Minster and the comprehensive effort in reaching the correct decisions in all areas. Specialist contractors were brought in to support those disciplines not normally carried in-house. Largely, it seems, due to the character of Bernard Feilden and his ability to assemble an appropriate range of specialist professionals, it became possible to seek advice without losing the ability to conduct the overall operation. In this respect the term *conservation architect*, regularly used by Feilden, seems to have been suitably chosen. The quality of survey, carried out to ascertain details of the foundations appears to have been exhaustive and defines itself as a positive reference in such circumstances. The emphasis throughout the work was on acknowledging and calling upon the correct discipline at the right time. In the sensitive case of archaeology, particularly below ground where excavation had possibly never previously occurred, when progress of the delicate engineering operation was not threatened it went ahead, but in more risky circumstances where the costs may have been catastrophic, it was regretfully sacrificed. During underpinning, the urgency of the work was never allowed to interfere with the need for a measured view and an accompanying steady approach, so that the boundaries of the Minster's many valued functions and purposes were not needlessly and insensitively transgressed. Unfortunately, due to the absence of an effective impervious membrane being inserted between the new concrete and the masonry, a great deal of moisture and soluble salts have transferred into the stonework and damage to the much of the stone surface appears to be continuous (see 2.3 *Soluble Salts* and *Hard Cements and Mortars*.)

In contrast to the work at York, where operations were closely orchestrated by the Architect, at Ely the coordination and responsibility for all the strengthening work lay with the Engineer, Jacques

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[1] These seriously impeded access, creating problems in fire precautions and safe exit for personnel.

Heyman, although still technically under the direction of the Architect. With regard to the collation of information and formulated opinion, regular site meetings were held and a close relationship was maintained between Surveyor,[1] and Engineer, who observed in his own words: 'it was the aim at these meetings to arrive at agreed courses of action for all aspects of the work.' (40) Whilst it is important not to draw too wide a difference between these two approaches, it is significant to observe the effect of personalities and professions on such projects. Suffice it to say that the work at Ely was conducted under the enlightened guidance of Professor Heyman, whose sympathy with such structures is of the highest order. It may not always be the case that an engineer possesses such judgement on design and integrity of the structure.

Tentative Observations

A further significant factor in the comparative approaches of these projects is the general method of maintenance of the two Cathedrals; York carries a large and comprehensive alliance of skills in its directly employed labour force, whilst Ely has traditionally commissioned the commercial company of Rattee and Kett (Cambridge) Ltd[2] to carry out necessary works. The principles of these two methods are at York a system of 'continuous' care (which is also embodied at Lincoln), and at Ely a 'when necessary' method of maintenance. The immediate effects on projects such as these are worth brief attention. Principal amongst the questions that these two methods raise must relate to the 'continuity' of care, where lesser damage or breakdown may not warrant the commissioning of a contractor. This might occur at a time when a large project has just finished or when the politics and timing do not allow for attention since continuous care is not the adopted philosophy. In this case, the danger may result in even greater loss or damage being incurred through delay. There arises also the inevitable point regarding profitability, which may be more close to the consciousness of the private company, with cost-cutting being more of a prime mover than a more emotional relationship to the work. It has to be recalled in connection with these points that the architect is generally not permanently in residence at the site and the question of who provides feedback on a continuous basis is worth asking. It can perhaps be presumed that monitoring of repair work will always be part of an initial specification.

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[1] Donavon Purcell, the Surveyor of the project passed away during the work and was succeeded by Peter Miller, of Purcell Miller and Tritton and Partners. This untimely event may have had an effect on the roles played by individual professionals.

[2] James Rattee, co-founder of the company of Rattee and Kett with George Kett, was commissioned by George Gilbert Scott in the mid-19th century to carve the rood screen and reredos at the east end of the Cathedral, thus establishing a long working relationship between the Cathedral and Rattee and Kett.

3.4 Enduring Influences on the Culture of Care at Lincoln

Immediately following the main Special Repair work of restoration on the towers and the west elevation there followed a flurry of publicity, with all involved being extolled for saving the fabric of Lincoln Cathedral. Nicholson, remained as Cathedral Architect until the late 1930s. Fox had received a knighthood in 1912 for his contribution to the nation's heritage. Robert Godfrey, initially employed at the Cathedral as a plumber, was presented with the insignia of CBE for his efforts relating to Lincoln. Caretakers of other architectural monuments, realising that the buildings in their care were perhaps in a less than healthy state of repair, sought advice from the Lincoln team of experts. Letters at that time, however, do not always amount to a genial exchange. Some architects were not entirely comfortable with the notion of a single remedy, and were unhappy with the way that the actions of pressure grouting were unable to be monitored. As is clear, William Harvey, then the Architect of St Paul's, felt that the technique of pressure grouting required 'exhaustive analysis of all conditions,' and even that its recommendation where there was movement in the masses of the structure was 'an idle waste of breath.' Furthermore, he stated that: 'To apply it is a waste of money and, worse still, of precious time, while the movements in the building go slowly and inexorably from bad to worse.' (41) Nicholson in a letter to Godfrey expressed no desire to become involved with those at St Pauls.

Not put off by such reactions, further areas of the Cathedral were focused upon as eligible for pressure grouting, and it is almost easier to point to those areas that were not so approached. Once the work to the west end and towers was completed, followed by the central tower, main transepts and nave clerestory, work to the east end commenced, moving to the Chapter House. Work of this volume carried on until the outbreak of the second world war, at which time many of the Cathedral labour force were conscripted into the armed forces. A reduced team, headed still by Robert Godfrey, carried out little maintenance throughout the war years and work of the same magnitude was not taken up immediately after the war. In the 1940s and 50s, there was more of an inclination towards the installation of monitoring programmes, a natural response perhaps to the state of the economy and funding at the time.

During the 1920s and 30s, the team comprised of an array of skills, with drillers, grouters, and workers of a general engineering background, working with masons of varying craft ability not always of the highest order, who were employed in making good the fabric where it had failed. The evidence is that maintenance work was generally fair, although it is clear that traditional stonemasonry techniques were frequently absent. After the war years, a dearth of skilled men and, presumably funding, further reduced links with traditional tradecraft. Many men were invited to attend centres for retraining, which seems to have been based on local demands. At Lincoln, several men who had received short and intensive training in stonemasonry were appointed at the

Cathedral to assist with maintenance work.[1] Following the war, the works team was not replenished to its former levels, but Godfrey continued to lead the team until his death in 1953, having received an honorary Master of Arts degree in 1952 from the Archbishop of Canterbury. A valedictory comment following half a century of service was made by Bishop Dunlop and was recorded in the Diocesan Magazine. It stated the following:

> ' His name will go down to posterity among those who have pre-eminently served Lincoln Minster: Richard of Gainsborough, Richard of Stowe, Sir Christopher Wren, James Gibbs, William Essex[2] and others, although his task was perhaps the largest and most crucial of all.' (42)

Links with Tradition

Work carried out in the 18th century, it has been seen, often denied the notion of continuity with medieval masonry traditions. This was not always the case, as was exemplified by much of the work of Essex and his choice of craftsmen. Some of the workmanship carried out by the carver James Pink, for example the altar screen in the choir, is of the highest quality of design and craftsmanship. As stated by Cocke, on occasion the work 'is so good that much of his activity can hardly be distinguished from the original.' (43) Essex's intuition might even be described as a last link with medieval understanding and with the Gothic ethos of building. At the same time, some of the work carried out in the early nineteenth century was also of good quality, but the mid-century restoration work of Buckler,[3] described by Cocke, as being conducted 'on traditional lines,' (44) was not always acceptable by today's standards. Until late in his career, Godfrey cannot be found making much critical comment on his predecessors, although he was accustomed to stating his anxieties regarding the efficacy of medieval corework, which he felt to be essentially unreliable, as well as the efficacy of traditional building repair. He is persistent in his reverence of 'that wonderful building material known as Portland Cement,' (45) and seemed to employ it in whatever circumstances he could, even as a bedding mortar for masonry. Practice of this kind is anathema to the traditionally trained mason, due to the hardness and impervious nature of the material, and its general incompatibility with stone. The qualities of traditional lime mortars are not reliant upon serendipity, but are a carefully considered matter within the boundaries of their effectiveness. Portland cement mortars tend to deny the nuances offered by traditional mortars in the context of masonry construction and are immensely damaging when incorrectly applied (see 2.3 *Hard Cements and Mortars*).

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[1] One of these was Mr Ron James from Portsmouth, who had served in the Royal Navy when he met his future wife. In 1950 he came to live in Lincoln, seeking work at the local Labour Exchange. He was offered the opportunity to re-train as a Mason, going on to work at the Cathedral until 1987. Much information and direction in this section has been derived from conversations with him.

[2] In fact the Christian name of Essex was James not William; this seems to have been an error.

[3] A controversy emerged over the techniques employed by Buckler at Lincoln, specifically on the west front, with accusations made of scraping back the stone surface. Buckler denied this and was moved to write A Description and Defense of the Restorations of the Exterior of Lincoln Cathedral, Oxford, 1866.

It is clear from his writings, that Godfrey believed he was at the cutting edge of historic building repair; a typical reference being made to 'a wonderful repair which has been acclaimed to be the greatest achievement of its kind ever carried out.'[1] (46) Constant references were made to the 'scientific' nature of the grouting operation, in Godfrey's reports, and he certainly felt that he was working in the best interests of the building. But how far removed from the ethos of Gothic construction he felt himself to be is difficult to estimate, or how closely he ever comprehended or identified with it. Strong though the references to a scientific approach are, support for this is weak, since there is little evidence of any essential understanding of the Gothic Cathedral structure, let alone its failings. Occasional information suggests some curious proposals in later years, again denying the functional imperatives of the structure, and following Godfrey's example. For instance, J. A. Higgins, Clerk of the Works from 1953 until 1978, in a report to Chapter in 1963 made this comment regarding the apparent slackening of vault ribs in the south transept: 'To overcome the failure it would be advisable to introduce a concrete member on top of the vaulting, immediately above the ribs, to which they could be secured.' (47) (Fig 3.18)

The Works Department and Office of Clerk of the Works

Attitudes to maintenance at Lincoln were established during Godfrey's long influence at the Cathedral and through the ostensible success of the Special Repair, sustained to a great extent until the mid 1980s. At this later time, the inception of the Fabric Council and, only several years later the Care of Cathedrals Measure 1990, were to wield a fresh influence on the both policy and methods of work (see 4.2 *New Systems of Critical Dialogue at Lincoln*). The Cathedral works staff still occupy the premises developed at the time of the Special Repair and all workshops operate more or less as then. The Cathedral quarry, established in the 1850s, which supplied the vast quantities of stone for the Special Repair, is once again effectively and economically worked, (see Appendix C *Case Study: Re-opening the Cathedral Quarry*).

The somewhat unique nature of the Works Department, although growing and reducing at times in number, has retained its character. A comprehensive range of skills is now carried, adhering to a minimum five year plan of work, with the team tailored to suit those actions prescribed through fluctuating needs. In the earlier part of the century, it was prudent to retain sufficient abilities to contend with whatever contingencies might arise, since work often proceeded into unknown areas. The purpose of the masons at that time appears to have been chiefly to provide support for the drillers and grouters, making good those substantial areas of masonry that were damaged. Perhaps partly due to this, there seems to have been a sustained reduction in allegiance to traditional trade practices. Often, the only contact with mainstream influences has been during

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[1] The gathering momentum of Godfrey's self esteem over the years may amount to no more than a denial of those criticisms which most certainly occurred, or they may suggest a growing isolation after so many years in office. In neither case, do they embody the anonymity or humility often associated with the traditions of caring for such buildings.

Fig 3.18 Reinforcement metalwork in place over vault ribs (Lincoln Cathedral Works Archive)

training of apprentices on block release to a training establishment in Dorset[1] and the occasionally recruited mason, who tended not to stay long. This was turned around in the early 1980s by the appointment of Peter Hill as Clerk of the Works. Himself a mason, Hill possessed a greater sympathy and clearer understanding of the needs of the building than many of his predecessors this century. Both he and the Architect, Keith Murray (architect from 1977 to 1987), set about modernising the masonry workshop, as well as attempting to generally broaden working perspectives. Systems of approaching the work were instigated, formulating a long-term work programme. A setting out shop was established, a pivotal facility in proper masonry practice, which had been allowed to lapse over the years. Setting out had been carried out by individual masons, with little coordinating influence over the work. Aspects of safety were concentrated upon, and lifting equipment installed, along with other improvements. At this time, initiated and driven by by Murray, first mention of conservation as an 'in-house' ancillary option was recorded.

Godfrey, seems to have made the role of Clerk of the Works his own, although his full title was Surveyor and Clerk of the Works to the Dean and Chapter (Fig 3.19). Any report for public consumption on the Special Repair, including lectures, reports and even a BBC radio broadcast script proposal, were made through that office. This might normally be expected from the Architect, or other professional. By 1938 Godfrey had laid claim to virtually all credit for the work, to a large extent single-handedly influencing the structure and philosophy of repair for decades to come. It may not be an exaggeration to conclude that in holding such a position in isolation for so long, the effect was to allow the custom of care at Lincoln to separate itself from the current of mainstream understanding of historic building care for much of the twentieth century. This is possibly due to the modern office having been fashioned around the personality of a willful individual such as Godfrey, and being somewhat confirmed in a Bye-Law in 1985 (see Part 6.0 *Conclusions and Recommendations*), the office of Clerk of the Works at Lincoln operates differently from many other cathedrals. A large degree of executive control over operations relating to the fabric and close houses is held by the Clerk of the Works, who also sets the fabric budget and directs the work. In holding this responsibility, he manages by far the largest single budget within the Cathedral system. For this reason, the architect's role is also arranged differently from other cathedrals, receiving his brief from the Masters of the Fabric via the Clerk of the Works. The Architect makes representation to the approving bodies on behalf of the works team and negotiates its position regarding policy and methods of practice. Once the views of the specialists have been collated, such as those held by Consultants, Masters of the Fabric, and members of staff, they are presented before the Cathedral's own advisory body, known as the Fabric Council (FAC), as well as other agencies.

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[1] Apprentice masons are sent to Weymouth College, which runs a masonry technology course. The instructors are mainly ex Portland masons, who embody and teach the traditions of the trade as they were passed down to them in a more or less unbroken line. (see 5.4 *Training Opportunities for Masons and Conservators*)

Fig 3.19 Robert S. Godfrey, Clerk of the Works from 1916 until 1953 (Lincoln Cathedral Works Archive)

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Part 4.0

Towards Effective Conservation Policy

Part 4.0 Towards Effective Conservation Policy

Introduction

Following the excessive and irretrievable damage executed during preceding centuries, the caretakers of medieval cathedrals consciousy changed their approach on entering this century. This section traces the parallel pressures and influences that led to the forming of a new national perception of the need to regularise caring for medieval cathedrals. More specifically, the changes at Lincoln were precipitated by the pressing demand for work on the Romanesque Frieze, which itself became pivotal to subsequent maintenance action. This programme of conservation, and the arguments which were examined during the formulation of a policy for the frieze, shaped attitudes in all areas of work on the fabric. The example set by Lincoln partly influenced the structuring of the Care of Cathedrals Measure 1990, which became effective in 1991, specifically in its example of establishing Fabric Advisory Committees (FAC), Lincoln being the first Cathedral to formulate policy through such a body. In this and other respects, Lincoln had little difficulty in adapting to the Measure, although difficulties did emerge relating to grant approval procedures in the case of the frieze.

4.1 The Evolving Perception of Care

In the late 18th and 19th centuries, conflict concerning the care of cathedrals intensified to such a pitch that various societies were formed to defend the integrity of the buildings. Following a series of brutal restorations carried out by architects such as James Wyatt (1746-1813), who was responsible for the destruction of the Beauchamp and Hungerford chapels at Salisbury, and for a host of crudely interpreted repairs at the Cathedrals of Litchfield, Hereford and Durham, a demand for restraining action emerged. The Society of Antiquities, having received the Royal Charter in 1751, commissioned John Carter (1748-1817) in 1780 to embark upon a systematically approached drawn record of ancient monuments and buildings. The existence of this archive reference produced the immediate benefit of a visual reference against which future comparisons could be made. Accompanied by a torrent of incensed articles and addresses by Carter to the Society of Antiquities vilifying the practices of Wyatt, it had the ultimate effect of halting a proposal to rebuild the Durham Galilee chapel.

It is possible to understand the thinking behind the actions of Wyatt and others of a similar disposition. The cathedrals that fell into their care were often the cumulative results of continual architectural additions, which had moved away from any grand design. To Wyatt and others of his persuasion, many past developments were themselves corruptions of the Gothic ideal and this, combined with the neglectful state that many of the cathedrals were found to be in, provided them with the inspiration to make them into what they felt were more suitable places for the worship of God. Contact and familiarity with the original workmanship, design, and engineering did not always persuade these Revivalists to treat the structures in their charge with sympathy.

In 1833 Pugin visited Hereford; 'I rushed to the Cathedral; but horror! Dismay! the villain Wyatt had been there, the west front was his. Need I say more? No! All that is vile, cunning and rascally is included in the term Wyatt.' (1) This general controversy was not a short-lived affair, persisting for more than a century, and begs the question why successive deans and chapters entertained the risk of commissioning architects suspected of such practices. A possible answer is that there was no risk attached to it at all, with clerics relatively immune from discipline and able to nourish the opportunity of being in the architectural vanguard when the gamble succeeded. A further likelihood was that deans and chapters provoked their architects into rationalising such features as access; it was common for interior monuments to be removed and at Durham, Wyatt was commissioned to design the replacement of the 12th century Galilee chapel complete with open terrace. The practice of over-restoration continued into the nineteenth century, with the tower and spire at Rochester being completely dismantled by L.N Cottingham, and restored in 1825 in the unadorned Gothic style. The son of Cottingham continued this family tradition at Hereford, becoming renowned for rebuilding rather than restoring, and was responsible for demolishing 'all the post Norman additions to the cracked central piers,' (2) before repairing them. In the nineteenth century, and as controversial as Wyatt, came G.G Scott (1811-1878), who appears to have received a mammoth share of commissions in his time.

Although a most thorough architectural historian, medievalist, and archaeologist, Scott seems to have allowed these talents to become corrupted by tendencies towards 'moral zeal and professional ambition.' (3) However, evidence of his better qualifications is manifested in the rebuilding of the Octagon at Ely Cathedral, where he utilised old engravings in combination with the original carpenter's marks. At the same time, he was not always inhibited by a lack of original evidence to complete a restoration. At Westminster Abbey, 'the ideal on which he based so many of his own buildings,' (4) in the rebuilding of the north transept front, he eradicated any evidence of its original state. He admitted that 'There is, in fact, scarcely a trace of original detail of the eastern portion of the exterior left.' (5) It was in particular protest against the indulgences of Scott that the Society for the Protection of Ancient Buildings (SPAB) was eventually founded.

Debate raged at the Society of Antiquities, but no policy was pursued, with members swaying opinion by their influence. Matters began to move against the restorers, when in 1855 the Society accepted an offer from John Ruskin (1819-1900) to donate £25 a year if it would agree to 'the promotion of the more intelligent conservation of the architectural riches of England, and manage a fund to be subscribed for the preservation of medieval buildings.' (6) The Society, after long deliberation, accepted the offer and the idea of a conservation fund, and drew up a paper announcing the existence and purpose of the fund. The society simultaneously condemned the practice of over-restoration on the basis that the character of ancient monuments was being destroyed. In the same paper a call was made for immediate protest in order to protect the monumental remains of the country. Many responses countered these sentiments, some coming from church members themselves, such as the following from the Revd Yates of Aylsham:

> 'That paper, I fear, is calculated to do much harm. I fear it throws an unjust and unwarranted stigma on many persons who have during the last 10-12 years been anxiously desirous of promoting the Glory of God and the spread of his Gospel by affording increased and improved accommodation in our Churches for our increasing population, particularly for the labouring classes.' (7)

In a statement made to the Royal Institute of British Architects (RIBA) on 2 March 1877, a new page of the long-running debate was opened up by J.J Stevenson (1832-1908), a Scottish architect trained in Scott's office, who criticised the way replacement work was often indefinably fused with the original. Denouncing Scott's recent replacement of a Perpendicular chapel at Chester for one in the Norman style, Stevenson stated that it 'did not add to value of the building as a historical record.' (8) Stevenson used the term 'faking', amongst many depreciative terms, but of particular significance was his remark that it was not only the medieval styles which were of importance but that later periods were also of significance, since they were often more in sympathy with monuments than current restoration work. Stevenson went so far as to quote William Morris, stating: 'when in doubt, do nothing'. (9) On learning of proposed radical restorations at Burford Church and Lichfield Cathedral, Morris had called a meeting to discuss opposition to the proposals, a meeting attended by Stevenson. Soon after, on 10 March 1877, in a letter to the *Athenaeum,* William Morris announced the founding of a new society, stating specifically the responses of a group of concerned individuals to recent proposals by Scott to restore Tewksbury Abbey, as well as their views of recent restorations and contemporary attitudes to antiquity, and the determination of the group to become a Society.

> 'Is it altogether too late to do something to save it - it and whatever else of beautiful or historical is still left us on the sites of the ancient buildings we were once so famous for? Would it not be of some use once for all, and with the least delay possible, to set foot an association for the purpose of watching over and protecting these relics, which, scanty as they are now become, are still wonderful treasures, all the more priceless in this age of the world, when the newly-invented study of living history is the chief joy of so many of our lives?' (10)

The sentiment implied in this statement was that no justification could be made for altering structural heritage, since such works belonged just as much to those who had originally constructed them as they did to the custodians of the present.

The Society for the Protection of Ancient Buildings

It is important to consider the Society for the Protection of Ancient Buildings (SPAB), not only because of its prodigious effect on the nature and thinking in relation to the repair and maintenance of ancient monuments in general, but also because of its specific importance in the procedure of maintenance of cathedrals. SPAB philosophy pervades the ethics of maintenance care of historic structures and is founded on common sense. It has to be reported, that its proponents sometimes reside at the extreme of discussions where active ways forward are sought.

Now written into the legislature as a national amenity group,[1] the views of the Society are taken most seriously by the Cathedral Fabric Commission for England (CFCE), who effectively monitor cathedral care through the Care of Cathedrals Measure 1990. (11) The views of SPAB need to be convincingly addressed before any action may be initiated in matters of conservation of important structures, or architectural works. This situation has been made evident in the current conservation of the Lincoln Romanesque Frieze (see 4.3 *The Lincoln Romanesque Frieze: A Case Study in Policy Shaped by Practice*).

The Founder: William Morris (1834 - 1896)

Having had the benefit of a comfortable early life, during which he was brought up in a large Palladian mansion in Epping Forest called Woodford Hall, it is not surprising that Morris was acutely sensitive to nature and various artistic responses to it. He was inspired at an early age by both visual and literary works, particularly the writings of Sir Walter Scott. By the time he was twenty, Morris could be found touring northern France and Belgium, studying Flemish works of art, as well as the surviving Gothic architectural structures in those areas. On leaving Oxford in 1856, having gained a degree, Morris, as an apprentice, entered the offices of G.E.Street, an architect who had also been apprenticed to Scott. It was there that he met Philip Webb, who would become a life-long acquaintance and fellow supporter of many causes. Morris was not long in leaving the architectural practice, convinced by Dante Gabriel Rossetti and Burne-Jones, with whom he had recently become acquainted, of the value of pursuing the life of a painter. Not long afterwards, however, in 1861, he set up the company of Morris, Marshall, Faulkner and Co., the aim of which was to manufacture artifacts both designed and made by craftsmen, in the medieval manner. This intention quickly revealed itself as doomed due to differences between medieval and Victorian society, with the labour-intensive and expensive commodities produced by the firm being available only to the wealthy, and therefore exclusive. Feeling his ideals compromised, Morris moved towards the Socialist party which he joined in 1883, describing himself as a 'practical socialist'. With these obvious social differences in mind, and the consequent relationship to design, production, and craftsmanship, Morris became increasingly convinced that the revival of the Gothic was founded on a false premise. 'Such an ordinary thing as a wall, ashlar or rubble, *cannot* at the present day be built in the same way as a medieval wall was.' (12) Ultimately persuaded by his company's own involvement in repairing the stained glass windows of churches, Morris began to condemn any hint of reinterpretation or pure restoration, feeling that all repair should be honest and therefore evident.

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[1] The Town and Country planning Act (1968) introduced a system, with specialist preservation amenity groups having a consultative role in proposed planning arrangements, a system later adapted to the Care of Cathedrals Meansure 1990.

The Manifesto

In writing the *Manifesto of the Society for the Protection of Ancient Buildings*, (13) Morris clearly opposed the notion of ancient buildings possessing a single identity in period and style. Rather, the building is represented by its entire history, including its maintenance record and any changes that may have been made along the way. Whereas the concept of care in the recent past had effectively attempted to 'strip from a building this, that, and the other part of its history - of its life that is - and then to stay the hand at some arbitrary point,' (14) Morris felt that the emphasis must now be placed on the relevance of the building's entire evolution. It was essential as far as Morris and his colleagues were concerned that monuments were handed to posterity as something of a 'living' record. This would be a summary of the performance of the structure and by implication the impact and influence of those caring for it through the centuries. Even those changes that 'were harsh and visible enough,' were also 'by their very contrast, interesting and instructive and could by no possibility mislead.' (15) The term 'forgery' was used in the Manifesto, in the context of wasted talented labour. This deliberately raised an ethical question regarding authenticity and the legitimacy of repair and replacement, at the same time referring to the nature of skills employed to carry out such work. As expressed in the Manifesto, intervention would always benefit by being evident and ought to 'show no pretence of other art.' (16) Maintenance is a key-word in the Manifesto, with the emphasis upon moderateness of intervention, a point emphasised by the by now famous phrase: 'to stave off decay by daily care'. (17)

Sustaining Influences of SPAB

The Society became known as the 'anti-scrape' society because of its active stance against many proposed restorations that intended to embody the malpractices employed over the past century and a half. Morris and other members of the Society, on arriving in person at some of the sites in question, were frequently greeted with open hostility. Rather than attempting to halt maintenance of any kind, it was the Society's intention to slow down the more radical of intentions, and persuade them to be more measured and carefully considered. The mere mention of the Society for the Protection of Ancient Buildings has sometimes been sufficient to suggest an argument for inaction, and even to promote the concept of 'graceful decay', but the original intentions of the Society were far from such a notion and were never intended to halt structural repair at any level. Rather, the Society was founded in order to ensure that 'suggested alterations are indeed necessary, and to see that these are seemly.'(18) The idea that a set of principles of repair could be dogmatically followed is most effectively denied in the words of A.R. Powys (1881-1936), Secretary of the Society between 1912 and 1936. In his book *The Repair of Ancient Buildings,* in the context of such suggestions, Powys explained:

> 'At the outset, however, it will be well to state that no fixed rule can be set up to be followed invariably. Each case must be considered on its merits ... It is also important that repairs to an old building should not be carried out hurriedly. Time should be allowed in which the effect of the repair of each section may be fully realised.' (19)

More than a century after the founding of this Society, and following the introduction of a new discipline into the arena of building care, namely architectural conservation, the words above may be quoted without fear of criticism. It is perhaps only in the dogmatic interpretation of the letter of the manifesto itself that reservations may reside, as with guidelines of any description. In the above mentioned publication, Powys was both fair to the building and to those attempting to care for it, and insisted on intelligence in those entrusted to carry out work. He referred to the need for a smooth continuity of work, without the halting circumstances of awaiting instruction, for instance from an architect working from a distance. At the same time, Powys insisted on establishing the correct instincts within the crafts, an enlightened attitude in which he recognises the high levels to which training should be provided. 'Until a single sane tradition takes the place of fancy conventions, repair work cannot be done well.' (20) Powys made comment on the latitude which should be given to the physical execution of work and the quality of supervision to be made available, as opposed to the slavish following of instructions. He concentrated also on the disparity of skills, and of the mistaken tendency to employ skills outside of their specialist area. As though striking a line under all his own advice, Powys observed: 'if an architect succeed it is because fortune gives him workmen who know their job.' (21) At a time such as today, when new legislation combines with stringent approval procedures, and conditional funding, such views as those held by Powys are refreshing in their recognition of the needs of the building and those caring for it. In the preface to his book Powys himself observed with some humility:

> 'The architect may be disappointed that the advice given is not more precise, and the layman may complain that it is too technical. If this is so I would remind the first of these critics that each case must be treated as a separate problem, that he can expect to find nothing in the text of this book which will completely apply to any actual case. The advice is intended to be helpful in suggesting a right treatment, and not as providing dogmatic instructions as to the only way to proceed; and if the layman learns from the following pages that the difficulties are greater and the alternative methods more in number than he had thought, and therefore comes to realise what an infinity of care must be exercised in arranging for, and carrying out, such works, my two objects will be fulfilled.' (22)

The underlying messages put forward by SPAB that have survived until now are articulated in Powys's practical advice, and are essentially three in number. Firstly, any proposed restoration of an ancient monument should be carefully considered at the planning stage, with exhaustive pre-survey and recording taking place. Secondly, any intervention should be to a minimum, and is preferably classed as maintenance care, with historic material being preserved wherever possible. Thirdly, any repairs or replacements will benefit by not attempting to deceive, but should be obvious and, indeed, 'seemly'. All three of these comments would find favour in ethical conservation today. A major omission, however, in the declarations of SPAB is the consideration of sculpture and other architectural artworks, of which no mention is made with regard to its protection or the overall maintenance of the concept of façades.

The Charters

A series of international conferences has been held throughout this century, the purpose of which has been to clarify operations in the care and conservation of historic monuments. Of these, three have been chiefly responsible for influencing the nature of conservation actions, with the production of three separate documents, or Charters. The first, the result of a conference held in *Athens* in 1931, was followed by the *Venice* Charter of 1964, with the *Burra* Charter of 1979, incorporating most of the salient points of the previous recommendations.

It is worth remembering that the Athens gathering of 1931 was by no means the first conference of its kind, others having been staged in Strasbourg in 1899, Lubeck the following year, Madrid in 1904, Paris in 1921, and so on. The Athens conference appears to have been something of a mixed blessing, on the one hand suggesting the local clearance of modest domestic dwellings to enhance the surrounding site of a monument, whilst dangerously condoning the use of modern materials such as concrete. Perhaps one of the main benefits of this gathering was that it provided a model for other conferences to build upon. The Athens meeting attempted to focus European thinking, at least, on the maintenance and repair of architectural monuments, stating seven main topics, or doctrines. Amongst these were the definitions of a) 'dead', and b) 'live' monuments, defined as a) 'those belonging to a past civilisation or serving obsolete purpose', and b) 'those which continue to serve the purpose for which they were originally intended.' (23) As far as the practical person charged with the care of monuments is concerned, it is difficult to see the relevance of these definitions. A positive move, however, was the decision to drop the term restoration in favour of conservation. Emphasis was placed on international cooperation, and particularly on educating the young to respect cultural heritage. Measures of control were also brought to the fore, so that mere private ownership was insufficient to justify neglect.

More than thirty years later, many of the ideas examined in Athens were expanded upon at the *International Congress of Architects and Technicians of Historic Monuments*, held in Venice in 1964. In the preamble to the ensuing Charter, reference is made to the Athens Charter of 1931 and its role in the development of an 'extensive international movement which has assumed concrete form in international documents.' (24) Recognition is given to the limitations of the Athens document, a factor that persuaded the Venice assembly to 'enlarge its scope in a new document.' (25) In so doing, the Venice Charter significantly outlined two major definitions. First of all, article 1 states:

> 'The concept of an historic monument embraces not only the single architectural work but also the urban or rural setting in which is found the evidence of a particular civilisation, a significant development or an historic event. This applies not only to great works of art but also to more modest works of the past which have acquired cultural significance with the passing of time.' (26)

In article 2 of the Venice Charter the conservation of any monument was recommended to be provided with access to all associated disciplines of research and application.

> 'The conservation and restoration of monuments must have recourse to all the sciences and techniques which can contribute to the study and safeguarding of the architectural heritage.' (27)

It is interesting to note that the term 'restoration' had itself been restored to use, following the resolve in the Athens Charter to drop it. The conditions provided in the Venice document, however, created a more valid context for the term, with article 2 opening up the working arena into a more multi-disciplined activity. Whereas the Athens Charter had condoned the principle of using modern materials such as concrete (it should be borne in mind, a plethora of radical engineering solutions had been carried out on cathedrals, in both England and abroad in the first decades of the twentieth century), the wording in article 2 strongly implies the importance of surrounding research and the support of this to the application of conservation. In this broader context, the term 'restoration' may find respectability, for example in the restoration of structural integrity, and never more so than where sculpture and decorative work are concerned. Significant in this respect is article 8, which refers to sculpture and decoration, references to which had hardly been made previously in any charter:

> 'Items of sculpture, painting or decoration which form an integral part of a monument may only be removed from it if this is the sole means of ensuring their preservation.'(28)

The subjects in this document are sub-divided into five headings: Conservation, Restoration, Historic Sites, Excavations, Publication. This lay-out may have appeared rather loose to the practitioner looking for guidance, but these headings are intended to provide an array of principles to be pushed and pulled around as the individual application may demand.

A more practically useful document, which extends upon both the Athens and the Venice charters, is the Charter produced from the 1979 Australia ICOMOS conference in Burra Burra, known as The Burra Charter. In this work, a considerable effort was made towards clarity and simplicity, and a useful definition of terms was included. The entire matter was set out beneath three major headings, as follows:

- Conservation Principles
- Conservation Processes
- Conservation Practice

All these subjects are described in the most economical language, with only twenty nine articles in total. Moreover, three sets of corresponding guidelines are included to cover the issues, and provide a strategy for implementation. The format suggested by the Charter begins with a

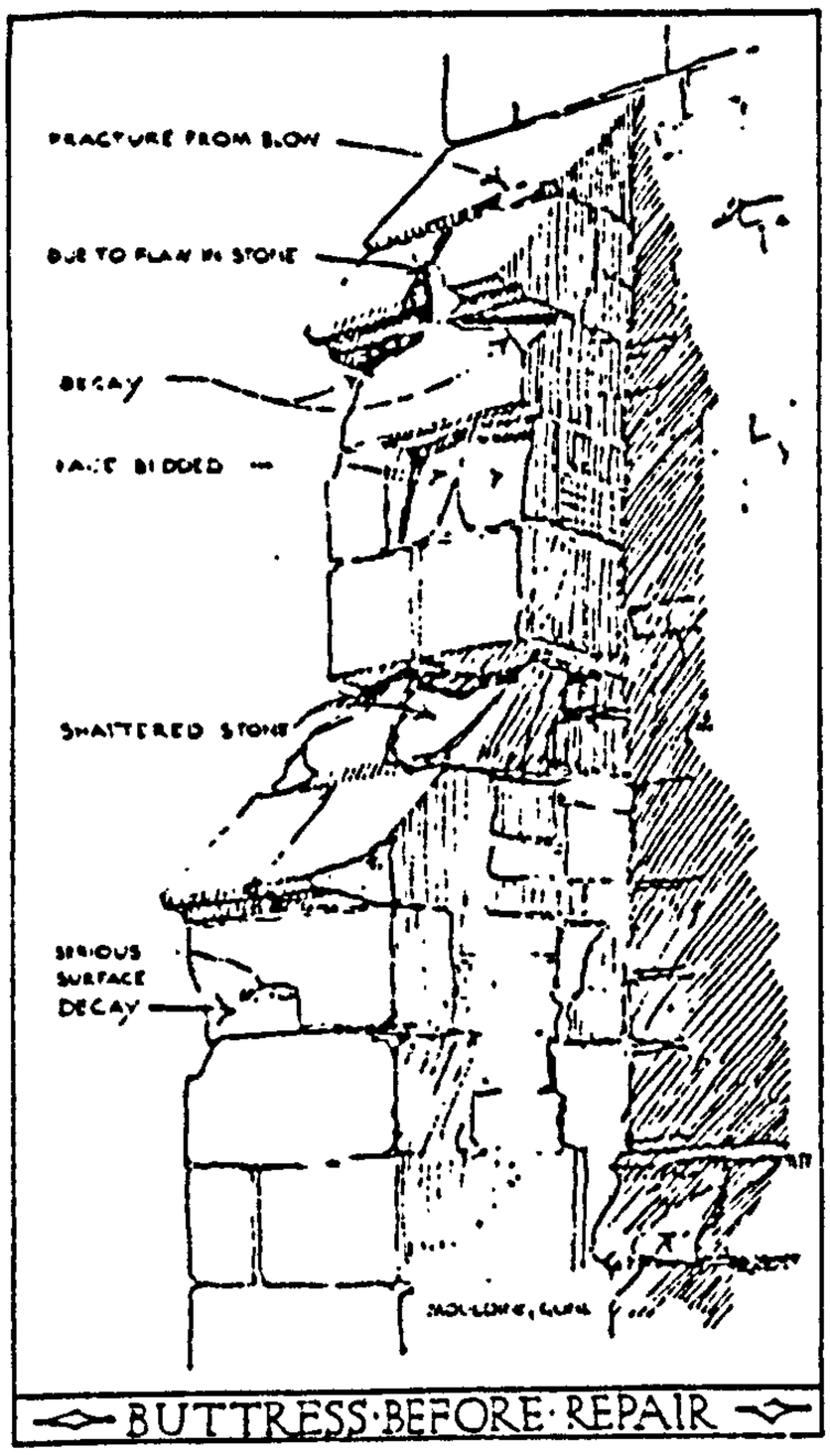
statement of Cultural Significance, providing a context for the principles and practices to follow. The guideline is helpful in establishing such a convention, which is helpful in all cases, but perhaps especially so in the case of sculpture or architecturally decorative works. The Burra Charter is a balanced document, employing language that is at once clear and accessible, refusing to become ensnared in jargon, and is far-reaching in its capacity for interpretation.

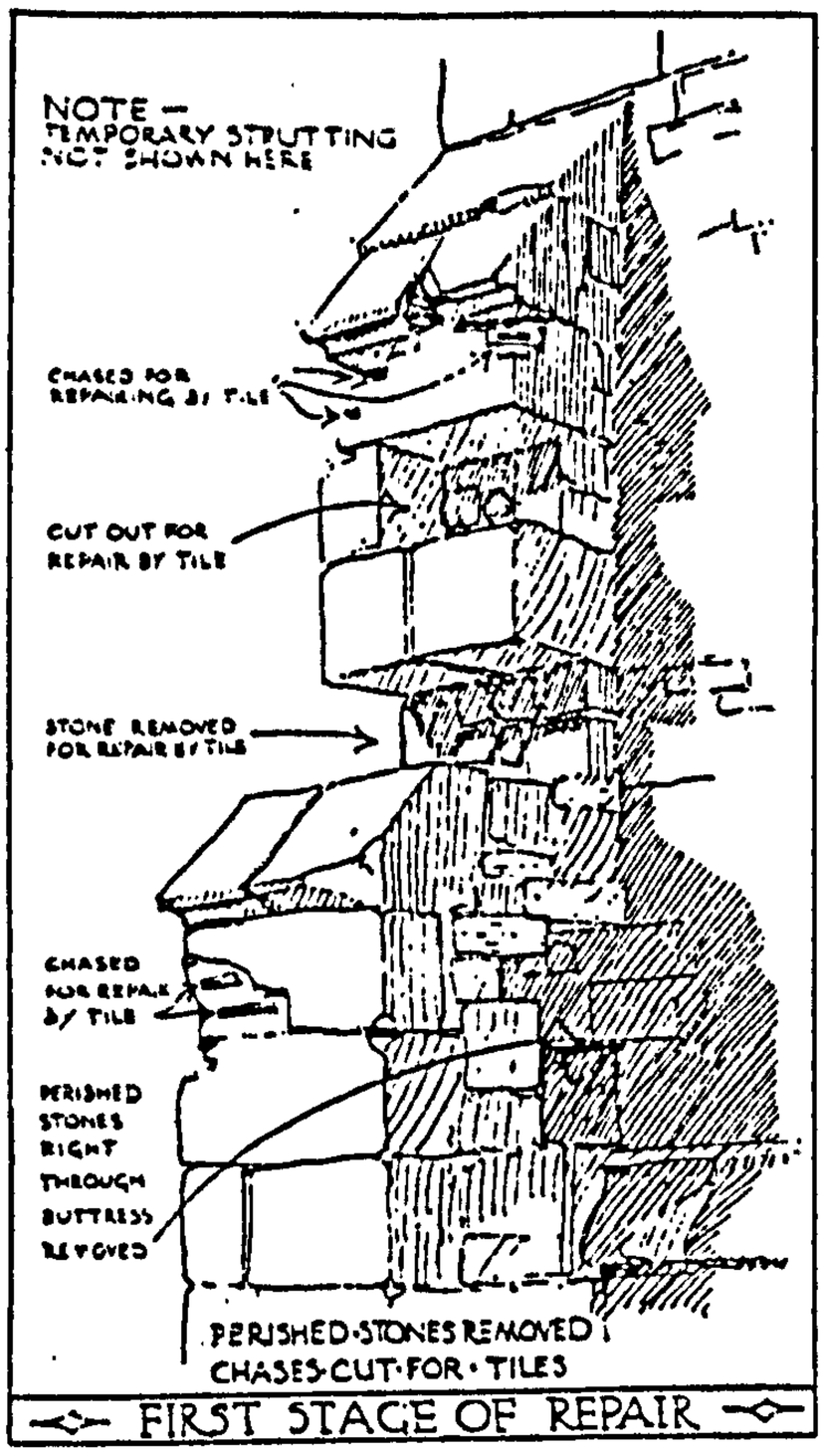
Conclusions

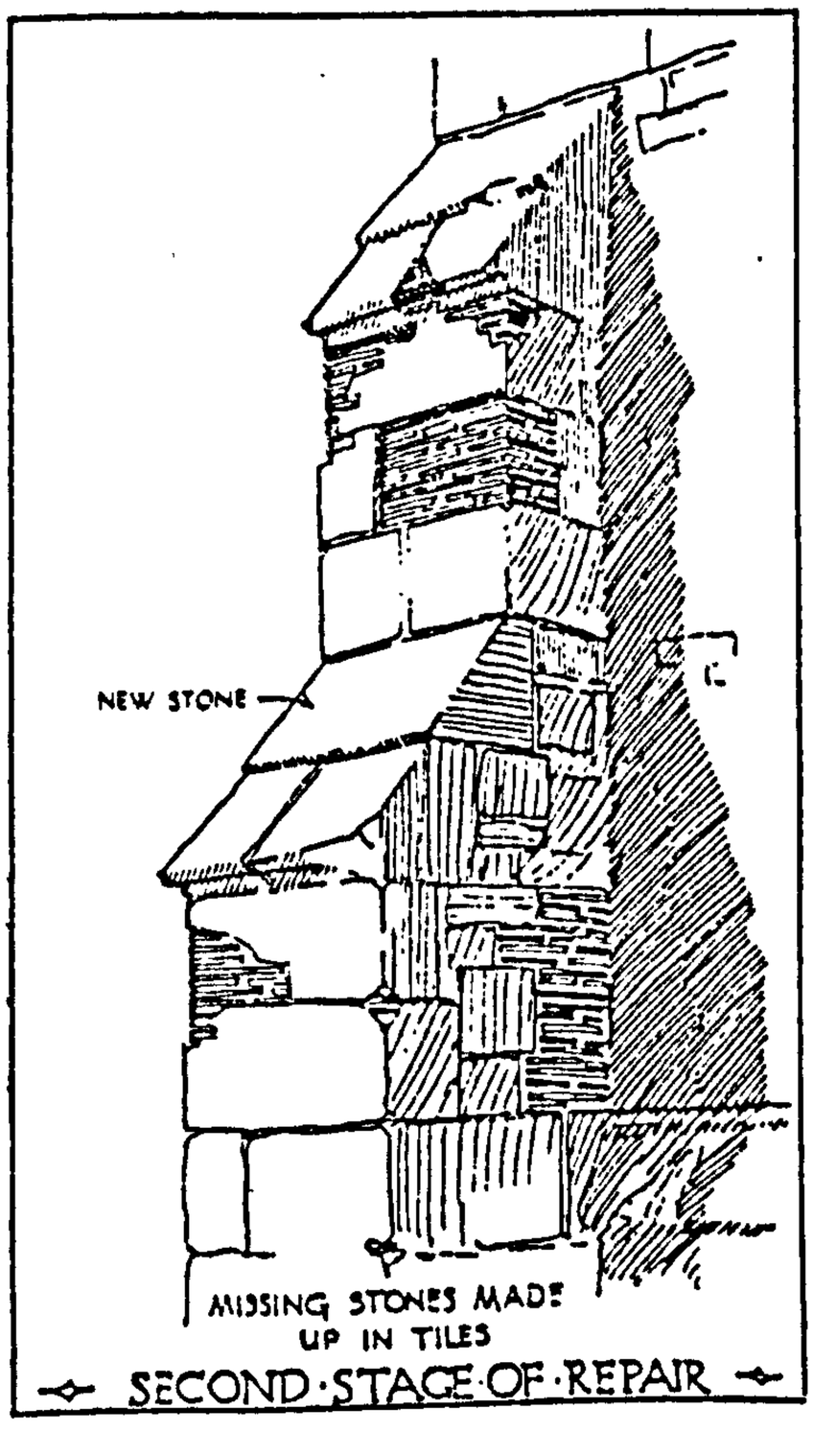
The history of conferences and charters dedicated to the maintenance, preservation, and conservation care of heritage monuments is a journey from abuse and confusion towards simplicity. Much may be found in the precepts of The Burra Charter (1979) that was propounded by Morris and the co-founders of SPAB, although the language has been made more comprehensible. At the same time, there have been constant problems of interpretation along the way. It is now accepted that English is the *Lingua Franca*, but many charters were written in other languages, for example the Venice Charter (1964) was written in French, and others were written in Italian and German. Technical terminology is often difficult to relate in another language and is confusing even in translation. Some of the difficulties in commonality of meaning were highlighted in the editorial introduction to the ICOMOS conference held in Bologna in 1986.

> 'One of the more simple problems is that English, roughly speaking, originates from three languages with separate words for slight variations in meaning, which do not exist in the Romance languages. Thus 'umidita' in Italian could be 'humidity' in English, but English has also 'dampness' and 'moisture', so we have the humidity of the air, the moisture-content of wood and the dampness of walls. Almost every European paper submitted used an equivalent of the word 'intervention' which has to be substituted according to context by around eight different English words. In English, 'intervention' generally means or implies interference. In Western European languages it can mean a range of activities from attending a meeting to carrying out a major work of restoration.' (29)

The Burra Charter has attempted to cut through this confusion, with the successful use of clear terms of reference, although the use of guidelines in general has its limitations and this needs to be recognised. Where guidelines become strict rules of thumb, the results may do less than credit to the effort. In Powys's work, guidelines are accompanied by examples and the effect is to broaden the reader's understanding of the typical problems at hand (Fig 4.1). In the case of the SPAB manifesto, its messages can often be heard being quoted line for line as instructions to be followed, with a consequent departure from good practice and reason.







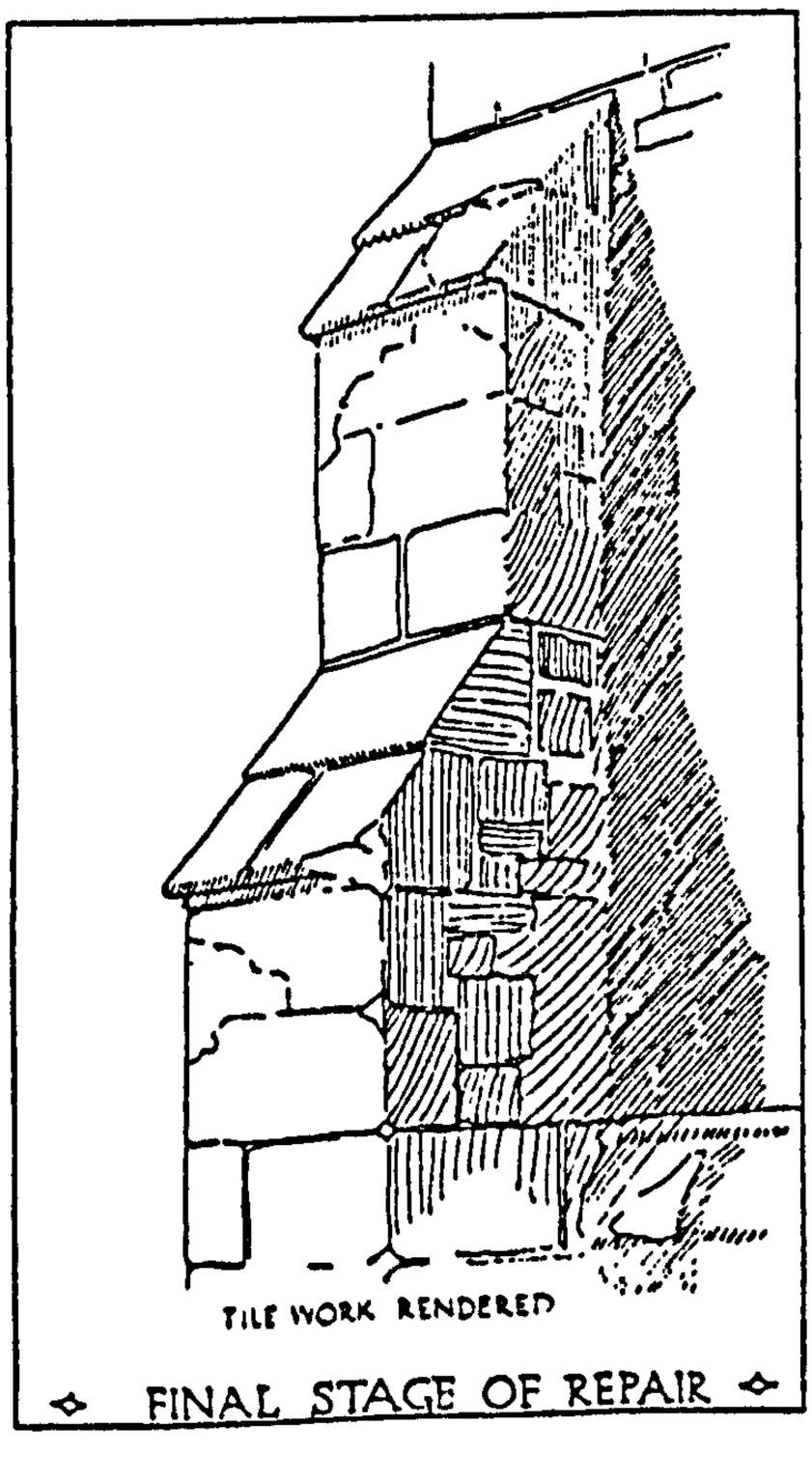


Fig 4.1 SPAB examples of 'honest' repair (POWYS, A.R. *Repair of Ancient Buildings*, London, Dent & Sons, 1929)

4.2 New Systems of Critical Dialogue at Lincoln

Due to pressing needs in relation to the rapidly deteriorating condition of the Romanesque Frieze, the Dean and Chapter of Lincoln were compelled to make a considerable effort in order to accommodate the most up-to-date views in caring for the Cathedral. During the last three decades, the result has been a change in the planning, processing, and implementation of work of general maintenance. This has seen the introduction of the new workshop discipline of practical conservation at Lincoln, and major modifications of the traditional trades. The Dean and Chapter of Lincoln were the first cathedral in England to anticipate forthcoming legislation in cathedral care, at the same time embodying some of the likely recommendations in their own system of approaching the work. These actions took into consideration contemporary moves and developments in the practical conservation of historic architecture, at the same time recognising the new profile of above-ground archaeology, which was to form a part of the overall conservation strategy. Within the emerging discipline of practical conservation was an awareness of the history of ethical discourse that had occurred during the preceding century and a half, and this was assimilated into planning procedure at Lincoln. Developments over the past twenty-five years have irrevocably altered the main thrust of maintenance care of historic monuments, even from the description of maintenance work being converted from restoration, with its connotation of active intervention, to the more passive term of conservation.

In the 1970s Professor George Zarnecki visited Lincoln to view the Romanesque Frieze for the purpose of revising an earlier publication. (30) He immediately observed that its condition had dramatically worsened. This led to the commissioning of a specialist condition inspection of the Frieze and other major external sculptures from John Larson, then senior sculpture conservator at the Victoria and Albert Museum. An initial survey of external sculpture and carving was organised in 1977 through the office of Peter Burman, secretary of the Cathedrals Advisory Committee (CAC) at that time. Access to the Frieze was gained by means of hydraulic hoist, or 'cherry picker', and it was immediately clear from earlier photographs that more recent losses had been incurred. It was felt that deterioration was perhaps due in part to crude cleaning work carried out in 1961. During a conversation with a recently deceased Cathedral handyman, Don Mann, it was reported that high-powered water sprays and stiff brushes had been used. Some loss to the sculptures at this time are supported by contemporary reports. (31) Severe fissuring could be seen from the platform, with clear signs of imminent danger to areas of the sculptures. Larson observed that 'the most obvious signs of breakdown from acid pollutants are to be seen in the blistering and exfoliation on the more exposed parts of the sculpture.' (32) On receipt of this survey, Burman agreed that the most urgent measure was 'protection, as recommended', in order to keep them dry. A 'wait and see policy' (33) was established, but only the Judgement Porch sculptures were 'boxed-in', as recommended.

A Consultation on the Statuary and Sculpture (1983)

More than five years later, as the Cathedral Fabric Fund Appeal became 'more sure-footed,' (34) the Dean and Chapter felt that circumstances had become more conducive to expanding their policy. However, the question remained how best to go about this? The Cathedral architects of the day, Messrs Maguire and Murray, wrote perceptively:

> 'Different policies have been adopted by those responsible for medieval buildings, sometimes because of the particular circumstances of the buildings, sometimes because of different approaches to the care and conservation of buildings and works of art. These different approaches are often the result of the different disciplines and interests of those responsible for buildings and works of art connected with them.' (35)

Although recognising that there could be no fixed system of resolving such problems, it was clear that some form of independent reference towards approaching conservation issues was required. Adopting a process used in other matters, the Dean and Chapter decided to host a meeting to consult with others associated with the same work. A letter of invitation was written by Dean Fiennes for the conference to be held on 2-4 October 1983, in which he stated that the main objective of the consultation was to help 'in developing a conservation policy for the sculpture and decorative carving' (36) Areas of particular concern were the entire West Front, including the Romanesque Frieze; the Angel Choir, the Judgement Porch, and the Cloister ceiling bosses. A cross-section of independently minded and authoritative people from different disciplines were invited to Lincoln to talk through relevant issues (Appendix D *A Consultation on the Statuary and Sculpture (1983)* - List of Participants).

The Agenda

Comprehensive introductory notes were prepared by Sir Bernard Feilden, who in turn had consulted with Martin Caroe, architect for the West Front of Wells Cathedral. This document acted as both a springboard and agenda for initial discussion. A definition was provided and, in the broadest terms, an understanding of what conservation would entail, along with what could be described as an ethical check-list, with statements made such as the following:

> 'Any intervention must be governed by unswerving respect for the historical and physical integrity of cultural property and not be carried out by persons who are insufficiently trained or experienced.' (37)

An assessment of the complete range of values was recommended, ie. historical, emotional, functional, spiritual etc. In addition, he called for an understanding to be gained of all materials concerned, as well as for data to be gathered on the local environment and patterns of change. A list of intervention priorities was then suggested in ascending degrees, ranging from control of the environment to the need for full reconstruction, in the event of disaster. Finally, a list of seven abstract considerations was outlined by Martin Caroe, and worth stating for reference: Urgency, Strategy, Ethics, Techniques, Flexibility, Experience, Organisation.

The Debate

A great deal of ground was covered during the debate, focussing on four fundamental solutions. Firstly, the sculptures could be left to weather and age naturally, acknowledging the archaeological integrity of the building. Secondly, the carvings could be subjected to chemical treatment in their present context. Thirdly, they could be removed to a museum to be treated and monitored in a controlled environment, with either empty voids being left in place, or restored copies or replicas made to replace them. Finally, it was possible that a mixture of these options could be used, as each sculpture presented its own peculiar symptoms of distress.

Much passion was released in response to suggestions of the removal of sculpture from the fabric, either temporarily for treatment, or more permanently to a museum. The opinion of the public was mentioned several times, attempting to influence a move away from such action. The SPAB delegate reacted very strongly against removal on the basis that deterioration could occur as quickly in a museum as on the fabric and total loss was not a threat if left on the building 'because the *lime method* is a proven alternative.' [1] (38) There was a tendency for the art historians to favour the option of safe removal of sculptures to a museum for treatment, so that the finer details of sculpture would be preserved for study. This, it was stressed, should be determined by the importance of the sculpture and 'the degree to which deterioration can be halted more effectively' (39) by moving it indoors. A statement balancing the question of *in situ* conservation and removal was crystallised by Burman in a letter responding to the conference. 'In my view, the broad strategy should be to conserve all the external sculpture *in situ*, as far as may be, and I suggest here as a general principle that no sculpture should be removed unless the safety of the sculpture itself or the safety of the public is at risk.' (40)

Consultation and Implementation

Valuable points were made concentrating on techniques of recording. Warwick Rodwell presented the kind of techniques employed at sites that included Wells, Exeter, and Lincoln, and a comprehensive photogrammetric survey was recommended, and eventually an archive facility. In the event of sculpture being removed from the fabric, the nature of storage was raised. Regarding treatment, what became known as the 'great lime v. silane' debate ensued, with promotion coming from respective proponents, though with few conclusions drawn (see Appendices E *The Lime Method*, and F *Silane Consolidants*). Caroe was familiar with the lime method, and advocated it as well as the employment of silanes, having supervised use of both approaches on the west front of Wells Cathedral. Others were wary of any long-term consequences. If sculptures were removed, what would replace them? The suggestion was put forward that only cast copies would provide

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[1] This claim has never been made by exponents of the lime method, who maintain that it is a series of treatments during which meticulous care and attention is administered to the sculpture being addressed, including cleaning and minimal repair, resulting in effectively slowing down deterioration, rather than halting it permanently.

sufficient integrity, but a contrary suggestion was made that traditional skills should be employed to make a 'free copy.' Burman, drawing a line under speculative debate, declared that:

> 'A broad strategy should be evolved for the eventual conservation of all the external sculpture on the cathedral; it should be regarded as having considerable priority over most other projects,' (41)

In the first instance, he recommended that a practical pilot scheme could be initiated and the statues of Edward and Eleanor on the south-east corner buttress might prove most suitable. As a holding operation, the Frieze panels and other carvings were urged to be boxed-in, similar to the Judgement Porch figures, to protect them from harmful elements

Edward and Eleanor: A Conservation Pilot Scheme (1986)

This was to be the first project carried out on the Cathedral fabric using formal applied techniques of conservation. As in-house skills at Lincoln did not include a trained conservator at the time, the work was contracted out to the Wells Cathedral Conservation Centre, comprising most of the team that had not long completed work on Wells Cathedral west front. Having recently started to operate commercially, the Wells team offered as their specialised treatment the lime method which had seemed to be so successful at Wells, and it was from that range of lime treatments that it was hoped this area of stonework would benefit. The use of deep penetrating consolidants was fairly abruptly ruled out following the recommendation of a case for the lime method by Burman:

> 'the use of chemical consolidants, even in ideal circumstances, gives rise to hesitations all over the world on account of the fact that we simply do not know their long-term effects in real circumstances. In the lime-based methods we have an approach which is essentially pragmatic, but the effects of which can be seen objectively at Wells, Exeter, Crowland, Iffley and Bath.'(42)

As part of the contract arrangement a member of the Lincoln Cathedral staff, a stone mason who had also trained in sculpture,[1] was to work with the Wells Conservator Roger Harris, so that long-term benefits would be gained, perhaps providing the basis of a future conservation team at Lincoln. An initial visual inspection of the surrounding stonework helped to assess the circumstances for treatment, with the structural condition of the statues studied at the same time. Similar methods of recording as had been applied at Wells were to be made before, during, and following all work. All materials employed in the treatment were carefully considered in relation to the local stone and its known patterns of weathering.

The two figures were cleaned using micro air-abrasive employing 17 micron alluminium oxide abrasive at approximately 15 psi. (see 5.3 *Cleaning*) Following cleaning and continual meticulous recording of the sculptures, it soon became clear during the intitial stages of treatment that clear

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[1] The author of this study worked with Roger Harris on the conservation of Edward and Eleanor, later completing some of the surrounding work on the buttress, including cleaning of ashlar and working of replacement stones for decayed masonry.

differences between the Doulting stone from which Wells Cathedral was built and the compact limestone of Lincoln would make a straight application of the lime method impossible. The pore structure of Lincoln stone (see 2.2 *Pore Structure and Moisture Content*) was so fine that it prohibited the essential action of some of the lime treatment, e.g. the absorption of limewater into its structure. Many fractures were repaired, using conventional methods of stone repair[1] and the figures were structurally stabilised. Extensive lime mortar repairs were made where the stone had blistered or fractured, along with localised shelter coat applications. Both these treatments were part of the lime method. The benefit gained by the sculptures was from a combination of conventional repair, modern cleaning methods, selected parts of the lime method and general care, such as the clearing away of pigeon detritus (Fig 4.2).

Significant benefits were made to the works team, which was for the first time persuaded to acknowledge the necessity of recording and report writing. It was resolved that such treatments to which the carvings had now been subjected were not a once and for all event; the concept of after-care was introduced, with monitoring an inherent factor in the continuing care of precious items of statuary and sculpture. The presence of a skilled conservator, who was as familiar with the care of stonework as other tradesmen, but had a somewhat different approach, was new to masons and the other traditional trades, and presented fresh ideas for consideration. The notion that research might be necessary in order to establish more fully the treatment history of the sculpture was a new consideration, helping to formulate proposals of treatment which would be better evaluated. Perhaps of greater significance was the acknowledgement of the validity of another level of understanding in the work and recognition of its potential value as a part of the team. Having had a conservator working for the first time alongside the traditional trades for half a year, a realisation had emerged that this contribution could form another facet in the overall care for the buildng.[2]

Extending the Scope of the Debate

In 1982 Richard Gem of the CAC had called for a specific study of the Romanesque Frieze. A highly regarded former student of Zarnecki's named Deborah Kahn, who had studied the Romanesque sculpture at Canterbury Cathedral, was commissioned to carry out a visual survey.

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[1] Those methods referred to as conventional stone repairs are well known in the masonry trade, and employ polyester resins with non-ferrous dowels and cramps. The King figure was not fixed to the main fabric other than by gravity, and could be felt rocking to and fro with the slightest push against the chest with a finger. A phosphor bronze fixing secured the figure firmly to the wall.

[2] On revisiting the sculptures in April 1997, as was always intended, it was interesting to note that several of the mortar repairs had broken down, although the friable Lincoln limestone immediately adjacent to the repair was in precisely the same condition as in 1986, with no further deterioration over the ten year time span. A lime mortar shelter coat, judiciously applied to local areas of the figures, had weathered away in places and needed to be reapplied. Again, this showed the efficacy of the method, since the coating, like the mortar repairs, was intended to be sacrificial, thus safe-guarding the sculpture itself.

Fig 4.2 The statues of Edward and Eleanor on the South East corner buttress.

This record, made in June 1984, revealed previously unseen areas of fissuring. The survey was not always entirely accurate in distinguishing fracture from joint, but this can be blamed on the rapid discoloration of the panels and the masking effect of a fresh pollution layer. Dr Kahn explained:

> 'That the state of the sculpture has been dangerous for many years is demonstrated by the set of photographs taken in the 1960s to accompany Professor Zarnecki's cathedral pamphlet on the Romanesque sculpture. If, however, we compare the condition of the sculptures in the 1960s with that at present, their rapid deterioration is abundantly clear. (43)

Kahn's survey further emphasised the poor physical condition of the panels and the need for an acceptable way forward (see 4.3 *The Lincoln Romanesque Frieze: A Case Study in Policy Shaped by Practice*).

A Response to Concerns of General Synod (1984)

At around the same time, Chapter was seriously studying a current report, researched and issued through the Faculty Jurisdiction Committee, a body operating under the auspices of the CAC for Synod. This was to lead to several recommendations which would seriously and qualitatively affect consideration of the condition of the fabric and furnishings, helping towards the implementation of a conservation policy.

In July 1984 the General Synod of the Church of England approved a document entitled *The Continuing Care of Churches and Cathedrals* (44), submitted by the Faculty Jurisdiction Committee. The report examined the existing legal and administrative systems of caring for the Church's historic buildings and contents, making substantial comments on improvement, with a view to legislation. In Chapter VIII of the document, specific recommendations were made to those Deans and Chapters operating under statutes made by authority of the Crown, under the provisions of the Cathedral Measure of 1963. The principles of such counsel were immediately acceptable to the Dean and Chapter of Lincoln, the operative proposals being to establish three inter-related committees to secure efficient avenues of care for the fabric:

> 'The first is a Fabric Committee which more or less responds to the Commission's Report. The second is to set up a joint Masters' Committee which meets a long standing expectation of the Dean and which met, formally, for the first time on 10 January 1985 and will now meet fortnightly. The third is to invite a re-shaping of the Fabric Fund Appeal Committee, which was accepted by that Committee at its meeting on 22 November 1984.' (45)

The Cathedral constitution would require a by-law to accommodate such changes, and this was introduced in 1985, drafted by Canon Rex Davis, effectively revising part of the Statutes. These are referred to as they are affected.

The Care of the Fabric By-Law (1985)

A brief introductory statement to the By-Law states the right of Chapter to include such amendments as those recommended by the Fabric Jurisdiction Commission. 'A By-Law was made by the Dean and Chapter of Lincoln under Statute XXVIII of its Constitution and Statutes to make provision for the better exercise of its rights and duties under Statute III 2 (i), 2 (iii), 6 (3), Statute VIII 2, Statute XXII, XXIII and XXIV.' (46) The by-law took effect from 1 April 1985 and was to be reviewed every five years, with such ammendments made by Chapter to be first considered and advised upon by the Fabric Council and the Preservation Council.

Masters' Committee

Under Statute XXII, it was stated that there should be two Masters of the Fabric, whose duty was to supervise the Clerk of Works in the maintenance of the fabric of the Cathedral Church. These offices are held by the Dean and the Subdean, who are charged with keeping the fabric in substantial repair, as well as all approaches to it. The By-Law allows support to be received in the form of a group to be known as the Masters' Committee. It was to be the responsibility of this committee to implement policy as determined by the Fabric Council and agreed by Chapter. The Committee would normally be chaired by the Subdean, or the Dean in his absence, who held specific authority for the maintenance of estates, buildings and property belonging to the Dean and Chapter, including the fabric of the Cathedral. Apart from membership being held by the Masters, the Clerk of Works would act as Secretary, other members being the Architect, a person appointed by the Executive Committee of the Preservation Council, and a member of the Fabric Council. Both of these bodies were to be established and would be appraised of the decisions of the Masters' Committee in a summary of the minutes.

Fabric Council

Assistance was to be extended to Chapter in their pursuit of the care of the fabric of the Cathedral in the form of a Fabric Council. This would be a policy-making body, which would advise Chapter:

> 'upon any proposals which it deems to be a significant work or works to preserve, alter or add to the Cathedral building or its contents which would materially affect the architectural, artistic, historical or archaeological character of the Cathedral and which should be referred for advice to the Cathedrals Advisory Commission.' (47)

Membership should comprise of the Masters of the Fabric, the appointed Architect, the Consultant Archaeologist, and between one and four others appointed by Chapter, one of whom should be a member of the Executive Committee of the Preservation Council. A member of Greater Chapter, though not the Administrative Chapter, should also be appointed. Additional to these, should be three persons nominated by CAC, agreeable to Chapter, chosen for their specialist knowledge of historic building care and for their ability to identify themselves with the Cathedral.[1]

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[1] The inaugural meeting of the Lincoln Fabric Council was held on 3 June 1985, in the form set down by the Care of the Fabric By-Law 1985. The Council consisted of twelve members and the

Preservation Council

Although there had by ancient custom been a fabric fund, a sum of money invested or held in accounts exclusively for the purpose of caring for the fabric of the Cathedral, the By-Law stated that there would now be constituted a system of funds and bodies to maintain a regular and continuing appeal for support for the preservation and maintenance of Lincoln Cathedral. Another committee would take responsibility for these activities, principally to raise funds, to be known as the Lincoln Cathedral Preservation Council. There was to be a chairman and a vice-chairman of the Committee, to be elected annually, neither to hold office for longer than three years. Other members would include the High Steward of Lincoln, who with the Treasurer would be ex-officio, the Masters of the Fabric, four members appointed by Chapter and four appointed by the High Steward and a representative member of the Friends of Lincoln Cathedral.

It would now be possible for the Preservation Council to set up a permanent fund-raising staff, working from its own offices, with all costs paid from the Fabric Fund. An appeal fund could be specifically shaped to suit such work that was necessary to the fabric, with records and investment supervised by the Executive Committee. This committee would hold responsibility for:

> 'disbursing funds for the maintenance of Lincoln Cathedral in accordance with the budget presented by the Masters' Committee and agreed by the Executive Committee and adopted by the Chapter.' (48)

From this point onwards, it would be the responsibility of the Committee to inform the public of current work and of sigificant future projects.

A Note on Finance

Until formal dedication of a fund-raising mechanism, the identification of finance solely for maintenance had relied to an extent on crisis appeals. Cathedral finances mainly consisted of the Capitular Revenues, referred to in Statute XXVI as comprising

> 'all payments accruing to the Dean and Chapter from whatsoever source except such benefactions, offerings and donations as are made or given for any special purpose other than a purpose on which the Capitular Revenues may be expended.' (49)

The Fabric Fund, it can be clearly seen, would provide a vital link towards the confirmation of a conservation policy.

Management of the Work

As well as defining the roles of the Masters of the Fabric, in order to fully understand the major routes relating to the execution of work to the fabric, two further offices may be helpful to mention

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Masters of the Fabric, the Dean and Subdean.This event was attended by Peter Burman, as invited member of the Cathedrals Advisory Committee, who congratulated Chapter on being the first cathedral in the country to form such a committee.

at this stage, those of the Clerk of the Works, and the Architect. (Statute XXIII and XXXIV) Specific duties are allocated to these offices, which in the case of the Clerk of Works is to:

> 'superintend the maintenance of the fabric of the Cathedral Church in proper repair and the execution of works recommended by the Architect and ordered by the Chapter.' (50)

The Clerk of Works is charged with ensuring to pay the workmen their weekly wages and it is incumbent upon him to report regularly to the Masters of the Fabric with a 'report of the work done and the workmen employed.' (51) He should 'make provision for any necessary work of a special character that may be required', (52) as well as making an adequate examination of all costs incurred during work.

No work may be carried out to the Cathedral fabric except under the superintendence of a competent architect. His duties include reporting to the Chapter from time to time:

> 'upon the state of the fabric of the Cathedral Church and of the buildings connected therewith and upon the repairs which in his judgement are necessary, to examine the work done and to certify if it is done in a satisfactory manner.' (53)

At Lincoln these roles operate differently from many other cathedrals, and at times this has created some confusion (see 3.4 *Enduring Influences on the Culture of Care at Lincoln*.).

The Care of Cathedrals Measure 1990

Buildings continually in use for ecclesiastical purposes have been exempt from scheduling under the Ancient Monuments and Archaeological Areas Act 1979. Care of cathedrals has been carried out under the discretion of provosts, deans and chapters. Concern was felt regarding the 'thoroughness' of some cathedral repair programmes, as expressed by the then CAC and, in accord with the recommendations made in the *The Continuing Care of Churches and Cathedrals* submitted by the Faculty Jurisdiction Committee in 1984, a Measure was subsequently formulated, a final draft presented in 1990. The *Care of Cathedrals Measure 1990* was duly introduced on 1 March 1991.

Establishing a context within which it should be viewed, the measure sets out the primary purpose of cathedrals as 'the seat of the bishop and a centre of worship and mission'. (54) The main intention of the measure was to establish a formal method of regulating work to the fabric of the cathedral church and its immediate environs, with constraints imposed with regard to approvals and the establishment of archival records. A statement is given in the measure that approval would henceforth be required for any alterations to the character of the fabric of the cathedral, or to the immediate setting and surrounds. This included any matters relating to the architectural, archaeological, artistic or historic nature of the immediate setting or of any remains that may exist within it. Any sale or loan of significant objects would require approval also, as well as the intention

to add to the structure in a material sense. Two systems of control were to be set in place, which would function in tandem: the first was the establishment of a Cathedral Fabric Commission for England (CFCE), to be formed from the CAC, and the second was the establishment of a Fabric Advisory Committee (FAC).[1]

The CFCE (referred to in the Measure as the Commission) had its duties set out in five main areas. These were to advise the administrative body of cathedrals in respect of the care, conservation, repair, and development of the cathedral and buildings as follows:

- To advise on care, conservation, repair, and development of the cathedral.
- To consider and determine any application made in accordance with the Measure.
- To promote cooperation between the Commission and other bodies concerned with the care and study of such areas of cathedrals as described above.
- To assist administrative bodies of cathedrals to participate in educational projects that might in their view promote care of cathedrals.
- To maintain together with the Council for the Care of Churches (CCC), a library of books, drawings, and photographs etc. relating to the cathedral and the objects within it.

In this respect, the Commission would require to be informed or directly involved in discussions and decisions relating to works of a fundamental nature, where the fabric might be permanently or seriously affected. More routine maintenance issues would be dealt with by the Fabric Advisory Committee, whose membership would be partly made up of CFCE nominated members. As such, this would reduce the burden of the Commission, although records of the minutes of FACs would ensure that they were informed of all intentions. Even in the case of these somewhat lesser issues, however, the Commission would be available for advice. The importance of a relevant membership of each cathedral FAC is implicit in the Measure, so that a correct level of responsibility would be felt by the FAC and the Commission. The FAC should maintain a balance of representatives in the disciplines of art history, archaeology, and conservation, with equal numbers of nominees from the cathedral and the CFCE, with deans and chapters not themselves being members. The duties of the FAC can be briefly described as follows:

- To advise the administrative body of the cathedral on the care, conservation, repair, and development of the cathedral.
- To consider and determine applications made in accordance with the Measure by the cathedral.

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[1] The Lincoln Fabric Council, anticipating the Measure, was formed in 1985 and as such was allowed to retain its original title, rather than requiring to be called a Fabric Advisory Committee. In this text it will be referred to as the FC in reference to the Lincoln committee and FAC in the general context.

Meetings of the FAC were to be no less than twice a year, with recognition given of the attendant costs. Definitions of what project proposals might or might not be a matter for either body would be a matter for the FAC and the CFCE to decide.

Brief Observations on Practical Issues Relating to the Measure

The intention and effect of the Measure is to slow down all decision-making processes in the care and maintenance of cathedral fabrics, so that they accommodate a broad and specialist view, thus preventing hasty and unacceptable restorations, the destruction of archaeological sites, or the sale of significant objects. In the approval of such matters, conservation, repair, or development, the Commission may call upon the experience of two separate bodies for advice. The SPAB is written into the legislation as a 'national amenity society.' [1] In addition the CFCE use English Heritage (EH) as their advisor on matters specifically relating to technical conservation detail. The Measure insists upon a regular survey being carried out every five years by the appointed architect, thus ensuring the likelihood of long-term thinking in respect of maintenance. It also spot-lights the more mundane elements of caring for the fabric, which are often the most important issues and dissuades maintenance by crisis. Major strengths installed within the structure of the Measure are the significant accountability brought to cathedral authorities, its insistence on continuous survey, and reports of the structure, and that it has installed within it a mechanism for continual refinement by the process and desire for discussion.

4.3 The Lincoln Romanesque Frieze: A Case Study in Policy Shaped by Practice

The following case study will outline the complexities of the debate which surrounded proposals to carry out practical conservation to the Lincoln Romanesque Frieze. A further international conference was held in order to discuss the proposed work to the Frieze, an explanation of which highlights the range of views and the general disarray that the world of conservation was in. Many prejudices and misconceptions had to be overcome in order that work to the Frieze could commence, any consent relying on clarity of intent. Several attempts were made to formulate an open policy in order to accommodate the broadest of opinions and anxieties, but this tended to create more confusion and suspicion than it helped to alleviate. This description of events does not always proceed chronologically, but in a way that best explains the influences that opinion had on the work. This point is underwritten by the case that it was practice that paved the way forward, a factor that ultimately places great emphasis on the ethical and practical responsibility of the practical conservator. Questions also emerge regarding approvals and the dispensation of grant-funding, and the subsequent effect on the sculpture or building, and best practice and development in the discipline of conservation.

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[1] The 'national amenity societies' are: the Ancient Monuments Society, the Council for British Archaeology, the Victorian Society, the Society for the Protection of Ancient Buildings, and any other body as may from time to time be designated by the Dean of the Arches and Auditor as an advisory body for the Measure. *The Care of Cathedrals Measure 1990*, Section 16, no. 2.

A Description of the Frieze

Since 1963 the opinion of Professor George Zarnecki has commanded support in attributing the sculptures to Bishop Alexander (1123-55). A major restoration to the west front was accompanied by the rebuilding of most of the Cathedral following its virtual destruction by fire around 1141. Alexander, a prodigious builder and a much travelled and cultivated man, was known to have been in Rome in 1144, and must have at least been aware of Wiligelmo's frieze cycle at Modena, which bears iconographic resemblances to the Lincoln frieze. In his elaboration of Remigius's austere design, Alexander enriched the three main doorways, extended the height of the gable, and inserted the frieze beneath the existing string course.[1]

The surviving carved reliefs stretch across the original Norman west front of Lincoln Cathedral, touching both vertical joints where the thirteenth century building surrounds it. From the central portal to the south of the façade, returning with the eleventh century wall into the Ringers Chapel, eleven of the nineteen original panels[2] illustrate scenes from the Old Testament, and are intended to be read in that direction. From the central doorway to the northern extreme, although none on the return, the remaining nine panels read also from left to right, depicting scenes from the New Testament (Fig 4.3). A late 18th century replacement panel is included here, the subject of which is not clear. Comparable schemes of the twelfth century emanate from the centre, usually from an image of the *Christ in Majesty* over the *Tree of Jesse*. Fragments of these images survive at Lincoln, having been excavated in 1832. The 14th century insertion of the gallery of kings and the gothic windows in the central, north, and south recesses led to some panels being removed and subsequently lost, creating a discontinuity in the intended iconography.

Across the northern section, from left to right, scenes from the New Testament begin with the *Torments of the Damned in Hell* and consist of four panels, *The Punishments for Lust, Sodomy, Avarice* (the Miser), and a late 18th-century insertion. The *Harrowing of Hell* panel forms the quoin, and is structurally bonded into the *Elect in Heaven*, itself fixed into the adjacent ashlar.

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[1] Recent archaeological inspection and analysis of the core behind the frieze panels, carried out by Dr Lawrence Butler, has reached the interpretation that the stones of the reliefs were part of the original eleventh century building campaign. Stylistically, however, art historians, led by Professor Zarnecki and firmly supported by T.A. Heslop of the University of East Anglia and others, insisted at a Colloquium held in October 1995 at Lincoln that the carving could not have preceded the middle of the twelfth century. Butler felt that the stones must have been fixed in place by Remigius's builders, perhaps intending to have them carved at a later date. In this event, since the evidence of the art historians was held to be safe, they must not have been completed until some sixty years later, during the rebuilding of the Minster by Alexander. It was felt by some, although without any evidence of a precedent, that the panels may have been painted in the interim, and eventually carved in-situ (see Appendix G *The Lincoln Frieze Colloquium: October 1995*).

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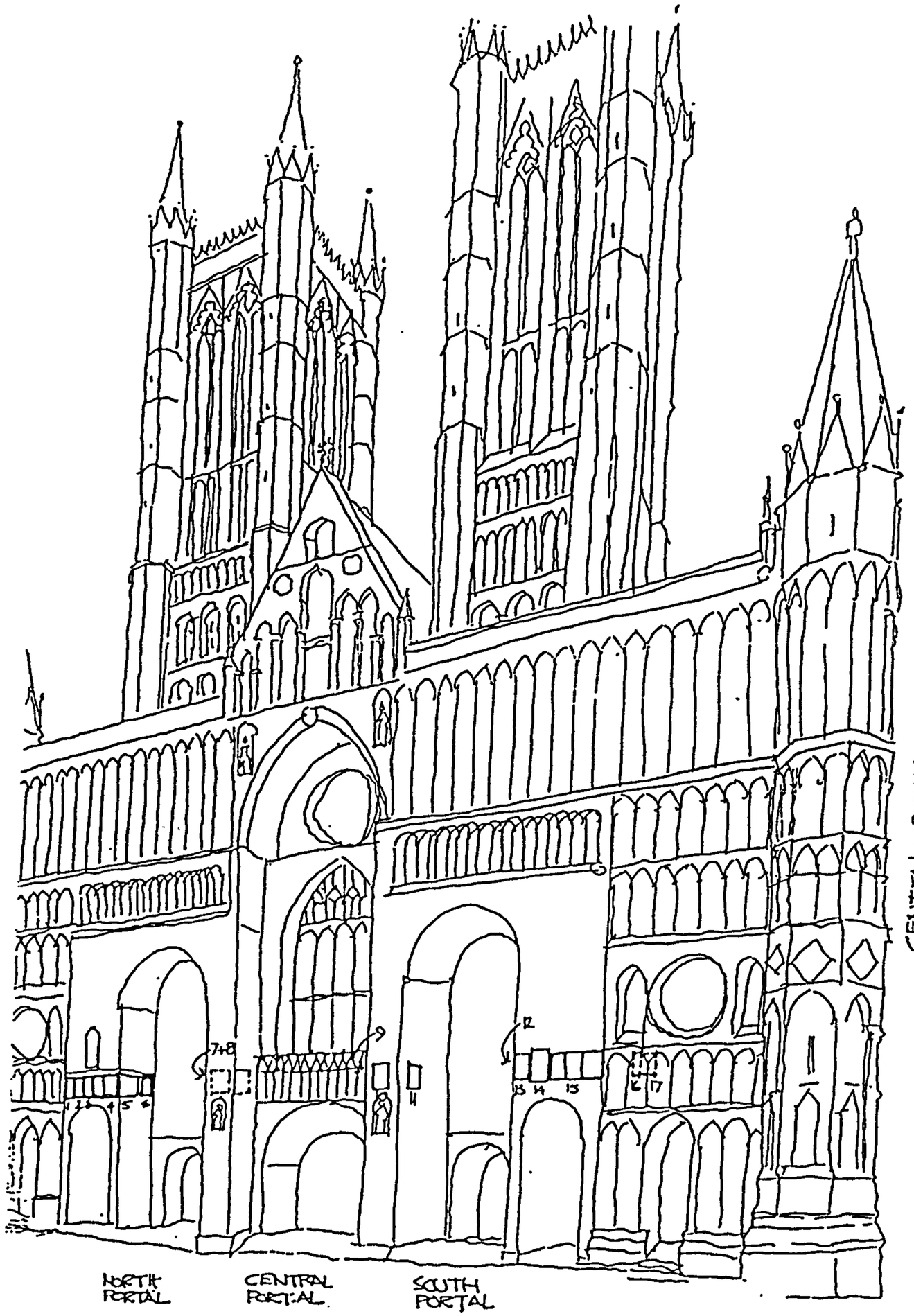
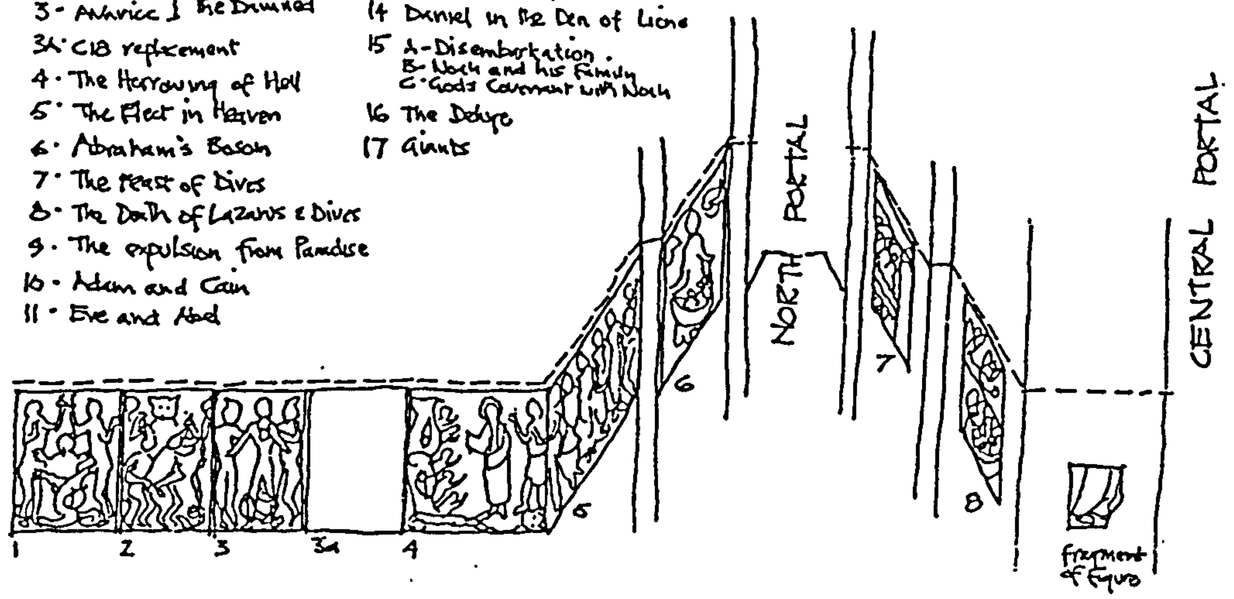
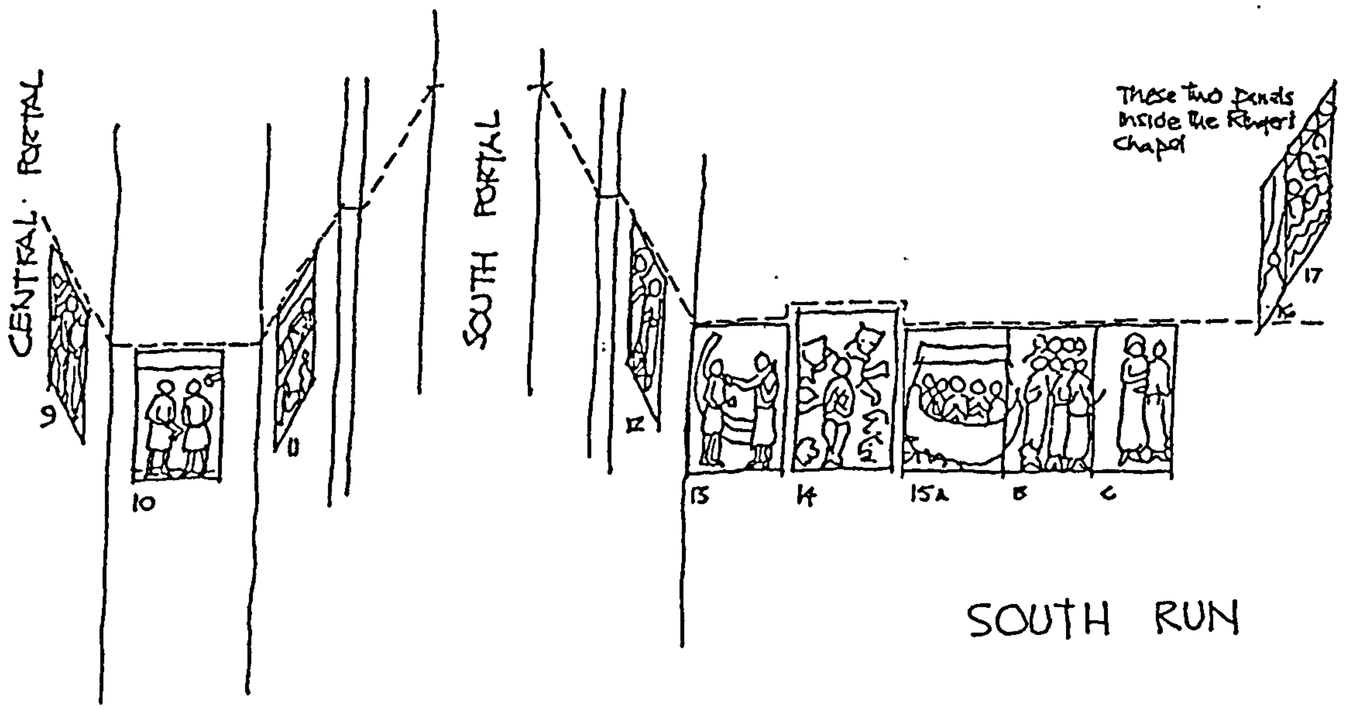
[2] A description by Dr Deborah Kahn shows the panels as being seventeen in number, plus the small fragment on the north side, and is adopted by Zarnecki *et al*. This is based on the number of scenes depicted, rather than actual images, In this study, the panels are referred to as nineteen in number, plus the fragment, based on physical separation.



FRIEZE PANELS
Numbering from G. Zarnecki: Romanesque Lincoln. 1988

1 - Lust
2 - Sodomy } Torments of the Damned
3 - Avarice }
3A - C18 replacement
4 - The Harrowing of Hell
5 - The Fleet in Heaven
6 - Abraham's Bosom
7 - The Feast of Dives
8 - The Death of Lazarus & Dives
9 - The expulsion from Paradise
10 - Adam and Cain
11 - Eve and Abel
12 God instructing Noah
13 Noah building the Ark
14 Daniel in the Den of Lions
15 A - Disembarkation.
B - Noah and his Family
C - Gods Covenant with Noah
16 The Deluge
17 Giants





THE ROMANESQUE FRIEZE · LINCOLN CATHEDRAL

Fig 4.3 The Romanesque Frieze location diagram (Lincoln Cathedral Works Archive)

Abraham's Bosom confronts *The Feast of Dives*, with what would certainly have been the starving figure of Lazarus being denied food, now missing. The scene of *The Death of Lazarus and Dives in Hell* completes the run, with an unidentified fragment of a further panel around the corner. The southern section concentrates on the book of Genesis and begins with the *Expulsion*, in a manner echoing the Duomo at Modena. The Old Testament scenes continue with the stories of Cain and Abel, and Noah, but the latter is interrupted by a framed panel of *Daniel in the Lions Den.* Inside the Ringers Chapel are two scenes, described as the *Deluge* and *Giants (Figs 4.4 and 4.5)*.

According to Zarnecki, the central section, a length of 6.7m, would have included scenes from the *Creation*, since this would logically precede the Expulsion scene, as it does at Modena and elsewhere. The Noah cycle would have been preceded by further scenes in the southern recess of the sacrifice of Cain and Abel, and the murder of *Abel and the Death of Cain*. In the northern recess a *Last Judgement* scene might have been a logical focal point, for the message of reward and punishment. Unity would have been provided to the total scheme of both the Testaments, according to Maria Munoz de Miguel, by the important presence of the *Tree of Jesse*, 'as a symbol of the manifestation of God in the history of salvation (the coming of the Messiah born from the Virgin Mary).' (55) She also supports Zarnecki's summary of the theme of the Frieze:

> 'the message conveyed by the scenes which survive is a simple one, that God rewards virtue (Noah, Lazarus, the Elect in Heaven) and punishes sin (Adam and Eve, the Deluge, Dives , the Miser, the Wanton).' (56)

Aspects of Style and Building

There are clear signs of several distinct levels of ability at work on the frieze, giving a strong suggestion that a team of carvers was involved, whether or not within 'the imprint of one artistic personality.'(57) Fernie even questions the continuity of the carving, there perhaps having been a 'disruption of work on the façade' due to fire. (58) The images cut into the Ringers Chapel wall are unfinished, but at no point in their realisation could they possibly be attributed to a carver of the same accomplishment, as the *Feast of Dives*, or the *Elect in Heaven* (Fig 4.6). There is an absence of incisiveness in the cutting of the stone, the design outline poorly drawn where it has been drafted in by chisel. The sophistication of execution of the *Elect in Heaven* and the *Eve and Abel* panels is apparent and can only be regarded as accomplished. There are similarities to the later south porch figures of Malmesbury, the carving of the apostles strongly resembles the cross-legged figures of the *Elect*. Kalinowski says of this compositional device: 'The motif was much loved by Anglo-Saxon artists and was endlessly used,' (59)

THE FRIEZE

Surviving panels, numbered from north to south:

North of main portal

1–3 Torments of the Damned in Hell
- 1 Lust, 1.05m × 0.80m
- 2 Sodomy, 1.05m × 0.71m
- 3 Avarice; 1.05m × 0.71m

A late 18th-century relief has been inserted between these three panels and:

- 4 The Harrowing of Hell, 1.05m × 1.09m
- 5 The Elect in Heaven, 1.04m × 1.37m
- 6 Abraham's Bosom, 1.04m × 0.86m
- 7 The Feast of Dives, 1.02m × 0.83m
- 8 The Death of Lazarus and Dives in Hell, 1.05m × 0.75m (top) and 1.05m (bottom, including carving on ashlar)

South of main portal

- 9 The Expulsion from Paradise, 1.05m × 0.67m
- 10 Adam and Cain, 1.02m × 0.69m
- 11 Eve and Abel, 1.04m × 0.86m
- 12 God instructing Noah to build the Ark, 1.03m × 0.68m
- 13 Noah building the Ark, 1.03m × 0.71m
- 14 Daniel in the Den of Lions, 1.15m × 0.71m within frame, width of frame 0.16m
- 15 The Disembarkation of Animals Noah and his Family leaving the Ark God's Covenant with Noah 1.08m × 2.12m

In the Ringers' Chapel

- 16 The Deluge, (what is visible) 1.07m × 0.43m
- 17 Giants, 1.07m × 0.78m

Fragment in centre, 0.47m × 0.40m

Schematic drawings of the frieze

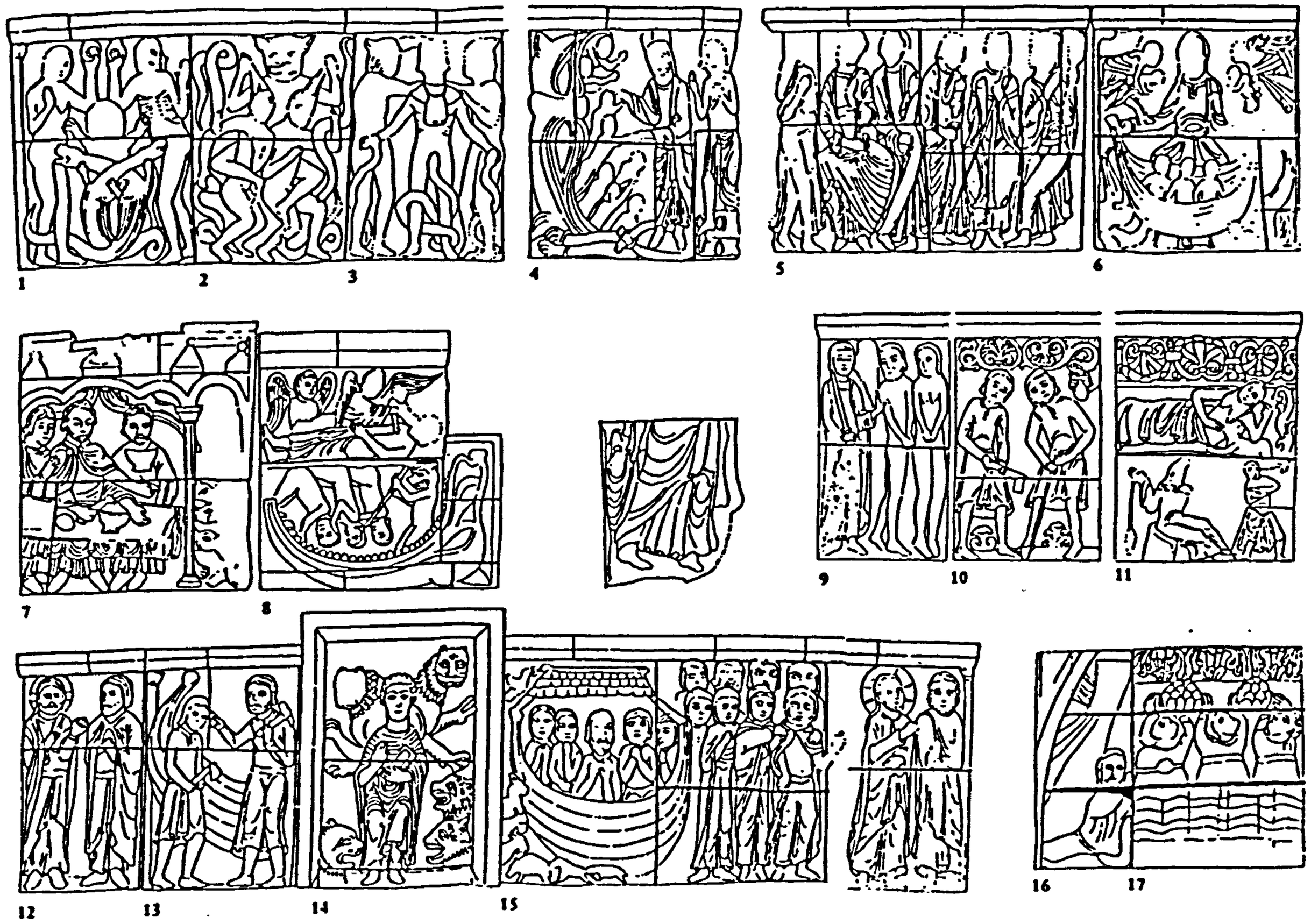


Fig 4.4 Schematic drawing of the Romanesque Frieze (ZARNECKI, G. *Romanesque Lincoln: The Sculpture of the Cathedral*, Lincoln, Honywood, 1988)

Fig 4.5 Parts of the Northern and Southern runs of the Romanesque Frieze (Lincoln Cathedral Works Archive)

Fig 4.6 The Elect in Heaven

A Sub-Committee for the Frieze

Although the desire for a general strategy of open debate had been effectively endorsed by The Consultation of 1983, the Dean and Chapter were keen to establish a point of reference. It was decided by the Fabric Council in 1985 to set up a Frieze Sub-Committee chaired by the Reverend Peter Hammond, retired Head of Art History at Hull College of Art. This was formally answerable to the Fabric Council, and consisted of Peter Hill, the Clerk of the Works, and Keith Murray, the Cathedral Architect and Surveyor, their remit being to assess all aspects in relation to the care of the Frieze. Their evaluation was responsible for the production of specialised information and documents produced during that time. These include: *A Summary of Practicalities*, by Peter Hill, and amounts to an initial feasibility study of removing individual panels; *Preliminary Suggestions for the Conservation of the Frieze: Lincoln Cathedral* by John Larson, a sculpture conservator, working for the Victoria and Albert Museum. Ross Dallas, then of the English Heritage Photogrammetric Unit carried out a photographic record and survey assessment; Keith Murray collated a survey of all significant carving and sculpture on the fabric, pointing out specific areas of vulnerability; an estimated view of replication options was commissioned from Voitek Sobczynski, a London-based sculptor and a specialist in casting techniques. These reports were submitted in late 1986 for discussion with the CAC.

A Steering Group for the Romanesque Symposium

In March 1987 the Frieze Sub-Committee was asked by the Fabric Council to broaden the scope of its enquiries and to set in hand an investigation into ways of conserving the frieze in situ. This was to be explored in parallel with the option of removal to a museum. The Sub-Committee, with Dr Richard Gem and Jeffrey West of the CAC, Professor Zarnecki, as well as Dr Kahn, Neil Stratford of the British Museum, and the Masters of the Fabric, was then expanded into a Steering Group for a forthcoming Symposium. Following a meeting with Dr Gem in March 1987, a discussion was recorded projecting a Romanesque Symposium of experts on Romanesque Art in which Dr Gem expressed his hope that conservation issues would be extensively discussed. That meeting was attended by the Subdean, Professor Zarnecki, and Dr Kahn, and a provisional title, date and list of participants was discussed. This conference was intended to initiate a practical route to developing a conservation policy building upon a resolve to maintain open links during the forthcoming work, which now seemed inevitable to the frieze, and other cathedral statuary.

A campaign such as the conservation of the Lincoln Frieze would be of international significance and a Symposium was set for June 1988, the purpose being to assess the continuing deterioration of the panels and their future conservation and repair. The symposium was to be presented under the heading: *Romanesque Sculpture in its Architectural Setting*. This would underline a sub-text expressing a desire for the sculptures to exist for future appreciation, preferably in their originally designated context. Around forty participants were invited, from Europe and America, including architects, art historians, archaeologists, scholars, practicing museum conservators and associated

scientists in the field of conservation (see Appendix H *The Romanesque Frieze in its Architectural Setting: A Symposium (1988) List of Participants*).

The Romanesque Frieze in its Architectural Setting: A Symposium (1988)

The Symposium was planned along three exploratory themes. Firstly, it was intended that a discussion of Romanesque sculpture in its architectural context would help to lay a general foundation. Secondly, the particular case of the Lincoln Frieze in its setting could then be developed. Finally, the care and conservation of the Frieze and other Romanesque sculpture at Lincoln would be considered so that a practical way forward might develop. Some exploratory cleaning had been carried out on one panel, *The Death of Lazarus and Dives in Hell*, which would form the basis for discussion. Case studies from Italy, Spain, Germany, France and Britain were presented. Site visits to the west façade gave a realistic understanding of the condition of the Frieze sculptures, so that theory did not displace the practical imperative of the conference.

Although the dual objectives of where and how to go about conserving the Frieze were pursued throughout the symposium, it was immediately acknowledged that the views of the art historians would form an essential part of any active programme of care. Certain historical questions could not be separated from conservation aspects. If, for example, the iconography of the scheme could be proved to have been interfered with since original insertion,[1] an explanation might be forthcoming regarding mortars or other materials behind the panels. At the same time, it would be an art historical evaluation that would determine the provenance of the sculptures, knowledge of which would have a bearing on the stone-type. In turn, this would enter the equation of patterns of weathering and the ultimate recommendation of relevant treatments. Close comparisons had already been made with Wiligelmo's frieze on the Duomo in Modena, prompting the unlikely suggestion that the Lincoln Frieze may even have been brought from Northern Italy, perhaps by Alexander. Finally, though not exclusively, in the event that one or more of the Frieze panels required to be removed from the façade, never to be returned, restored copy carving might prove to fulfil the requirements of replacement. In such a case, the opinions of the art historians would be invaluable in helping to gain an understanding of lost detail, and of the 'feel' of the proposed copy carving. On many levels, the views of the academics would always be essential to the satisfactory conservation of architectural sculpture. Any solution to halting their progressive decay, to the continued life of the building, as well as the ultimate presentation of the panels would benefit by scholarly opinion, since new insights would inevitably emerge, perhaps shifting the fragile balance of opinion and decision-making upon which the future stability of the sculptural scheme depended.

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[1] It had long been thought that several of the panels were not as originally positioned. *Daniel in the Lion's Den*, for instance has a frame around it, which interrupts the sequence of *Noah and the Ark*.

A Precis of Art Historical Opinion

Three papers may be concentrated upon to focus what was a powerful contextual presentation. It is convenient to present them here in reverse order, since this more effectively emphasises the impact of stated points on the practitioners of sculpture and architectural conservation, and also issues that were perhaps surprisingly greeted with solidarity. In the main, such details revolved around the location where the panels might eventually best reside. It soon became clear, a quality borne out until the final session, that all delegates from their varying disciplines were intent on achieving the best possible solution for the Frieze.

In her presentation, Dr Kahn underlined the development of frieze sculpture in England from the mid-seventh to the mid-twelfth century. Examples were given where models had been provided by provincial Roman sculptors, themselves perhaps influenced by more significant metropolitan works. At the seventh century church of St Peter of Monkwearmouth, Northumbria, in the west porch, Kahn felt that 'the appearance of carved stone figures may be attributable to the emulation of the sculptural remains of the Roman occupation.' (60) By the ninth and tenth centuries, continuous reliefs had begun to illustrate angels, the lives of saints, as well as everyday scenes, such as the narrative of the life of a vintner, as at Breedon-on-the-Hill, Leicestershire. The relevance of locally absorbed influences is supported in a paper by Maylis Bayle in a published edition of a selection of Symposium papers, (61) in which a study of friezes and carved slabs in Romanesque Normandy revealed only two examples of the narrative frieze, at Bernay and at Graville-Sainte-Honorine.

An examination by Walter Cahn concentrated on how works of art can be interpreted, not in the conventional manner of studying the intention of the artist and his patron, but by giving attention to the role of the spectator, described by Cahn as 'a relative newcomer to art-historical studies.' (62) Emphasis is consequently placed on the context of the work viewed, and the manner that meaning is presented as a form of address. Interpretation is dependant only to a degree on current social and theological awareness of the day, but to Cahn's reasoning such messages are capable of spanning 'an increasingly capacious and indispensable social space.' (63)

Willibald Sauerländer opened the event with a presentation of the development of Romanesque art as it moved from the interior of churches to the façades, citing examples of paintings, capitals, choir screens, pulpits, and fonts. Moving to the external fabric Sauerländer fixed on the portal as the ideal position for 'a poster at the entrance of a church.' (64) The scale of such a presentation could be seen to range from relatively simple signs to the occupation of the entire façade, as at Angoulême. The emergence of the Romanesque frieze and the usual choice of its location attributed to it a very specific purpose. It was from this position, that Sauerländer made the point that the Romanesque frieze was exclusively about presenting messages, and therefore entirely dependent on its particular architectural context. This message was itself pushed home forcefully

by Sauerländer, punctuating each stage of his argument with the repeated view that, were the Lincoln Frieze to be removed, for example to a museum, it would immediately lose its relevance, becoming 'simply a document of art-history.' (65)

Some General Responses

As well as describing the broader context of the Frieze by deepening the 'understanding of the specific characteristics of the works,' (66) the art historical presentation had as a whole placed 'emphasis on the significance of Romanesque sculpture throughout Europe in relation to holy places.' (67) In all respects, the value of the object was in no way left uncertain throughout the conference hall. At the same time, the presentation managed to polarise a unifying desire to preserve the positioning of the Frieze in its original setting. Paul Williamson, then Curator of Medieval Sculpture at the Victoria and Albert Museum, felt that the Frieze would eventually need to be brought down from the façade and confessed himself, perhaps not surprisingly, a 'great believer in cathedral museums.' (68) Referring to the Museo dell' Opera del Duomo at Florence and at Siena, Williamson strongly contested Sauerländer's view that the sculptures could be not be better appreciated away from their originally intended site and that they would in some way lose their meaning. It remained the fears of some conservators, however, that physical evidence already indicated that some panels would need to be worked on in the controlled environment of the conservators' workshop. An overriding anxiety was that the reliefs would suffer dramatic and irrevocable damage during attempts to remove them. This severe doubt was to remain a gulf between theoreticians and practical conservators for some time.

Conservation Opinions Expressed and Some Taken for Granted

During presentations given by those directly responsible for hands-on conservation, there began to emerge three principal choices as a way to move forward. Broadly, these were: a) to allow the panels to decay, b) to carry out in-situ conservation, or c) to take them down, either entirely or piecemeal. The first option was an extreme interpretation of the philosophy advocated by the SPAB and the very event of the Symposium precluded this line of action being considered further. A notion expressed by the German delegation offered the chance to delay any unenviable decisions for the time being. Current research in Germany, it was felt, was perhaps three or four years away from delivering a solution. T.A. Heslop of East Anglia University, stated his impression that in the sixteen years since he had first seen the Frieze, there 'have been areas of deterioration.' (69) All the same, he felt 'there may come a time when it is necessary to remove the frieze, but that time is not now.' (70) This safe view found many companions amongst the participants of the Symposium. However, Roger Stalley of Dublin University, commented strongly on the 'alarming fragility' of the frieze. (71) He was sceptical of the potential of simple solutions around the corner, and added that these may not at any rate be applicable to Lincoln. Far from being a 'question of conservators versus art historians,' (72) as had been feared by Burman, surprisingly unexpected stances were taken by both.

Attention was inevitably drawn to the complex matter of the atmosphere, with admittedly lowering sulphur dioxide levels, but rising nitrogen oxides, and their as yet unquantifiable synergistic effects (see 2.3 *Acid Deposition*). The point was recognised that even if the atmosphere could be miraculously purified, the residual pollutants in the stones would continue to cause decay. All that could be offered by the BRE was the continuation of the monitoring of the local atmosphere, which was part of the National Materials Exposure Programme (NMEP)[1]. The aim was to 'enable quantitative cause and effect relationships to be developed and methods of prediction of decay rates in a changing environment to be devised.' (73) Various methods of external protection were put forward, some of them quite disfiguring to the architecture, with suggestions of hood arrangements and lead flashing fashioned over the string courses, replacement of the wooden box covers, and even of placing the Frieze behind protective glass screens.

No-one contested the need to continue cleaning the Frieze, which was felt to be beneficial 'in order that decisions on its conservation may be soundly based,' (74) and because 'the black crust is an absorber of humidity and pollutants. It is therefore harmful and must be removed.' (75) The condition of the panels varied greatly and much had depended on their position in relation to weathering details as well as their orientation. Those panels facing north, or being within portals, seemed on the whole to have fared better against the elements. All the panels had to a degree been protected by the medieval Exchequergate.[2]

Two hard-hitting presentations were given by John Larson, then senior Conservator at the Victoria and Albert Museum and Consultant Conservator to the Frieze from 1986 until 1992. In the first paper, Larson outlined recent conservation events in Britain, and referred to Exeter and Wells Cathedrals, where the west front of both cathedrals had undergone recent conservation treatment. Examples were given which focused on less than exemplary instances, perhaps given as an aversion therapy to avoid a similar occurrence in the case of the Lincoln Frieze. At both these Cathedrals, the lime method had been selected as a suitable solution. Larson felt that polychromy had been sacrificed at Exeter, being too liberally covered with lime shelter coat (see Appendix E *The Lime Method*). At Wells, he felt that lime shelter coats had occasionally been applied indiscriminately, explaining the dangers of blocking the pore system of the soft Doulting limestone. This, he explained, prevented moisture from evaporating freely, causing deterioration to

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[1] The location of the Cathedral at Lincoln is one of 29 chosen sites being used to carry out the National Materials Exposure Programme. It is also one of four sites in Britain to participate in the International Materials Exposure Programme, which involves a slightly enhanced range of materials, and extra monitoring, including hours of sunshine. Actual monitoring at the site began in April 1987. The technical equipment and material samples were installed on the North-West Gallery overlooking the main west façade, approximately 30m from the ground. The main rainfall collector was removed from the corresponding South-West Gallery in 1989 following an act of vandalism, when a member of the public scaled the scaffold.

[2] The medieval gateway Exchequergate faces the west front of the cathedral and acts as a wind-break, actively protecting the bottom forty or so feet of the façade

accelerate. Whereas it was familiar for the lime method to receive benign responses, this description contrasted starkly, raising an awareness that no treatment should be regarded as a panacea, to be taken for granted.

Partly in defense of any risk of loss, methods of recording were consistently focused upon. On hand was Ross Dallas, who demonstrated the use of photogrammetry in conservation work. In his talk, Larson outlined his comprehensive recommendations for recording, to run in connection with the photogrammetric survey already under way at Lincoln (see 5.1 *Photogrammetric Survey at Lincoln*). However, large-scale contour drawings, such as one on display showing the Dives and Lazarus panel, were deemed an expensive waste of time. Larson suggested programmes of analysis, to be carried out through the auspices of several of the London museums and various universities. Only with a comprehensive view of conditions, in his opinion, could any recommendations be safely made, and no indication of preference towards in-situ treatment or removal to a workshop was given. The following list of research lines was extended:

- petrographic analysis,
- pigment sampling,
- medium analysis (grounds etc),
- mortar analysis,
- pollution sampling,
- weathering and pollution monitoring.

All repairs, symposiasts were assured, would adhere to a 'strictly archaeological philosophy,' (76) with no areas restored, nor features replaced, and there would be no diguising of repair with protective coatings or paint. Larson raised the ethical question of 'reversibility' of treatments, stating that in his view this was impracticable, but that the notion should be extended to include the ability to re-treat at a later date. Needless to say, such a bold presentation and condemnation was not unilaterally well received, with criticism descending on Larson's museum background. Mention was made of the fact that both he and his predecessors at the V & A had been to some degree involved in those areas he himself had criticised.

Summary

The Symposium provided a forum for a variety of points of view, some exhibiting a protectiveness of the Lincoln Frieze, and others defensive of their own discipline. There were obvious differences in the substance of representations from practitioners from home and abroad, with the latter tending to rely on chemical solutions to problems of stone decay, and a reliance on the future development of improved consolidants. In Britain, perhaps partly due to instances of poor application of deep penetrating consolidants, particularly silanes, resulting in loss of detail in cases of sculpture, there was an expression of deep suspicion of such chemicals (see Appendix F *Silane Consolidants*).

The art historians identified the broad significance of the Frieze, and displayed the wide range of its values. This was possible by examining likely sources for ideas and techniques from within Britain and the larger context of Europe. Some consideration was given to the original function of the narrative frieze, with the term 'posters in stone' being aptly coined, and of what this might have meant to the original spectator in the context of his time, and how that meaning might have lasted. Finally, powerful emphasis was given to the relevance of the panels within their originally intended context, the west façade of Lincoln Cathedral. Here, the lasting notion was presented that the sculptures would lose their relevance if removed from that context.

Seizing on this last point, many symposiasts concurred that the panels should be retained if possible in their intended position. The German conservators suggested that the future might offer a solution to stone decay, and many participants sought refuge in this line of thinking. There were strong feelings that the panels were impossible to remove without a great deal of damage occuring. Whilst three main options were considered, the consensus agreed that environmental monitoring was vital, and that the black crust should continue to be cleaned from the panels. Some consideration was given to developing the idea of protective barriers, such as covering boxes as had been previously installed. The presentations given by Larson, outlined recent conservation background in England, so that a context would be provided for work to the Lincoln Frieze. Some critical comments were made regarding recent activities on two English cathedrals, where damage was suggested as having been done. An outline of attendant recording details and analyses was presented prior to recommendations being given with regard to the Lincoln Frieze.

Concluding Comments

Although it proved problematical to make definite recommendations at the end of the Symposium, certain issues were clear. Criticisms were levelled regarding the dearth of technical proposals available. For example, little reference had been made to the pilot conservation scheme of Edward and Eleanor in 1986 and the failure of the 'lime method' to apply totally to Lincoln stone (see 4.2 *Edward and Eleanor: A Pilot Conservation Scheme (1986)*) What had occurred was the presentation of 'general principles,' (77) and it was felt that due to the lack of tangible information, inevitable technical and ethical conflicts had been aired but not resolved. Almost everyone was wary of the technical difficulties that would be involved in removing the panels, although assurances were given by Larson that the operation would be practically feasible. Peter Kurmann, writing soon after the Symposium, made the point that 'despite scholarly arguments' the Lincoln Frieze 'is eroding increasingly rapidly.' (78) It could be deduced that from this observation, therefore, that it was unsafe to do nothing. Conceding these views to some extent, it was agreed that the Frieze conservation operation should become an integrated part of the projected programme of cleaning and selective repair of the entire west front. At the same time, each Frieze panel should be examined in detail and recommendations be based on the evidence that emerged. Any policy, it was clear, would need to be continually updated, as details were revealed

and patterns of decay and breakdown in the stone became clear. It was evident, according to Richard Gem in his follow-up letter, that 'It comes down to what is technically possible with respect to conserving the sculptures in-situ.' (79) Initially, work would be undertaken by contract labour, with an in-house team being trained alongside, and the facility of a modern conservation workshop being established as part of the Lincoln Cathedral Works Department resource.

Conserving the Lincoln Frieze: A Policy of Conservation

Although the Romanesque Frieze of Lincoln Cathedral has elicited some interest from those charged with its care in the past, notably Essex in the 18th century, and Archdeacon Trollope in the 19th century, there is little evidence of any concerted attempt to secure its long-term preservation. The Special Repair programme was responsible for thousands of gallons of liquid grout being pumped under pressure into the core of the walls of the west façade (see 3.2 *Case Study: The Special Repair Programme (1922-1932)*). A question must be raised in respect of the damage sustained to the stonework as a result of this method of consolidating the fabric; even though the medieval ashlars are up to 200mm (8") thick, a great many stones needed to be replaced as the programme progressed. The engineer Professor Heyman acknowledges: 'from personal experience that an ashlar stone can move under the action of a hand pump.' (80) In the case of the Frieze, many of the panels are extremely thin in section (*The Punishment for Sodomy* is less than 10mm (1/2") thick in places), as well as being face-bedded. This latter point means that they are fixed rather precariously on edge rather than in a natural position where they would rely on their optimum quality of compression (see 2.3 *Bedding of Stones*). Godfrey's reports record holes of up to six feet deep being drilled through Norman work, which current experience shows to mean through some of the Frieze panels, with delta bronze dowels of five feet six inches long being inserted into them prior to pressure grouting. (81) Forcing Portland cement grout, around, through, and behind the fragile Frieze panels has certainly caused mechanical cracking, and it is likely that this programme of repair accelerated the processes of deterioration (Fig 4.7). Following exhaustive research, looking at local stones and many from abroad, it is safe to say that the majority of Frieze panels are carved from Ancaster type stone[1] which is of a more porous nature than the surrounding Lincoln stone. Due to their position, they have been forced to perform as an

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[1] A research document entitled *An Investigation Into the Stones Used for the Romanesque Frieze at Lincoln Cathedral*, 1991. was produced by Dr David Jefferson, Consulting Geologist, which set out to establish the range of stone types used in the Frieze and West Front, all of which Jefferson concluded were of a local ooidal limestone. The stone used mainly for the Frieze scheme was typical of that quarried at Ancaster, approximately twenty-five miles south of Lincoln. The main fabric of the Cathedral was constructed of Lincoln stone, a finer grained limestone, which came exclusively from the Lincoln ridge, and was identical in type to the stone taken from the Cathedral quarry.

Fig 4.7 Detail of the Elect in Heaven panel showing damage caused during the Special Repair Programme. Grout holes were drilled through the face of the sculptures, and subsequent pressure grouting with Portland cement opened up cracks.

outlet for residual moisture in the core, a factor not helped by the fact hard cement pointing has sealed many surrounding joints. Sulphates pumped into the core within the Portland cement grout have crystallised at the surface of the panels as drying-out occurred, creating physical damage to the fragile sculptures (see 2.3 *Soluble Salts, Combinations of Stones,* and *Hard Cements and Mortars*).

As recently as 1961, archival records clearly illustrate the contemporary approach to preserving the sculptures in the general context of caring for the fabric:

> 'It now being the most suitable time of the year for outside cleaning, arrangements are being made for washing part of the exterior masonry of the West Front, the sculptured panels in particular which are heavily encrusted with grime. The method which will be adopted is that a small supply of water will be allowed to spray over each panel at low pressure, a process which will require no more than periodic adjustment. Mr Bond who wishes to make an inspection of the work will be informed when this is about to commence.' (82)

The choice of water washing itself demonstrates a lack of understanding, since this is possibly the worst conventional method that could have been chosen.[1] Prior to commencement of cleaning, it was apparent that many loose pieces of the sculptures were refixed. More recent inspection has confirmed that hard Portland cement had been added to mortars and that, whilst concern for the Frieze was shown, understanding, techniques, and skills at this time appear wholly inappropriate. Once again, consulting contemporary reports to Chapter by the Clerk of the Works, at this time in receipt of the Architect's instructions, a description of current activities is given:

> 'Preparation has been made for washing the sculptures commencing at the northern most panel, but Mr Bond, who has made his examination, finds that it will be necessary to undertake the precaution of [securing] several pieces of the exfoliating carvings before the process of washing is commenced.' (83)

There follows a report describing the drilling and securing of fragments of stonework to the sculptures, with reservations expressed as to 'whether the existing contours of some of these carvings which are extremely deteriorated and friable can be preserved.' (84) The report also expressed the feeling that it might prove necessary to carry out masonry repairs on them. In a report by a later Clerk of Works in 1986, an anecdote is related by the foreman mason Ron James on being questioned about the 1961 cleaning operation of the Frieze, with which he was practically involved: 'It was difficult to remove the black without pulling off pieces of stone. The whole thing was in a terrible condition and falling off in pieces.' (85)

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[1] A long standing tenant of the Cathedral close, Mrs Marlow, has disclosed that she remembers seeing from her window the use of heavy duty fire-fighting hoses aimed from the ground to clean the sculptures in the early 1960s. Although there is no written confirmation of this, it is easy to see how past written accounts may seem innocuous, but disguise worrying practices which may carry consequences for present maintenance procedures.

Reservations and Anxieties in Relation to a Practical Approach

It is perhaps only since the 1970s that real concern has been expressed about the long-term welfare of the Frieze, followed by active attempts to secure its preservation, and it is only since 1990 that any concerted attempt at formulating a coherent policy of conservation has been successful. In light of malpractices previously carried out on the Frieze itself and to sculptures elsewhere in the name of conservation, much controversy has accompanied these attempts. Often the feeling may have been that less dissension would have occurred had it been decided 'to leave the sculpture alone and let it deteriorate naturally on the building without any intervention.' (86) Many suggestions were made in the years leading up to the Romanesque Symposium of 1988 that were to cloud progress when work was eventually commissioned. Mere mention of silane consolidants was sufficient to elicit an adverse response, although in a report to the Cathedrals Advisory Committee in 1977, John Larson had suggested just that as a prospective treatment.

> 'I would suggest that a deep penetrating silane be used for the consolidation of the sculptures on the Frieze. This would cause the minimum change to the surface of the stone, and would not affect the clarity of the already eroded detail. The inherent water-repellancy of the silane would also help to reduce the danger of erosion from rainwater. This, combined with the renovation of the sills, would go a long way to ensuring the future safety of the Frieze.' (87)

Following a study of the document by the CAC, prior to it being forwarded to Lawrence Bond, the Architect and Surveyor of Lincoln Cathedral, the following provision was attached to the document:

> 'The Cathedrals Advisory Committee is not able to endorse the use of deeply penetrating silanes. Further experiments are in train, e.g. at Wells (where, however, this method has been rejected as the main method).' (88)

Surprisingly, even following the 1983 *Consultation on the Statuary and Sculpture of Lincoln Cathedral,* at which it was determined that principal amongst a presented list of ethics of intervention was the rule of reversibility, this did not dissuade the Architects in 1985 from placing consolidation using silanes in a list of nine ways of moving forward. (89) On the other hand, any notion of employing such radical techniques was more or less dropped by Larson. The following year, having debated their paper at the inaugural meeting of the Lincoln Cathedral Fabric Council, a revised version was offered for consideration by the Architects. (90) In this document, the option of consolidation, though still raised, was tempered by an acknowledgement that any conservation technique 'should be as far as possible reversible'. (91) A whole paragraph is then devoted to lesser statuary and the use of silanes, with a suggestion that appropriate trials might be made on 'some part of the building;' (92) although to date this suggestion has never been taken up (see Appendix F *Silane Consolidants*). This document discussed the most realistically available options, taking into account the recent history of debate on the subject. Reference was made at this

juncture to the proposal to carry out work on the figures of Edward and Eleanor (see 4.2 *Edward and Eleanor: A Conservation Pilot Scheme (1986)*).

Discussing the option of moving Frieze panels to a 'safe' location, within the Cathedral or elsewhere, the following comments in an Architect's report were unlikely to have lessened reservations held by many with regard to the approaching programme of work:

> 'moving the sections of the Frieze involves some risk of damage, but like the other alternatives success depends on the care of those doing the essential consolidation of the stone[1] and then in moving it. There is a considerable body of expertise in moving sculpture, some in Britain but more in Germany, France, and Italy, which could be called on.' (93)

Even following the extensive debate of the Symposium it was evident that major fears existed that damage could be incurred to individual panels if the option of removal was pursued. In his summary of practicalities regarding the removal of Frieze panels, the Clerk of the Works had made repeated reference to the use of levers and wedges to 'draw the panels out,' even going so far as to state that 'it was not beyond possibility that this may cause the stones to crack in half.' (94) A further document commissioned by the Fabric Council from John Larson was 'based on the assumption that the Frieze will be removed from its present position on the West Front and will be reinstated in a protected environment.' (95) Some reservations were openly expressed that Larson was a museum conservator and would naturally gravitate towards museum conservation solutions, with too little attention paid to in-situ treatment. (96) Further typical anxieties were revealed during a newspaper interview with Phillip Venning, Secretary of the SPAB, a month before the Symposium, in which Venning stated: 'Lincoln Cathedral has a fine Romanesque carving on its west front. They are considering taking it down.' (97) Murray wrote to the editor of the Independent stipulating that this was indeed one option, nevertheless there was a range of possibilities currently being openly discussed. During the Symposium, suspicions were again aroused when Murray himself outlined his own comprehensive plan for a museum, which even included a choice of site.[2]

The Death of Lazarus and Dives in Hell

The Sub-Committee for the Frieze, empowered to select a starting position for practical work, in discussion with Larson settled on *The Death of Lazarus and Dives in Hell* (Fig 4.8). This panel was chosen because it was felt to be in better condition than most others, as well as being positioned in the wall on its own, surrounded by Lincoln ashlars (some of them also carved). This would offer

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[1] It was stated in Keith Murray's document that consolidation of fissures, cracks, and blisters would need to be carried out using soft lime mortars, before the sculpture panels were handled or moved. It was accepted that some panels were so fragile that handling would risk loss of detail.

[2] Keith Murray gave a comprehensive presentation of his proposal that the Subdeanery garden could be converted into a museum devoted to the Frieze and other sculpture removed from the Cathedral fabric. In some quarters this was felt to be the development of an idea that should have been left until further down the discussion path and that it presumed the outcome of the debate.

less likelihood of 'knock-on' effects than if one of a sequence was worked on. In a meeting of the Fabric Council in October 1987, a minute stated that:

> 'The need for expert advice in drawing up the specification for conservation was emphasised strongly and it was noted that two specifications might be necessary to cover the alternatives of in-situ and museum conservation.' (98)

In line with the Sub-Committee's recommendations, the 'Dives and Lazarus' panel, as it became commonly known, was to receive trial cleaning, to be carried out by two professional conservators, Keith Taylor of Taylor Pearce Restoration Ltd., and Richard Marsh of Wells Conservation Centre. In the event, a consensual document was produced, agreed by the three conservators and a brief specification was written by Larson for presentation to the Fabric Council:

> 'This is a slightly unusual specification in as much as it has been formulated in agreement with the two contractors, Taylor Pearce Ltd and Wells Conservation Centre. It was their suggestion that they should work together and that their two companies should share the responsibility for the work. I felt happy to concur with this, as it eliminates much of the confusion and disagreement that has dogged similar operations at other cathedrals.' (99)

Putting together a prescription for work in this way unwittingly created a precedent for the future. A policy of conserving the Frieze would continue to come together in a similar manner, with conservators demonstrating what was often the only way that work could logically proceed. Larson's document was an uncomplicated iteration of known conservation procedure, reminding both contractors of their responsibilities to provide relevant equipment, instructing them to take regular photographic records, to clean the sculpture to the highest (ie museum) standards, and not to obscure original detail when cosmetic lime-mortar fillings were applied to blisters and fractures.

Cleaning was carried out successfully in time for the participants of the Symposium to visit the scaffold and pass comment. Removal of the black crust revealed new information that was to determine the next stage of work. This information related to the original polychromed design of the sculpture, with pigment traces now clearly visible, but was also structurally informative and showed that the sculpture was not in nearly as solid a condition as had been thought during selection. In fact there was clear evidence of previous repairs, perhaps those crudely executed in 1961, as well as other earlier ones. The figure of Lazarus gave serious grounds for concern, appearing to be almost detached, and it was recommended that at least partial dismantling would be necessary to establish the fixings of old repairs, their materials needing to be identified before

Fig 4.8 The Death of Lazarus and Dives in Hell (Lincoln Cathedral Works Archive)

further treatment could be recommended.[1] It was suggested that removing an entire panel would provide invaluable information of how the Frieze was secured into the wall. Past repairs were poorly carried out and several pieces did not correctly register. Dismantling, it was argued, would allow a more satisfactory reassembly of these details, with the opportunity arising to better align the separate elements, where previous repairs were poor in that respect. Much of this work, it was stressed by the conservators, would be necessary even if the panel was left in-situ, since to neglect such precarious structural arrangements would be unsafe for the sculpture.

A length of string course had been carefully removed from immediately above the panel of the *Death of Lazarus and Dives in Hell* in order to allow delegates to see the top bed of the stone. Clear evidence existed showing that the stone was seriously delaminating.[2] The general reaction was one of caution, ie that it could not be presumed that all panels were in a similarly poor state, and that this panel may have been in that condition for several hundred years. The German conservators, Dasser and Snethlage, had proclaimed that research in Germany might be on the brink of providing something approaching a panacea to the problem of stone decay and the majority view was that great danger lay in pursuing any treatment that entailed removal of the panels. This collective view was reinforced in written responses to the Symposium, requested by the Dean and Chapter, and made in the weeks following the event. The Fabric Council, however, was faced with the immediate problem of how to move ahead and during their meeting following the Symposium, a letter from Larson suggesting holding treatments to Dives and Lazarus was accepted, and a formal request was made for those points to be developed. By early 1989 these issues had been clarified, with a further paper by Larson entitled *Projected Work on the Lincoln Frieze 1989*, (100) There followed a three-way correspondence to refine minor issues between Larson, Dr Clifford Price, and Dr John Baily, the new Architect and Clerk of Works, and a first draft of a *Policy on Conservation* (101) by Baily was submitted to the Dean and Chapter on 19 July 1989. Simultaneously, consent was given that *Dives and Lazarus* should be removed so that

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[1] Some analysis had been carried out by Dr Heather Viles of the Department of Geography, University College London in Sept 1987, and a report had been produced entitled: *Report on the Condition of Stone in the Frieze 'The Ascent of Lazarus' on the West Front,* but the results of this had been inconclusive due to limited availability of samples. Access to the rear of the panel enabled inspection of the medieval core and at the same time allowed for deeper core samples to be removed from the sculptures so that petrographic thin-sections could be made for analysis. Data from this would be invaluable in identifying the various stone types that existed in the Frieze and would provide a working comparison with stonework from the main fabric.

[2] The *Dives and Lazarus panel* was originally constructed of two face-bedded slabs of stone. Larson states in an article in the inaugural Henry Moore Sculpture Gallery catalogue: *The Lincoln Frieze: A Problem of Conservation and Historical Investigation*, Henry Moore Sculpture Gallery Catalogue 1993. that the reason for this method of construction was because stone could not be found at these natural bed-heights, although this is not strictly so. Ancaster has always been available at these heights in natural compression, but mason-carvers often express a preference for carving this particular stone off its natural bed. No other reason can be found for this decision, which seems likely to have been based solely on aesthetic choice. The actual slabs of stone were not of uniform thickness and the bedding planes passed through the carving, which itself came perilously close to the rear of the panel.

conservation could be carried out in the controlled environment of the workshop and that the work should be directly undertaken by Larson and Taylor.[1]

A Policy of Conservation

As work proceded in the removal of the *Dives and Lazarus* panel, it became quickly evident that its condition was more precarious than previously estimated. The stonework had visibly separated into approximately twelve pieces, with easily identifiable cracks running not only along the bedding planes, but also at right angles to them. Evidence showed that some cracks had received previous attention, with traces of hard mortar still in place. A large front section was found to be only balanced in place, behind which were the remains of dead spiders and cobwebs, the break edges of the fracture themselves were extremely dirty unlike a fresh fracture, proving beyond doubt that this precarious state had existed for some time and had not been caused by recent handling. Concern was felt for the structure of the stone; less visible fissures might threaten further collapse of the sculpture. Cracking had provided past 'routes' for the traffic of moisture and soluble salts and had no doubt contributed to loss of carved detail. As a result of these findings a further document was requested by the Fabric Council, which should represent the practical dimension of the recent findings. Due to the severity of the condition of the panel, the controversial nature of past debate surrounding treatments of sculpture, and the complexity of a specific treatment proposal to this work, it was suggested that a joint proposal be prepared by the Architect and Consultant Conservator. The result of this was *A Policy Treatment of the Frieze Panels of the West Front of Lincoln Cathedral* (102) and was drafted for presentation on 7 June 1990.

During the next four years, the document was re-written no less than nine times, with six drafts of the final policy itself being submitted, and was ultimately called: *The Recording, Repair and Conservation of the Romanesque Frieze Panels 6/94* (103) (see Appendix I *The Recording, Repair and Conservation of the Romanesque Frieze Panels 6/94*). Eventually, the need for a continual update of the document was written into its structure. As such it was perhaps not a policy at all, if this is defined as a *course of action*, but more a descriptive statement of surrounding circumstances, general considerations, and a posting of current findings. A policy was, however, a requirement of the CFCE, in accordance with the Care of Cathedrals Measure 1990, and this document was realistically accepted as such. As far as the FC was concerned, the document served as a guideline to a standard approach in matters specifically relating to documentation and routes of information, and successfully bridged the inevitable gap between the advisory body, in this case the FC, and the team actively conserving the sculptures.

It was becoming apparent that written accounts of work to the fragile panels could be addressed only following practice, since so much of the operation was exploratory, each stage presenting its

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[1] Richard Marsh had subsequently left the employment of Wells Conservation Centre and had gone on to gain private contracts under the auspices of his own company.

own unique set of problems. Ethically, the work remained within the judgement of the conservators, the policy document effectively only ruling out certain treatments. Any tendency towards a prescriptive policy had been eliminated; firstly in 1977 by the CAC rejection of deep penetrating silanes, although these had been discussed on several subsequent occasions, perhaps only as a tactic in establishing middle ground. Secondly, following the case of the pilot treatment of the figures of Edward and Eleanor, where some of the treatments which make up the lime method were found to be unsuitable for Lincoln stone. [1]

Difficulties in Gaining Approvals

The policy document was repeatedly revised as physical conditions of the Frieze became apparent and as objections to the wording were fed back to the Architect. In the case of the CFCE, on 29 November 1993, (104) the fifth draft of *The Recording, Repair and Conservation of the Romanesque Frieze Panels* was broadly accepted as a general framework 'within which the detailed decision-making can now proceed.' (105) This would be subject to the inclusion of certain amendments relating to the specific letter of the document, such as emphasis on the consideration of in-situ treatment where possible, continuing discussions regarding replacement copies, and the demand for a full assessment from the Consultant Conservator Roger Harris, who had recently replaced John Larson in that role. Communications between CFCE and Lincoln at this time confirm that the continuing formulation of a philosophy of approach to the Frieze, as circumstances unfolded, was a correct way forward. A continuum of progress reports and proposals would ensure that the Commission was kept informed; these would not be considered as new applications but would be regarded as part of the overall approval. The policy and method statement: *The Recording, Repair and Conservation of the Romanesque Frieze Panels* 6/94, thereafter became the acknowledged policy document.

English Heritage was approached for grant-funding (and were in any case advisors to CFCE, together with SPAB the advising national amenity society), and required an explicit statement of intent. This included a description of all stages of any proposed treatment, a request with the potential to dilute the effectiveness of the developing Lincoln procedure. What was intended as an open policy was viewed with suspicion by EH, who saw the policy as unspecific at best, and intended to deceive at worst. A hidden agenda was suspected, which suggested a) that the

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[1] In fact, the difference between Lincoln and Ancaster stones, from which all panels but one (Avarice) were carved is quite significant. Ancaster is a more consistently oolitic stone and, therefore, more porous, which might have made it more receptive to the lime water treatment. Doubts resided about the efficacy of the lime method. Larson in his Henry Moore catalogue article: *The Lincoln Frieze: A Problem of Conservation and Historical Investigation,* made the following criticism of the method: 'Another alternative was to follow the approach that has become very fashionable in England and to coat the sculptures with lime to protect them from further damage. Although this would appear to be an economical and simple way to preserve sculpture it is in fact neither. Coating decayed sculpture with a mixture of lime and stone dust is little more than disguising the problems of decay in much the same way as commercial paints do.' No trials were carried out on Ancaster stone, but some lime treatments within the overall method are still used.

repeated denial of any intention to silane the panels showed that it was in the consciousness and remained an option, and b) that a plan was harboured to remove the entire run of panels to form the nucleus of a Lincoln Cathedral museum of medieval sculpture. In neither case was this true. In 1993, the SPAB published their views of the Lincoln programme of conservation:

> 'It is undeniable that some of the panels are in a very poor state - both through surface decay and delamination of the stone - and one of the panels fell into more than 60 pieces on removal.' (106)

This statement [1] did nothing to calm the suspicion that poor practices were in operation, although the article went on to be complimentary to the Lincoln team. Surprisingly too, SPAB made a first suggestion that it might be necessary to separate the sculptural scheme, the panels in poor condition being removed and the panels in better condition remaining on the façade.

> 'After Committee discussion and two visits to the Cathedral, the Society's view is that, except where there is a strong risk of uncontrollable future deterioration, it is highly desirable that frieze panels should remain part of the building.' (107)

A combination of disconcerting published reports such as this, the earlier suggestion of proposed irreversible treatments, and premature solutions to the long-term storage of the sculptures, alerted suspicions that the best options might not be being observed, and there emerged some adverse reaction to the proposed programme of work. By this time, three of the four panels that had been addressed had shown themselves to be in a markedly worse state than was evident from initial inspection of the face of the sculptures. [2] The face-bedded stones were separating parallel to the face of the panels, with additional fractures running in all directions between these laminations, offering virtually no structural integrity.[3] This had led to their removal to the workshop for treatment and a subsequent recommendation that those three should not be returned to the façade. The fourth, the 18th century replacement panel, was in fact returned to its position. At this point, poor understanding between English Heritage and the Lincoln authorities led ultimately to a delay in practical work of sixteen months and the consequent moving-on of members of the conservation

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[1] This was a reference to the *Feast of Dives* panel, which was removed in 1992 under controlled circumstances without any loss of detail. Due to continual water saturation and salt damage, as well as other mechanical damage (the panel residing immediately beneath a window), the panel had delaminated along its bedding planes and at right angles to them, separating in-situ into about sixty pieces. This was dismantled and rebuilt by Cathedral conservators.

[2] The three panels were the *Punishment for Avarice*, the *Feast of Dives*, and the *Death of Lazarus and Dives in Hell*.

[3] It must be remembered that the sculptures, far from being purely decorative additions to the building, performed as an integral part of the structure of the façade. A system of stainless steel frames was discussed, to be inserted behind any original panels should they be returned to the fabric.

staff.[1] It was felt necessary to introduce a protocol document to facilitate communication and establish terms of reference (see Appendix J *Lincoln Cathedral and English Heritage: A Protocol*). English Heritage began to suspect that the Lincoln authorities were ignoring the option of in-situ treatment, as had been emphasised as far back as the Symposium, and fully intended to remove each of the panels from the outset. It was becoming evident to the Lincoln conservators however, that in-situ trreatment was not appropriate to the conditions so far found and such treatments would have only addressed superficial problems. In this respect, a series of patterns was emerging to suggest that it was becoming obvious that the panels required removal to fully evaluate their condition (Fig 4.9). A subtle, though essential difference existed between removal for this reason and the intention to remove for permanent exhibition. In turn, the Lincoln authorities felt that English Heritage exceeded their brief in monitoring the affairs of the Cathedral's maintenance programme in general.

Some anxiety was expressed over this situation from the Lincoln conservators, since there were obvious inherent dangers in such a pause in working procedures. A great deal of the practical understanding gained of the eroded sculptures and their contextual situation risked being lost. It was not good practice to have a programme of conservation stalled in this way, since parts of the fabric were left dismantled for sustained periods of time, with the structure not in a fit state to take up the constantly re-ordered loads that attempted to find their way through the walls. Parts of the Frieze were put in temporary storage in boxes, with the separated elements wrapped and shelved Records of past work were stacked in drawers until required again when work would be restarted.

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[1] One member of the conservation team moved to another employer due to dissatisfaction with the work-flow, and another moved from the conservation department to take up a traineeship as a carver.

Fig 4.9 The actual condition of the Harrowing of Hell panel was revealed on removal (Lincoln Cathedral Works Archive)

A Question of 'The Principles of Repair' and Supporting an Open Policy

Complementing the Care of Cathedrals Measure, which became effective from March 1991, the Government introduced a system of grant-funding for cathedrals, to come into effect the following year. Running in tandem with this was a strategy of research in associated areas, the intention of which was to provide technical support in common areas of concern. English Heritage published a list of guidelines entitled *The Principles of Repair*, consisting of ten ethical points, which amount to an encompassing array of criteria against which EH grant applications may be assessed, serving also to inform the public of its intentions in terms of repair. Its chief precepts, condensed into the following words in a leaflet on repair work and grants, are as follows:

> 'to restrain the process of decay without damaging the character of the buildings, altering the features which give them their historic or architectural importance, or unnecessarily disturbing or destroying historic fabric. Repairs for which we offer a grant will normally be carried out using traditional methods and natural materials appropriate to the building, its history, and its condition. When replacement is necessary it should be done on a like-for-like basis. Because of the value we place on retaining historic fabric, we take the view that a number of small repairs, eg piecing-in of new elements in a historic window, will often be more appropriate than complete renewal.' (108)

In the case of the Frieze, the true condition of those panels already addressed was not agreed upon for three years, with no grant monies being approved. Eventually, this reached the point where English Heritage Commissioners, Committee members and a selection of their staff, were invited to meet with the Lincoln Cathedral Management team, including both Masters of the Fabric, Consultant Architect, and the conservation staff itself. The policy document was at this time finally and formally accepted by English Heritage. The 6/94 Lincoln policy document stated clearly that there were criteria for deciding both whether or not a panel could be removed for treatment and returned to the façade following conservation.

'The criteria for removal are:

4.2.2.1 That examination of the back of the panel from above and the side (where possible) indicates that the panel can be removed without fragmentation caused for example by previous pressure grouting adhering to the back.

4.2.2.2 That examination of the face and edge shows the presence of delamination or shear cracks or both, giving rise to the real possibility of actual loss of fragments or parts of the panel if no action is taken.

4.2.2.3 That in the judgement of the Dean and Chapter's consultants the panel can be removed without incurring significant material loss.

The criteria for deciding whether or not a panel can be returned to the façade are:

4.3.1.1 Whether the structural strength of the stone is capable of withstanding the action of the wind, rain and frost without loss of fragments or parts of the carved work for a period of 30 years.

4.3.1.2 Whether the surface condition of the stone, especially exfoliated areas, blisters and fissures can be sufficiently held by conservation techniques to withstand the action of wind, rain and frost without surface loss recurring for a period of 30 years.' (109)

This method of conservation relied upon exploration without prejudice, and was inconsistent with the normal requirements of an English Heritage application. In normal circumstances, provision must be made available giving a comprehensive specification, strategy, and timetable, complete with costings. At the above mentioned meeting between the two parties, which took place on 13 October 1995, whilst stressing their desire to be involved in a project of such great importance and technical complexity, English Heritage needed to maintain a position from which to defend itself in the event of any controversial decisions being taken. However, EH recognised that the Frieze conservation project was unique and could not be made to conform to normal grant conditions and the requirements of public liability. Agreeing to waive certain earlier conditions,[1] English Heritage expressed the desire for better relations. Richard Halsey of English Heritage pointed out that the Cathedral FAC was a legal body and interference in its procedures should not occur, and any insurmountable differences that arose would only threaten the funding partnership. Many workshop and site meetings had taken place between cathedral staff and officers of English Heritage, yet it was only at this meeting that credence was given to the continual and irrevocable decay that was seen to have taken place. The Chairman of the meeting, Professor Fernie, expressed hope that a quick resolution would occur from this frank exchange of views.

A Summary and Update

Deep suspicions have existed about the motives behind the proposals to conserve the Romanesque Frieze, and it has been difficult to determine their provenance. Whether early suggestions that chemical impregnation should be employed in their conservation, or that it was felt there was a hidden agenda held by the Cathedral authorities to remove all the panels to a sculpture museum, is difficult to know. Suffice it to say that SPAB are of the opinion, tacitly reinforced by individuals of English Heritage, that the conservation solutions proposed by Lincoln are not appropriate. In the best of all worlds, a treatment like the lime method, which could be applied in situ and would replace the jaded matrix of the limestone with a fresh cement of calcium carbonate, would have suited all concerned. The Frieze, carved from a porous stone and set into a façade constructed of a more impervious material, has acted as a drain for all the surrounding area, with all the impurities filtering through the panels. Added to this is the now certain knowledge

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[1] These conditions had insisted on a fortnightly attendance by the Lincoln Cathedral Consultant Conservator, now Keith Taylor, and monthly visits by their own conservation officer. Since this was regarded as of little value in the procedural chain, and was pointed out as a demonstration of little faith in the abilities of the conservation team and the processes of decision-making, including the Lincoln Fabric Council and the CFCE, it was agreed that the condition be dropped. Instead it was agreed that English Heritage officers might be invited to enter discussions at a) the point where panels were to be removed from the fabric for examination and treatment, and b) at discussions to decide whether they should be left from the façade on a permanent basis. This was argued against and the point was finally made and agreed that the Fabric Council was a legal body and no attempt should be made by EH to undermine its authority.

that it is not merely old age that has ravaged the Frieze panels, but mechanical damage has been inflicted, for example by the iconoclasts of the 17th century who brutally wielded axes at the panels, striking off certain religious details. Such impact must have structurally damaged the stone, given that in places the panels are less than 10mm (1/2") thick. During the Special Repair Programme, thick Portland cement grout was pressure pumped through the fragile face of the panels, and that grout can be seen to have oozed out of newly formed cracks (see Fig 4.7 p184). It can be safely stated that had the lime method been an appropriate option, that solution would have been most acceptable to the Lincoln authorities.

As it was, practical progress was made as policy details went back and forth from the Cathedral to the approval bodies, with true conditions of the sculptures as they were revealed justifying the next stage of action. Meanwhile, the policy document *The Recording, Repair and Conservation of the Romanesque Frieze Panels 6/94* (see Appendix I) continues to be the only document agreed upon, with necessary amendments following to maintain contact with the work as it unfolds. No practical conservator who has viewed the work has voiced an alternative method. Suspicions, however, do not abate. Although the document was not accepted by EH until the meeting of 13 October 1995, this is in principle the current agreed policy. A course of action was agreed upon that a mutually acceptable conservator would provide the necessary link between EH and the Lincoln operation, but more than a full year after that person was appointed, no visit has yet been made, and commitment to the programme of conservation is weak, although there is no vocal objection to it. As far as CFCE are concerned, the policy document stands. The Lincoln Romanesque Frieze conservation programme is now almost half complete, with eight panels conserved.

A current research programme has been established between the Cathedral Works Department and the Physics Department of Loughborough University, to examine the safety and appropriateness of laser cleaning of Frieze panels (see Appendix K *Laser Cleaning the Romanesque Frieze: An Investigation*). The possibility of such a development is mentioned in the 6/94 document, but its inclusion as an acceptable technique will only be decided upon by the efficacy of the practical research results. Mention has recently been made by the EH Cathedrals' Architect that the Lincoln policy of conservation of the Romanesque Frieze will need to be revisited as the programme approaches the southern run of panels

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Part 5.0

Towards a Practical Discipline:

A Review of Conservation Methodology

Part 5.0 Towards a Practical Discipline: A Review of Conservation Methodology

Introduction

This section reviews the skills that are directly applicable to caring for the historic masonry structure, and includes the central need for recording, and the skills of the mason and conservator. Recent changes, both in the traditional skills and in the more recently developed skills, insist that recording now accompanies all work, and must include the condition of the fabric as found, the descriptive nature of all work carried out, and the condition of the fabric as it is left. Part 5.1 *Recording and Archive* includes an outline of recording procedures and the reasons behind them. A presentation is made of current systems of recording at Lincoln, where a full time archive has been established which complies with British Standards (1) of archival materials and storage. Recording is a conservation activity and forms an essential part of conservation training. At present, there are often differences in levels of recording, which in various cathedrals are carried out by the archaeologist or conservator. Whilst there may be differences in the demands of recording by each methodology, standards need to be high so that a clear indication of conditions is available and relevant analysis may be made. At Lincoln, a qualified art historian / conservator has received additional training to attain the qualities of a conservation archivist.

The discipline of stonemasonry has long been the linchpin of maintaining the medieval cathedral and remains central to the upkeep of the integrity of its structure, although many attempts have been made to introduce short-cuts into masonry methodology. In 5.2 *Masonry Practice* the traditional methods of stonemasonry are discussed, and the emphasis is placed on the need for high quality setting out skills to be developed. Structural geometry is the core understanding of the stonemason, and within that knowledge the solutions to most structural problems reside. Certain acceptable modern engineering contributions are also described in this section. A case study looks at the recent replacement of two pinnacles on the South Transept of Lincoln Cathedral, where modern methods of post-tensioning were combined with traditional masonry.

An outline of the conservator's contribution to cathedral care is given in 5.3 *Conservation Practice,* with a description of some of the main options available within that discipline. The point is made that the conservator often acts as the conscience of the works team, since ethical points of reference are integral to both training and work. The *Case Study: Cleaning Black Crusts from Limestone Façades at Lincoln Cathedral* examines changes in attitude towards one of these practices.

Finally, in 5.4 *Training Opportunities for Stonemasons and Conservators* the essential differences in training are described and weaknesses in them are examined. Questions are asked, including whether the training of masons aptly focuses on the needs of the building, or if this has been corrupted by commercial demands in recent decades, and whether conservation should develop as a craft, from which professional status would naturally emerge.

5.1 Recording and Archive

Recording of all physical action carried out on the fabric of medieval cathedrals, from routine maintenance to the more permanent development of the site, is given unprecedented emphasis in the United Kingdom. It is perhaps the central concern of the Care of Cathedrals Measure 1990. In this section of the study the main description will be of those elements of recording which affect the practical conservation of the fabric of the cathedral. Several levels of operations arise, from the macro view of the whole structure and site, to studying micro-climatic conditions. Quinquennial surveys carried out by the architect perform an important function, as do the findings and analyses of archaeologists, but will be excluded here since those specialist studies belong elsewhere. Recording methods relating to cathedral maintenance will be described and underlined by the need for a secure and accessible archive.

Purposes of Survey and Recording

Two main sources of recorded information relating to the condition of the building come from carrying out surveys and recording conservation work. These may consist of a combination of drawings, photographs and written reports, and will include archaeological work. A survey can be as large or as concentrated as is appropriate to the task in hand. It may be an investigation commissioned for several specific purposes, but the primary function is to secure knowledge relating to the performance of the building. This will usually involve both the substructure and the superstructure and include the roof covering. Such an investigation must include the state of function of all services, for example electrical cables and fittings, plumbing routes and fire protective arrangements, such as dry risers or water storage vessels. Where possible, consideration should be given to adjacent properties, as well as local physical details. The ultimate aim is to adequately provide relevant data for any contingency which may lead to a failure of the fabric. Being forewarned will allow for pre-emptive action against calamity and can be regarded as the principal reason for instigating surveys.

All physical intervention to the medieval fabric ought to be identifiable in the form of conservation records, so that any treatments, including new masonry or other materials introduced during repair, may be accounted for in the future. These might include hidden metal dowels, cramps or other fixings, or chemical treatments, such as adhesives and consolidants, all of which may not be visible. Records such as these may also provide information relevant to the local area, such as mortar core samples, or the conclusions of research carried out on particular areas of the structure (which may only be evident when the wall is opened up for inspection).

Regular monitoring contributes to the larger conservation view, which is to ensure the life of the structure in perpetuity. The following is a list of main reasons for survey and recording.

- Valuation for Insurance

- Regular maintenance management
- Evaluation of repair
- Actual repair

Valuation for Insurance

Historic properties, as well as any other, require the protection of insurance, which will need some sort of evaluation. Whilst it is impossible to fully replace a building such as a cathedral, the recent example of the fire in the south transept roof of York Minster clearly illustrates the need for adequate documentation. Most insurance policies, particularly those extended by the Ecclesiastical Insurance Group, rely on any disaster not wholly destroying the building and therefore not requiring total replacement. Lincoln Cathedral carries insurance for what is estimated to be around only a third of the cost of total rebuilding, which is based upon the insurance company's own survey, periodically updated. This may well lead to recommendations of a physical nature, such as the introduction of openings in vault pockets for the release of water in the event of fire, or the reducing of roof spaces to inhibit the spread of fire. Such suggestions will not always be practicable.

Regular Maintenance Management

A cathedral hosts services, concerts and many other functions and needs to be able to manage the safe movement of people and to make arrangements for seating and the necessary services. These may be planned from basic measured ground plans, which clearly explain the various spaces to be utilised. Current information may include areas to be scaffolded, with some presence of risk. Drawn records can provide an invaluable aid in matters of health and safety and therefore need to be up to date. They can help eliminate vagueness in the planning of functions and may also accommodate dramatic fluctuations in attendance, where one day the congregation may consist of thirty and the next two thousand.

Plans may be extended, as they do at Lincoln, to include all physical levels, for example ground level, triforium, clerestory, and high roof. These provide an excellent aid in the regular maintenance of gutters, downpipes, and other services. Underfloor and otherwise secreted cabling and piping can be regularly checked by referring to adequately drawn plans. Ducting can be identified, which may be useful in the need to lay new cables. Fire-fighting methods and routes, such as lightning conductors, can be routinely checked and maintained. Throughout all levels of Lincoln Cathedral, a network of compressed air piping was installed in the 1920s (see 3.2 *Case Study: The Special Repair Programme (1922-1932)*). This follows complex routes and requires regular servicing, but has as yet no drawn plan.

Evaluation of Repair

In assessing the likelihood of repair, the observations and feedback of a permanent works staff are inestimable and are wisely capitalised upon.[1] Both elevational and plan drawings are vital for recording findings, and photogrammetric drawings, which can be reproduced on demand are ideal in this respect (Fig 5.1). The five year, or quinquennial inspection, carried out by the architect or surveyor to the fabric will provide a basic framework from which to hang the more incidental information. This may take the form of written notes, sketches, or photography and can help in the upkeep of a comprehensive understanding of the state of the fabric.

As a necessary part of the customary inspection of the medieval fabric, accurately detailed records may provide information from which judgments may be made. For instance, it is known that the likely life-span of lead is between 150 and 200 years, although depending on the quality and gauge of the lead this may be less, or greater. Reference to good records may alert the architect to the chance of failure, due to age and wear, in a specific area of the roof. Where resources are limited and demands are great, well informed documentation will assist in good economy, giving guidance to likely needs and estimating costs.

Actual Repair

Since 1991 and the introduction of the Care of Cathedrals Measure 1990 there has been a legal obligation to maintain strict records relating to work carried out to the fabric. This is reinforced by the requirement to engage the services of a consultant archaeologist whose duties include ensuring a high standard of accuracy in all recording procedures, including records produced by craftsmen, conservators, and archaeologists. It is essential to establish a corpus of knowledge for future caring bodies. This may include methods of repair, as well as specific materials employed

The importance is underlined by the inability to draw information from past records. During removal of degraded stonework and rotten timber, for example, alien materials may be found which were used in past repairs. Thousands of iron wedges and cramps have been removed from the masonry of the Cathedral and it is as well to be on the look-out for them, as they do much damage. It is recorded that in the early 19th century, sandstone was brought to the area for the purpose of repair to the Cathedral, which has proved incompatible with the local limestone, as with Weldon stone used extensively in the early part of this century (see Fig 1.23 p61).

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[1] A retired Cathedral Works Department employee (Don Mann, deceased 1997) was provided with a set of blank tape cassettes and asked to reminisce. Valuable information was revealed about the methods of a campaign of cleaning to the Romanesque Frieze in the 1960s, which became material to the current programme of conservation, adding to records. He also gave information about regular cleaning of the interior of the Angel Choir, under Godfrey's instructions, using hoses, the stone slabs then being lifted to allow the water to drain away. This has major significance in that the east end of the Cathedral is constructed on soft made-up ground over the Roman vallum.

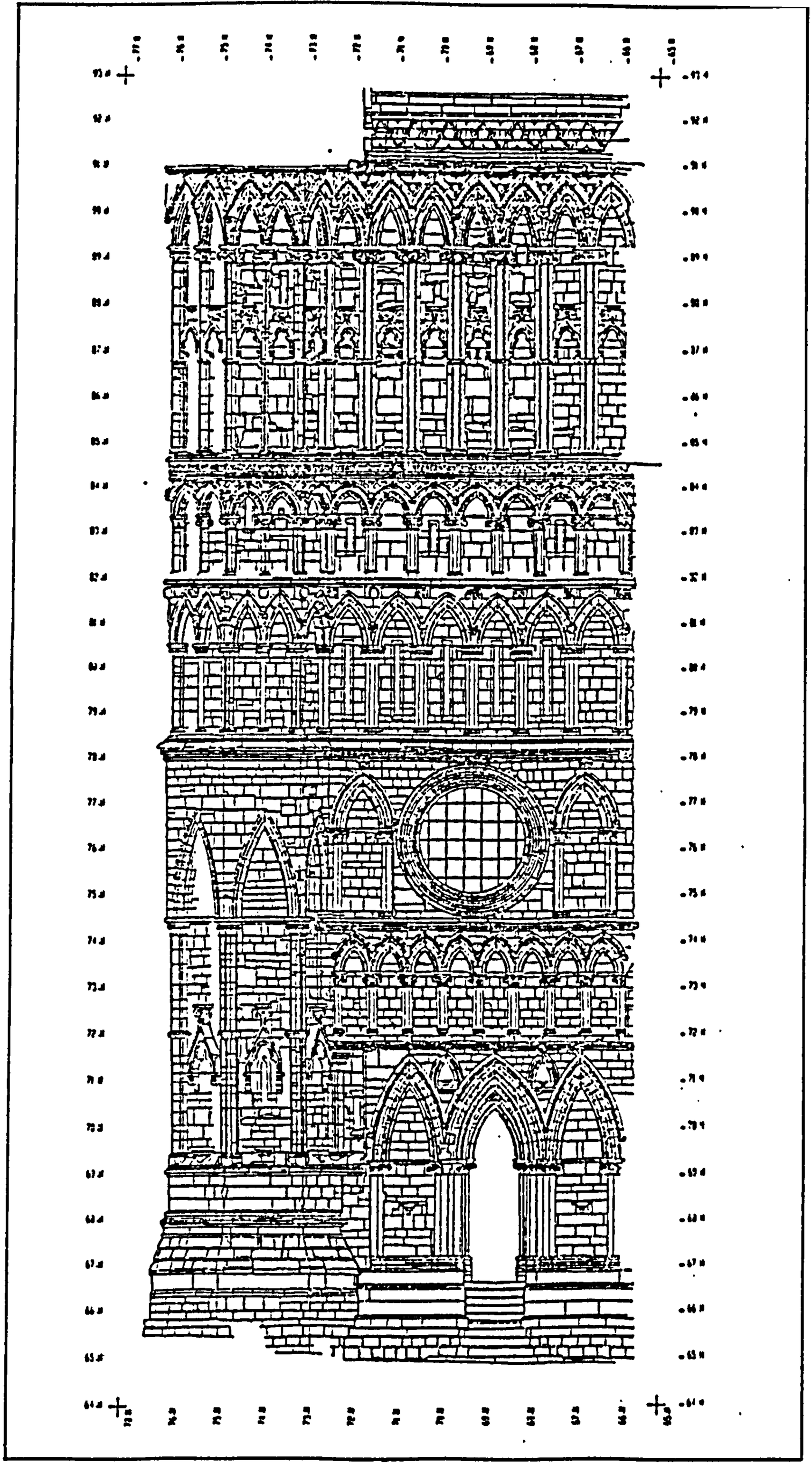

Fig 5.1 Photogrammetric drawing (Lincoln Cathedral Works Archive)

The Special Repair of the 1920s introduced massive amounts of rich Portland cement into the masonry core and although there is much recording from this period, the accuracy of much of this work is highly questionable[1]. However, the drawings, plans, and written reports provide some understanding of this dramatic intervention, and can save time and effort during later work. It would be invaluable today to possess knowledge of treatments executed by others, such as Essex in the 17th century, and Buckler and Pearson in the 19th century. Although Buckler wrote an account (2) of the restoration work carried out during his time, it is lacking in practical value

An Enduring System

Informative and impersonal recording may take the form of written reports, drawings and photography. This may be added to by video footage, CD-ROM, or any form of safe documented account. The key word is *safe*, since such material is to form part of the all embracing and permanent archive. As such, it will need to conform to archival standards of security. At the same time, for a building the area of a cathedral a coherent reference system will prove necessary, to which specific material may relate. Traditionally, this may have been a series of meticulously hand measured drawings, but these have been largely superseded by photogrammetric drawing.

Photogrammetry

Photogrammetry takes its example from the human function of seeing with two eyes. First use of the term was made by the architect Albrecht Meydenbauer in 1867, who adapted the technique from topographic map-making. Two separate images of physical objects are received by the brain and converted into a single three-dimensional image, providing a balanced perception of rounded objects in their setting and in relation to one another. Similarly, in photogrammetry two cameras are employed side by side, with slightly overlapping registration. This simulates how we perceive phenomena by eye, providing a more accurate stereo model than ordinary photography.

Once the stereo image is reproduced on film, it is fed into a stereo plotter where precise measurements can be established and coordinated. The images can then be reproduced as drawings, the contour of the image having been accurately interpreted and outlined through the stereoscopic viewer. Architecture has embraced the technique readily as a means of securing a reference for maintenance work. This has proved particularly useful at Lincoln, where the elevations are huge in scale and the area of the building vast, making it difficult to keep track of the condition of all its areas and features. Where conventional measurements may be difficult to obtain accurately, due to access problems, photogrammetry is very helpful since the survey can be carried out from a distance. Apart from the benefit of the drawings, the photographs are of such a high resolution that they themselves are useful in recording.

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[1] Much of the copious drawn and written record carried out under Godfrey's name (and signed by him) seems to have been done to support proposals, or to justify actions of work to the fabric, and does not correspond accurately to the state of the fabric damage as found, or repairs as executed. Unfortunately, this casts doubt on those drawings and records that are faithful to the facts.

There are three important considerations to be observed in the planning of a photogrammetric survey. The first is taking suitable photographs using appropriate equipment. 'For photogrammetry however we need to know very precisely the geometry of the camera, and for this reason we must use special *metric* cameras.' (3) Careful attention needs to be given to access and lighting conditions, which may demand standing time until circumstances are acceptable. Access may require purpose-built scaffolds, or the provision of a hydraulic hoist. An optimum distance is determined in order to obtain the most workable images. If the distance from the object is too far, 'the small distance between the cameras will produce a shallow stereo model with limited potential ability to define spatial co-ordinates accurately.' (4) Therefore a proximity of 10 metres or less is recommended for well defined results. Secondly, adequate three-dimensional co-ordinates at the site will ensure good references for later selection of scale. These may not be readily available, so an artificial reference can easily be set in place. Finally, the choice of equipment used in plotting is critical, as corrections in camera work may be needed, particularly where the camera has not been held perfectly parallel to the elevation. An *analytical plotter* has recently been introduced, capable of subtle adjustments using a reference point within the instrument to determine measurements in three dimensions, operating at a high level of precision.

Photogrammetric Survey at Lincoln.

At Lincoln a total programme of photogrammetry was embarked upon in late 1986,[1] and so far slightly less than half of the total elevational area of the Cathedral has been photogrammetrically surveyed, including the west front (see fig 5.1 p207), and the early thirteenth century rose window known as the Dean's Eye, in the north transept gable. The programme began under the auspices of the English Heritage Photogrammetric Survey Unit at York University, now moved to London. Survey work is carried out well in advance of plotting and drawing production and stored until required. The work is now commissioned on contract, and has been carried out by Photarc Surveys. For convenience the metric photography is gauged at 1:20 and the drawings produced at that scale.

Much of the work has been done from hoists, but in some cases, for example the facing elevations of the west towers, a team of 'access engineers', or abseilers, was commissioned to carry out photography whilst suspended from ropes. A prefabricated jig was made for the camera, so that its position in relation to the wall was constant, with the abseiler moving in drafts down the wall.

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[1] It was recommended by Lincoln Cathedral Fabric Council on 10 March 1986 that a sub-committee be formed to 'look at photogrammetry' as a way of providing a base for future recording to the fabric. The Sub-Committee consisted of Dr Lawrence Butler, Dr Philip Dixon, and Peter B. Hill, with Ross Dallas as Consultant. Their findings produced a recommendation that: 'Funding [be] sought for the Stereo Photographic Record of the Cathedral, [to be] undertaken sectionally and on an annual basis at a budget cost of £8000 p/a over an estimated period of nine years.' *Photogrammetry Sub-Committee for the Fabric Council, 12 June 1986.* It was proposed that this should be followed by an interior survey, both to be submitted to the National Monuments Record, now Royal Commission on the Historic Monuments of England (RCHME).

Advantages of the Photogrammetric System of Survey

Accuracy is the paramount quality of photogrammetric survey as well as its flexibility in operating at difficult sites. Inevitably, this method is compared with traditional measured drawing, carried out by hand and less costly. In many instances this would be the most effective method, for instance on areas of plain ashlar walling. Where complex areas of statuary or mouldings are to be recorded, the reverse applies. It is worth considering, also, the depth of detail which is available from the image, including a variety of choices of scale. This may be determined by the client beforehand, but according to need, can be altered during the project. In all cases, the level of photographic quality contributes to the conservation recording process, and can be printed on a one-to-one scale. The data gained may also be used in a computer aided design (CAD) system. The drawings are used as a tool to aid recording, the stones of the fabric being sufficiently clear to be discussed individually. The advantages of this system of survey seem easily to outweigh the disadvantages, which are mainly to do with cost.

Conservation Recording at Lincoln Cathedral

Almost all recording work is carried out by Cathedral staff, and is endorsed by the Consultant Archaeologist, Dr Lawrence Butler of York University. Specialist archaeology etc is commissioned as required, for instance through the City of Lincoln Archaeology Unit (CLAU). There is a grey area in distinguishing what recording is strictly the duty of the conservator and what should be done explicitly by the archaeologist.[1] The latter is technically concerned with the analysis of the evidence, but both conservation and archaeological records may serve both purposes.

Drawings

As a reference frame, the photogrammetric survey performs well, producing digitally co-ordinated drawings and photographs of high quality. Recording onto the drawings is done by conservators, and the team includes a trained conservation archivist. The drawings are initially rectified by the architect's office, by means of strict comparison with the architectural detail. Pre-treatment recording is then carried out by marking up a copy of the drawing using a colour coding system to indicate the presence of such evidence as the following:

- stone types
- replacement stones
- mortars
- metal fixings
- polychromy / surface decoration
- scaffold evidence (putlog holes)

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[1] It has been the experience at Lincoln that the level of accuracy of recording produced by conservators is generally higher than that expected of the archaeologist. It is more meticulous in presentation and accurate in detail, although it is appreciated that this may not apply generally and may only refer to the individuals concerned.

This level of observation is maintained and committed to the drawings throughout the work and the photogrammetric grid also provides references for identifying details. Supplementary drawings and diagrams are made as required, especially locating dragrams for hidden fixings etc or areas which are revealed during work (Fig 5.2).

Written Observations

All visual records are accompanied by meticulous written accounts of the condition of the area to be worked on, together with treatment proposals, and subsequent treatment reports. Condition reports follow a consistent format detailing location, reference number, dimension, materials, previous repairs, damage and decay.

Photography

All areas where work is carried out are photographed in 35mm black and white, and colour prints, and 35mm colour transparencies. General and detail shots are taken, before, during, and after conservation work. photographs are also keyed into the photogrammetric grid.

A Recording Policy

Recording policy documents at Lincoln have applied to individual projects, such as the Romanesque Frieze, the Dean's Eye window, and other important programmes of work. These have required individual approvals from the CFCE and, where grant funding was concerned, with EH. A unique policy has yet to be devised for the fabric of Lincoln Cathedral, although in determining details for the complex projects mentioned it can be stated that a consensus exists within the Works Department. Following a survey of the fabric of all cathedrals by Harry Fairhurst in 1991, as an exploratory study leading to Government assistance in cathedral repairs, a document was jointly issued by the CFCE and EH. This report, *Cathedral Fabric Records,* (5) which is intended to promote good practice, is an effective and solid working reference. Not all cathedrals possess the space or resources to establish a permanent archive, and the recommendations take note of such circumstances. The document states four principal terms of reference:

- To consider the location, cataloguing and storage of existing records of fabric repair.
- To evaluate the need to create new architectural and archaeological records.
- To consider the types of levels of recording necessary.
- To make an overview of resources available to progress recording.

At Lincoln all the recommendations within the report are embraced, with minor modifications only between the poles of the ideal and the realisable.

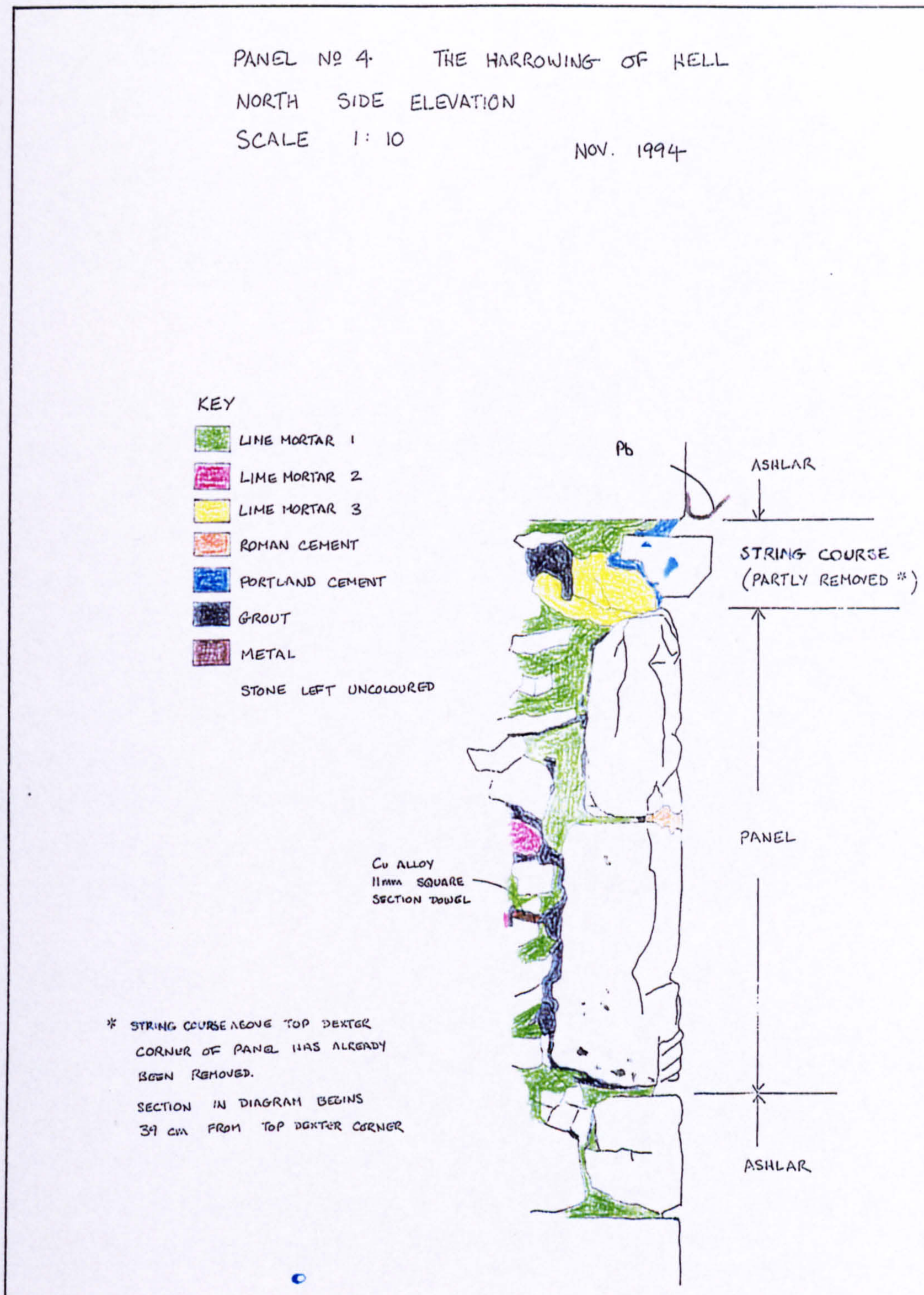

Fig 5.2 Conservation drawing of Frieze panel condition, north side elevation (Lincoln Cathedral Works Archive)

Lincoln Cathedral Works Department Archive

The Works Department Archive is distinct from any other, including the main Cathedral Archive situated in the Library, although it forms a part of this. It was set up to safely store records created by the continuing programme of conservation on the Cathedral fabric and the Close House properties, some of which are medieval. It forms an integral and essential part of the in-house maintenance facility, and is housed in what was purpose-built as the Clerk of Works office in 1929. This comprises a two room extension to the old Clerk of Work's residence, built originally as a public house in the eighteenth century. Many original wooden fixtures and fittings survive and are retained.

A large amount of paperwork survives in boxes, drawers and cupboards, including ledgers, photographs, and previous records and drawings of earlier work. Most of this originates from the late 19th and early part of the 20th century, up to the time of the Special Repair Programme of 1922. There have been one or two half-hearted attempts to index photographs and slides over the decades, but in the main this bulk of data can be regarded as a back-log, at some stage to be catalogued and collated. Combined with the current output of recording, including a constant supply of drawings, photographic prints and slides, and reports, the back-log is substantial. Bringing this space into the 20th century and simultaneously retaining its essential historic character has proved to be something of a struggle. However, the rooms have been sympathetically converted into a functioning archive with a modern system of controlled heating. Since 1995 the two rooms have formed a workable space, with a full-time conservation archivist in station, complete with a computer data base.

Intentions of the Archive

It is the principal aim of the archive to provide a secure and accessible repository for all forms of records and documentation associated with the Cathedral Works Department maintenance programmes of the Cathedral and the precinct houses. This includes selected data generated by the Department, including correspondence, and surveys. In the long term, this may include a limited materials reference library, with samples of glass, wood, lead, stone and mortars. A small library of technical books and personal records exists in the archive, which will be added to slowly.

Practical Operations

A functioning archive relies on clear liaison and communication between the individual working groups, ie joiners, masons, glaziers, conservators etc, and the archivist. It is the responsibility of each working group to maintain correct recording levels, as it is they who generate the work and are most aware of the timing of the operation. This must be effected chiefly through the relevant foremen and the archivist, but with support from the individual craftsperson. Matters relating to the deposition and retrieval of documents is therefore everyone's business.

The difference between 'dead' and 'live' material requires distinction, with inactive documentation, ie not in regular use, being regarded as fully archival material, as opposed to working documents. At this stage, it has proved appropriate to organise such data to be transferred to the permanent County Council Archive. If the business of caretaking a cathedral can be defined as containing a series of micro-crises, within the major framework of the fabric and its activities, then the nature of the documentation retained should reflect the likely needs of future caretakers. Major calamities do occur, but they are uncommon. Such an instance was the fire which seriously damaged the south transept at York Minster in 1984. With such a vast and ageing structure, minor needs often arise and it is important to be able to call upon good records to contend with them. Constant weeding of documents is necessary both to maintain a workable space, and so that the interpretation of live and dormant information can be easily made.

The Archive Environment

There are three main threats to the welfare of archival documents. These consist of exposure to light, and fluctuation in temperature and relative humidity (RH). Documents are generally made of paper, the deterioration of which may be accelerated by an intrinsic lack of stability. Therefore it is most important to maintain an environment that is clean, dry, cool and dark.

Since the archive consists of a mixture of materials, including wood, paper and photographs, the RH is kept at around 50 - 55%, ± 5%, with the temperature attempted to be kept below 20° C. Readings are taken on a regular basis and at a fairly low cost by using a whirling thermo-hygrometer, although a thermo-hygrograph would be preferable. Emphasis is placed on the environment being constant, both with respect to the RH and the temperature. Fluctuations in these conditions inflict greater damage than constant conditions that are not ideal. Inappropriate conditions may encourage biological growth, embrittlement etc.

General cleanliness and good housekeeping help to reduce the threat of insect infestation and a regular inspection is kept for insects and other pests. Attractant insect traps can be laid, even when there is no sign of infestation, since insects can damage items of paper and wood. Light energy may harm documents, so all archive material is kept in closed storage, making general light levels less critical. Levels of between 30-40 lux are recommended for temporary exposure.

Archival Storage

The preservation of documents begins when they are deposited in the archive. Here, all the materials used to store records are of archival quality, that is they are acid-free and chemically stable. The bulk of records are of paper and photographic prints and slides. Their safe storage includes interleaving between fragile pages, the lining of cupboards, drawers, and boxing with acid-free tissue, paper or card, as appropriate. Clear polyethylene or polypropylene enclosures and folders are also used where support is required. The longevity of photographic prints is further

enhanced by the use of sulphur-free coverings, and the conservation archivist will make customised enclosures for unusual sized records. As documents are released for consultation, consideration is made to the above methods of caring for them. In a permanent archive store, the other obvious threats are from intrusion and fire, and alarm systems for both threats are installed.

Retrievability and Establishing Secure Copies

A developing archive might be described as having an organic quality, permitting change within its structure. It relies on a coherent and comprehensive cataloguing system, identifying knowledge of both its contents and its deficiencies. Consistency in approach will ensure its preparedness for use, since the archive facility must be relied upon in matters of varying degrees of importance, whether it be routine planned maintenance or catastrophe. Standardised methods of archival procedure enable more efficient communication of information, for instance between archives, as does use of a data-base, CD-ROM mass storage methods, and the adoption of other digital capture systems. These will also facilitate the efficiency of consultation of information by users, both within the Works Department and others, such as CFCE or EH. At the same time, this restricts handling to either purpose-made copies, or by scrolling through the computer, thus safeguarding the original copies. Finally, as a security measure against disaster, selected key reports and other records are copied to be stored elsewhere. Second copies of essential documents at Lincoln are sent to the RCHME. If a document is of particular significance, a third copy may be sent to the Lincolnshire County Archive, to cover the transit period between the original becoming dead material and being passed on.

Part 5.2 Masonry Practice

Comments on the Current State of the Craft

Modern technology has influenced the stone industry, with only the material seeming to remain the same. Where the craft is practised in an environment such as a cathedral, there have on close examination been less fundamental changes. There is no mystery to the craftsman himself, a man relying on his skills to earn a living, working principally in the quarry, workshop, on the site itself, or a combination of all of these areas. Whereas the medieval mason would have possessed hundreds of fire-sharpened chisels, many of every size and each hand-made, constantly requiring resharpening or retempering, these are now often replaced by just a handful of durable tungsten-tipped favorites (Their cost alone is sufficient to prohibit a larger selection). The cherished mallet, once cut from a selected piece of apple or cherry wood, can now be replaced by one made of nylon, having a long life-expectancy. This applies only where compressed air tools are not used. On the scaffold, constructed today from iron or alloy, rather than wooden poles lashed together, electrical or air-powered hoists aid the fixer. Health and safety rules now apply strictly to every member of the operation, on both a professional and practical level.

In the commercial sector the demands of progress have exacted a greater toll on the stone industry, as has happened in other disciplines. Profit is the prime motivating factor, with quality often being the first casualty. In projects involving new building, the high cost of hand-dressed stone can be prohibitive, persuading it to be replaced by cladding and systems building. Here, machine-worked blocks, or even reconstituted materials, are utilised. There is frequently found on sites, a tacit policy of taking short-cuts, leading to the use of power tools, such as angle grinders and power hammers. These are used to trim newly worked masonry, to cut out old masonry, or to open up masonry joints for repointing. They are difficult to control and can easily overrun (and are in fact difficult to prevent from doing so), scarring the adjacent stonework, or creating stress along lines of natural mineral weakness within the stone, such as iron or clay beds (see 2.2 *Inherent Weaknesses*). The seal of nearby mortar joints, perhaps not requiring attention, can be inadvertently disturbed by the insensitive use of power equipment.

In the context of repair and conservation of historic buildings, the many books and manuals of instruction relating to stonemasonry are a poor substitute for a thorough training and beg the question to whom are they directed? The seminal work *Modern Practical Masonry* by E.G. Warland (6) has been the Bible of the masonry industry since the early part of this century and as such has formed the basis of many current courses of training. This book responded to the demands of the day, which were for methods of construction using stone around steel frames. It was for the industry a period of prodigious development. Much of the instruction outlined in this manual refers to the expanding industry of civil engineering, building around iron frames, with machine cut masonry. In context, Warland updated the earlier work *Practical Masonry* by William Purchase, (7) which was also an excellent work of its day, contributing to the mainstream of

Victorian masonry construction, and with a chapter on Gothic mouldings that is still useful today. Suffice it to say, that in the early part of this century Purchase's book was inadequate to contemporary needs, and required updating, just as Warland's views are outdated today. A more recent book *Practical Stone Masonry* by Hill and David,(8) both at one time employees of the York Minster Stoneyard, makes more appropriate reference to the repair and maintenance of historic building fabric. There is, however, a disappointing reluctance to align the traditional craft with the developing disciplines and perceptions of conservation; making only a fleeting and rather dogmatic allusion to the philosophy of repair. It is taken that the ethics of replacement and repair are transmitted through generations in the traditional manner, without recognition that recent fundamental demographic and social changes, have severed the tradition of tradecraft being handed down from father to son or tradesman to apprentice. Although the book is a comprehensive and intelligent appraisal of what a thriving industry might require, its weakness lies in its unwillingness to entertain new ideas. What is required is a clear view of what actual needs the stone industry must serve, so that relevant training demands may be clarified. This will itself provide sustenance to the tradition of stone masonry by aiding it to develop (see Part 6.0 *Conclusions and Recommendations*).

Setting Out

This aspect of the maintenance of stone structures is often felt to be the nerve centre of masonry as it is essential to the control of quality. It involves the making of sympathetic full-scale drawings, with all errors and difficulties of replacing elements eradicated during working out on that drawing (Fig 5.3). When individual stones are cut, they should match the dimensions of the drawing precisely.[1] Masonry is a complex trade since it uses as its building module elements carved from solid blocks of stone (referred to as stereotomy), each module demanding the highest level of skill in technical drawing and execution. The erection of these elements into architectural structures requires a separate but equal skill to working the stone, both necessary to the skill of a stonemason. The reference point for all stages is the full-scale drawing.

In the masonry trade at large, it is most often the discipline of setting-out which is dispensed with. The taking of dimensions from the existing decayed stone is frequently guessed at from a distance and the making of templets (moulds) is often given little credence. Masonry contractors, ever under pressure to maintain a profit, may save the rental cost of a scaffold at the expense of accuracy. The same contractor may use less expensive cardboard for templets, even for repetitive

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[1] Chapters on setting-out can be found in all three of the books previously mentioned, but again it is only the volume *Practical Stone Masonry* by Hill and David, London, Donhead, 1995. that addresses work to historic buildings. Even so, instructions on setting out persist in drawing a ramp and twist staircase, which is of the highest difficulty. The successful accomplishment of such an exercise is held in high regard within the trade, although the opportunity to actually build one must be rare indeed. Justification for this level of exercise, given by Hill and David, is that the temptation to simplify replacements must be avoided, and a high level of setting-out ability will discourage this.

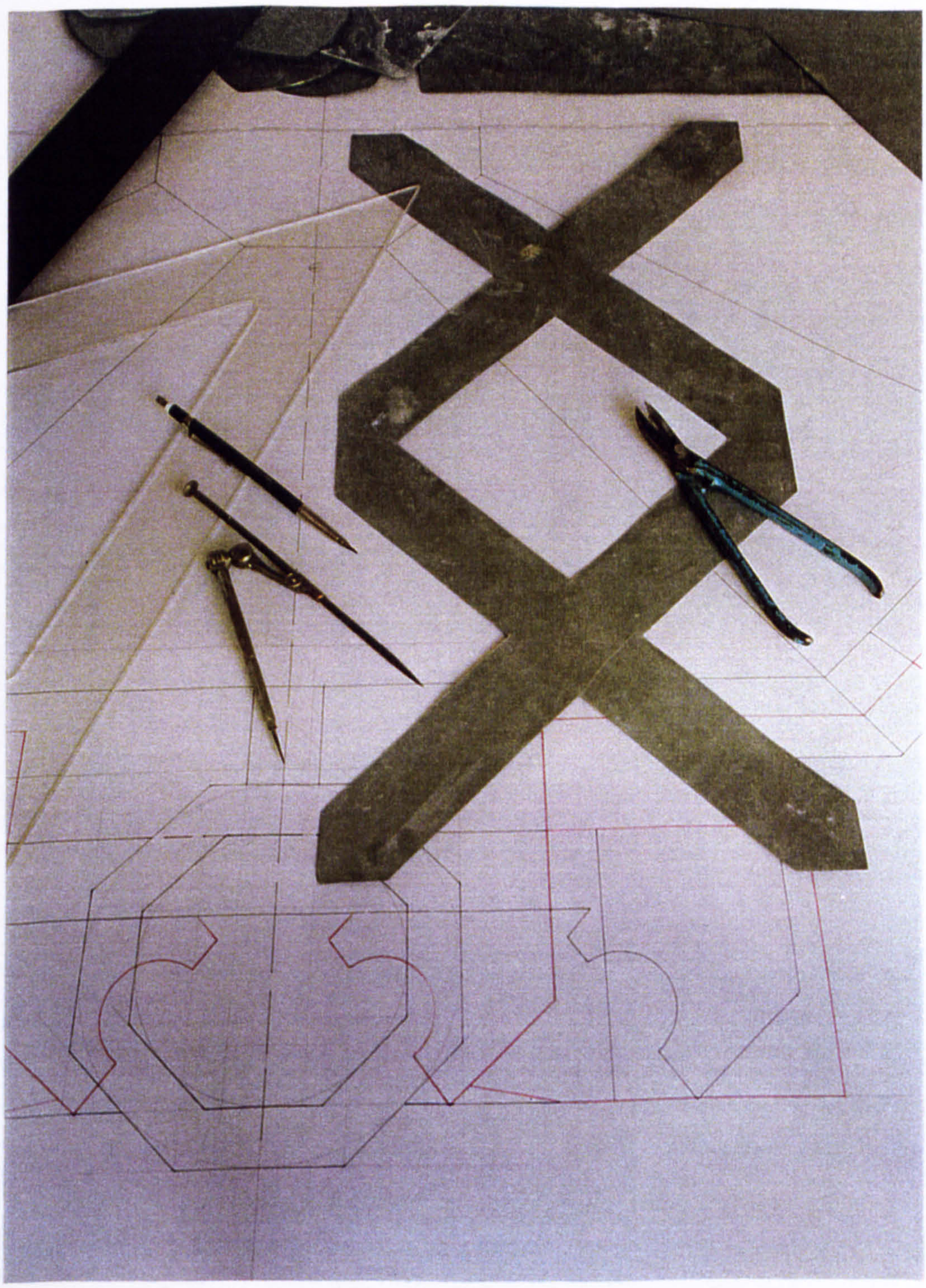

Fig 5.3 Setting out drawing of the replacement pinnacle on the south transept, with drawing implements and zinc mould (templet).

runs of moulding. Stones are brought in from the wet atmosphere of a sawyer's shed and the moulds placed on the stone, maybe overnight. After a short time, the true form of the intended pattern is lost. Zinc is the correct material for moulds, since it will not easily deform and an accurate and smooth profile can be drawn around it without hard scribing along its edges distorting the shape.

The skill of setting-out demands an intimate knowledge of geometry and a sensitivity to the thinking that went behind medieval design, with nothing being taken for granted. Correct replacement, for example of a section of cornice, may be hampered where it is the only original stone left, and may require scrutiny in other areas of the building in order to establish a feeling for the design,

> 'The great mistake of the Victorian restorers was to reduce everything to a series of rigid conventions. Never assume that two mouldings on the same feature are the same, even though they may look the same.' (9)

The same rule applies to mouldings and carvings as is instructed in the above quotation. There is generally sufficient detail and evidence for adequate detection of a moulding around the area for an authentic replacement to be drawn. It is often necessary, in order to establish the missing element in context, to draw not only that stone but also the surrounding are, a task that may well be worthwhile and does not take long. Full scale drawings may be useful for both architect and engineer, presenting a more realistic idea of scale and detail than scale drawings, as well as forming a permanent archival record in themselves.

The Banker / Fixer Mason and his Environment

In broad terms, there are two areas of the very wide discipline of stone masonry which affect the care of a cathedral. These can be described as work associated with the banker, (like many masonry terms of French origin, *banque* meaning bench) and the fixing of finished stones into the building. In conjunction with both these sets of duty is the practice of setting-out. Such a tradesman is therefore referred to as a banker/fixer mason and carries out duties in the workshop and on the fabric of the building.[1] The banker shop will be well illuminated in the interior, preferably by daylight, so that the mason's work can be viewed in dramatic light, offering clear definitions of the lines to be worked. Bankers may comprise of a single large block of stone, flattened to form a work surface, upon which a length of 'softening' or carpet is placed to protect the edges, or arrises, of the stone as it is moved around. The banker may be constructed of balks of timber, but should be sufficiently sturdy not to vibrate or shift as the stone is being worked (fig 5.4)

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[1] At Lincoln the mason will also work on the saws and will at times be engaged in quarrying. In this respect, the mason may follow the stone throughout the entire process; from the ground, through the primary and secondary sawing stages, sometimes being called upon to set-out the moulds, or templets, to working the stone, and finally to fixing it into the building.

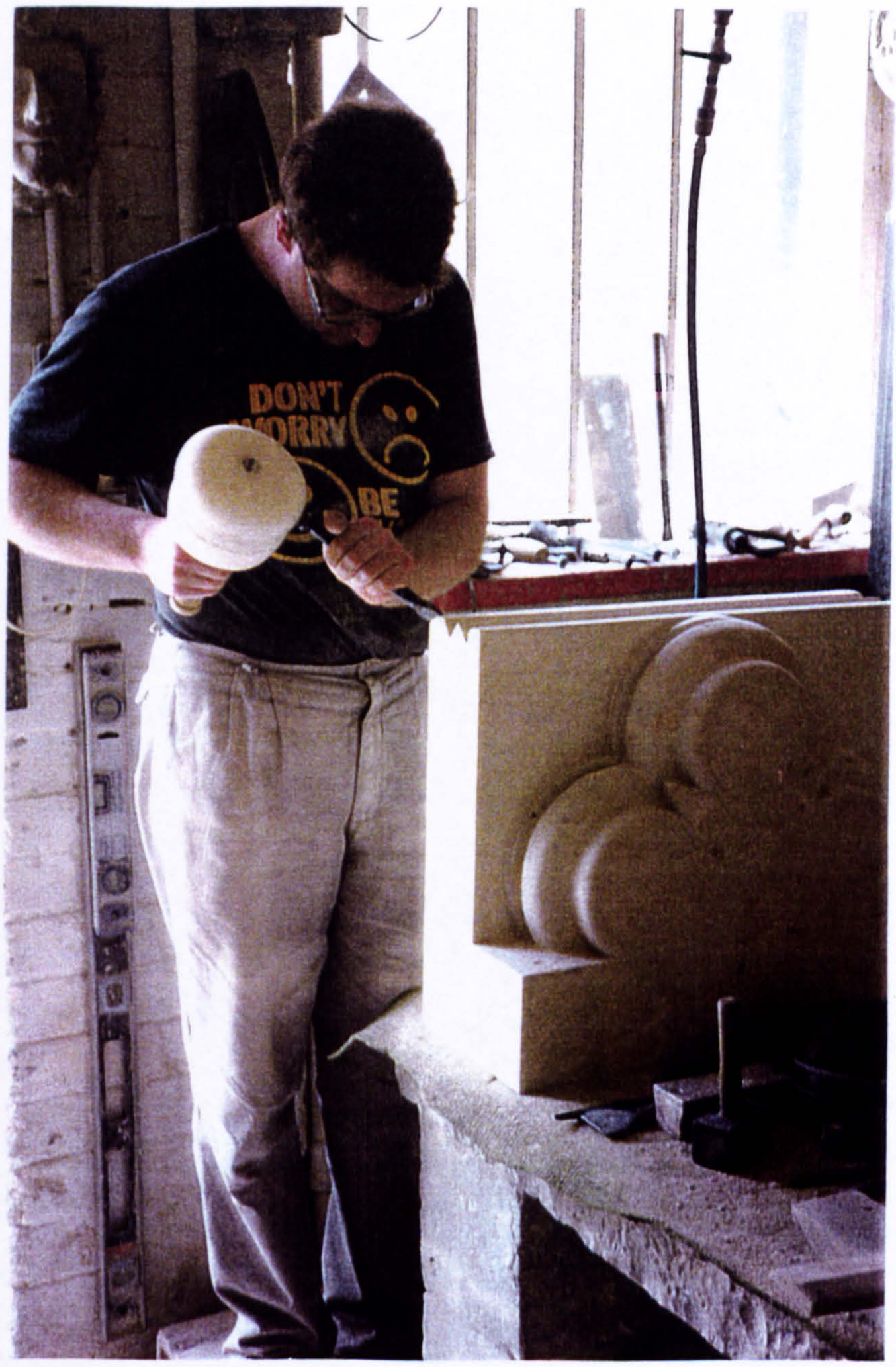

Fig 5.4 Banker mason at work with nylon mallet, on a rigid banker under clear light. Note carpet softening. (Lincoln Cathedral Works Archive)

Adequate lifting facilities for a wide variety of circumstances should be available, so that the stones may easily be moved around without endangering either physical health, or stone. In lifting, physical strength is the last resort, there always being a stone to come which is too heavy to lift. Stones move through an endless variety of shapes and sizes as they are worked and the workshop will naturally become a store for a range of implements peculiar to the work in hand, and the particular local methods of the team of masons. These may be wooden blocks, wedges, rollers (lengths of heavy duty wooden dowelling used to manouevre stones along the length of the banker or scaffold). Such aids may be home-made and are often not commercially available. 'Millers', for instance, are circular pieces of flat timber upon which the largest block of stone will spin with a minimum of effort, and are indispensable to a mason's work.

Modern health and safety regulations are keen on countering the dangers of stone dust, although masons have often adopted a cavalier attitude to this over the years. All limestones contain silica,[1] which is particularly dangerous to the respiratory system. Where environmental air control and dust extraction is lacking, personal safety wear is a must. The law is always developing its view on these issues, making sometimes burdensome safety equipment a legal requirement to the benefit of all concerned. It should be borne in mind that personal protection is the least effective method of safety in such circumstances.

Masonry Tools and Methods

The mason must today be prepared for work both in the workshop and on the scaffold. In the banker shop the mason relates primarily to the block of stone and the relevant moulds provided, whereas on the scaffold his relationship involves the stone in the context of the building. Simplistic though this explanation may seem, it defines the mason's need for almost two complete sets of tools. On the banker he will mainly employ compass, square, mallet, chisel and straight-edge, whilst on the scaffold he is more likely to require hammer, punch, trowels and larger straight-edge. The mason's kit of tools is extensive and can never be considered complete. Working in the framework of a Gothic cathedral, almost every job is a 'one off' and might sometimes require the manufacture of a peculiar tool, maybe to gain access to a particularly inaccessible corner.

Contrary to the approach of a sculptor or carver who may work directly into the rough block, the discipline of the mason is fundamentally confined to following scribed lines and the working of flat surfaces. Curved work is achieved in the same way, with a continual working of flat drafts around a curved profile until the facets are so reduced that they form a curve. The mason's collection of chisels are for this reason different from those of the carver, who works altogether more freely. The mason will possess an array of flat tipped chisels, from two inches (50mm) down to an eighth of an inch (3mm). The broader bladed chisels are known as boasters, which according to Portland

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[1] Lincoln limestone contains between 1.5 and 10 per cent silica, which is especially high for a limestone.

masons are so named to mark the accomplishment of their successful use. A mason will also have a broad selection of larger gouges, for the purpose of working hollow mouldings. Roughing out the block of stone, once the main waste is removed by saw, is carried out manually with a mason's hammer and punch, the size of the latter being appropriate to the mass to be removed. Once the waste is worked off in drafts closely parallel to the designated plane, a claw tool is then used to come even closer to the outlined surface. The final tooling is achieved with a boaster, or fine chisel. The expertise of the mason can to some degree be discerned by the fine rhythm of the tooling marks on the finished stone face.

Masonry Repair - Conventional and Combined with Modern Engineering

Traditional practices of maintenance and repair are those adopted by most cathedrals[1] No threat is offered to the structure in conventional replacement by way of differential behaviour of materials and, provided that the stones, the mortar, and the skills employed, all operate within the tradition of original construction, repair should be compatible and long lasting. However, it is worth considering a range of options which lie within the ethos of the original processes of construction, which may be enhanced by modern engineering wisdom.

Initially, all proposed work commences with a fact finding venture. In the best of circumstances this would be an amalgamation of the views and experience of three key figures, and collated by the architect. These are the architect himself, the engineer, and the mason, the latter of whom must embrace the design point of view together with an intimacy of the mechanics of masonry. For his own part, the engineer will have his particular method of reading and analysing the conditions, restricting his notations of circumstances to the structurally relevant and comparing his findings with the architect's knowledge of design. From this, the architect will be appraised of what the structure can tolerate and how suggested repairs can actually work without adversely affecting the design concept of the building. The mason will have knowledge of what is practically achievable and advise on how proposals can be realised.

Once stone in a building has lost its structural integrity it becomes eligible for replacement or repair so that the safety of the whole structure is assured. There can be no strict decision-making rule in this since circumstances vary. Added to this may be the art historical or archaeological value attached to the stones. A 19th century ashlar may not have the same value as a piece of Romanesque carving, though its structural importance may be similar, or greater. If a valuable piece of stone is in danger of being lost due to degradation, this may be justification for its removal for safekeeping to a lapidarium or museum. It is important when assessing stonework for repair that the larger context of the structure and its stability is considered, together with the compatibility of the proposed treatment. The circumstances determining the fate of eroded or damaged areas of

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[1] At Lincoln traditional masonry practices were interrupted in the early 20th century at the time of the Special Repair, but were effectively reclaimed, more or less, following the death of Robert Godfrey in 1953. (see 3.1 *A Legacy of Repair*).

stonework are limitless, but once the decision is responsibly taken, the work needs to be facilitated with confidence. Buildings are not safe enduring temporary large holes in their walls during partial dismantling, and benefit by swiftness of repair in combination with the correct skills.

Contending with Cracking in Masonry

Tolerable cracking can be regarded as the natural state in masonry (see 1.2 Common Symptoms of Failure in Walls), but beyond the level where displacement creates significant bulging in walls more radical rebuilding may be required. In all cases, it is important that the wall arrangement, ie an inner and outer skin with core filling, is regarded as a single entity. Where possible, conventional masonry repair is preferable, since this is most compatible with the original form of construction and is less likely to conflict with the traditional structural system. In extreme circumstances of cracking, a combination of localised replacement of stonework, combined with some reinforcement using grouted non-ferrous bar and anchor arrangements, will normally be acceptable, and will restore structural balance. Where such a combination of techniques is employed, great care is required to ensure compatibility, so that weaknesses do not develop at points where loads are transferred.

Removal of Decayed Stonework

In many cases, stones to be removed are dispensable and may be chopped out destructively, relying on the skilful use of a hammer and punch, and the judicious use of the mallet and chisel. Where old mortars are tenacious there may be a danger of plucking the edges of the adjacent stone. To avoid this, the mortar joints can be cut away with a sharp chisel, working away from the stone. Once the neighbouring stones are so 'relieved' the mass of the stone may be chopped out with a punch. Where the old ashlar is a through stone, forming a dressed face on both external skins of the wall, or at least set very deep into the wall, it is not normally necessary to remove the entire stone and is generally preferable not to do so. A good working rule is for ashlars to be replaced at between 6" (150mm) and 8" (200mm) on bed, depending on their function. Slightly more than this depth will need to be cut away to leave room for the mortar bed. Where the stone to be removed is to be kept, needing to be painstakingly released from the enclosing mortar, a thin and sharp cutting implement such as a tungsten hacksaw blade is useful to cut around the joints. The stone can then be dislodged from its backing mortar and gently eased forward. Wedges, inserted in the joints, will prevent the sudden release of the stone from falling and snipping the arrises below.

Fixing Replacement Stones

Once the old stone is removed and the receiving hole is prepared, the new stone is ready to be fixed. This means that all the five inner surfaces of the hole are free from obstruction and the new stone will fit without force, sufficient room being left for the mortar bed. The surfaces of the hole must be free of dust and pre-wetted prior to the application of mortar. The new stone is eased into place so that the face is in line with the surrounding stones, the fresh mortar squeezing out.

Parallel joints comparable with those in nearby original stonework are then established.[1] It is then thoroughly wiped clean, preferably once the mortar has undergone its initial setting with fresh, uncontaminated water. Most masonry joints on ashlar walling are flush jointed, i.e. without protrusion or recess, but this will depend on the building being worked on and the instructions of the architect. It is important that rain water is allowed to run freely across the face of the stonework, with the joint not acting as a collecting point. If the stone being replaced is moulded, the salient points and facets of the moulding should correspond to the adjacent stones (fig 5.5).

Piecing Stones

Letting-in slips of stone into running mouldings, referred to as piecing, may be regarded as a somewhat questionable practice, but is requested constantly by architects and others (this practice is recommended by EH) and may be regarded as justifiable in certain circumstances. It is a compromise between saving a partly damaged original stone and replacing it with a new stone.[2] There are many so-called 'stone glues' commercially available today, which are comprised in the main of polyester resins. The life of such adhesives is uncertain, but they will certainly eventually fail. For this reason, they ought to be used in conjunction with dowels, or cramps. It should always be recognised that it is best practice, wherever possible, to bed stones into the building using traditional lime mortar, observing local characteristics of stone size and jointing patterns.

Grouting and Stitching

The use of liquid grout used on its own or in combination with repair and replacement of stonework, or stainless steel bar and anchor reinforcement, can in almost all circumstances be considered a worthy option, so long as correct mixtures and skillful application is employed to assure the efficacy of the operation. No matter how solid or stable a masonry wall may appear, there are many avenues of access through which water can penetrate, degrading the lime mortar and rubble core, even washing away the bedding joints between stones. Blocked up gullies and other weathering features can lead to untold damage, water travelling through the core from the gutter to the ground.[3] At the very least, voids will be created within the wall, introducing weakness

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[1] Joint widths vary from early Norman to the various stages of Gothic stonework, and visual compatibility will provide the most satisfactory finish. Often, joints that have been raked out repeatedly over the centuries may appear thicker, but are tighter immediately beyond the face.

[2] According to an unpublished paper written by Roger Harris, repairs were frequently carried out in this way in medieval times. Harris describes evidence of the practice found at Wells Cathedral, where stone was pre-heated and a mastic applied as an adhesive. There is also much evidence of similar medieval piecing on the tympanum of the Judgement Porch of Lincoln Cathedral.

[3] In 1993, work commenced on the north east triforium parapet of Lincoln Cathedral where water had been penetrating under the lead sheeting. It was discovered that this situation had been occurring for many years and water had entered the core of the ashlar. Further investigation showed that moisture and soluble salts had reached the Burghersh monument at ground level, with a great deal of damage being incurred. This eventually resulted in the monument, a chest tomb built into the north wall of the Cathedral, being totally dismantled and treated, before being reassembled.

Fig 5.5 New hood moulding fixed into old element. Note the correct alignment with salient points of the moulding

with pressure being unevenly passed to the outer skins of the wall. Cavities may exist due to constructional error, such as putlog holes, or because of subsequent deformation. It is safe to assume that a traditional masonry wall, relying on compression, needs to be constant throughout.

The objective in grouting masonry is not to restore the core to a new state. This cannot be achieved, nor can it become a perfectly stabilised and entirely grouted, but the carefully considered repair of the wall is a worthwhile goal in helping to preserve the entire valuable original structure. As such, the question of survey, analysis, and assessment assumes importance, since the accuracy of the operation will correctly locate the specific areas to be treated. The principle requirements of grouting are to close existing voids within the masonry core, to add strength to loose elements within cavities, and to replace areas of missing or degraded mortar. It may be necessary to secure reinforcement bars and anchor ties to the masonry and defend them against corrosion. This will permit the safe transfer of loads, through the entire section of the masonry wall, as well as contending with whatever new forces may be introduced into the structure.

There are a variety of grouting methods and materials, and reference to part 3.2 will illustrate that not all of them are sympathetic to medieval masonry structures. Pressure grouting has a place in repair work, particularly where deep penetration is essential, for instance in work below ground. There are methods of hand pump grouting, which are not so aggressive as those working from compressed air. It is worth noting, however, that gravity grouting where the weight of the grout itself forms the pressure, is usually sufficient to force the grout into interstices in the core that are far from the point of access. This point may either be a natural fissure in the masonry, or a void where stonework had been removed, or it may be necessary to discreetly drill a hole specifically for the grouting operation. In extreme circumstances, a regular system of grouting points may need to be made to ensure consolidation in the core. In the case of replacement stonework, an opportunity exists to introduce grout if voids can be seen in the core.

The drilling operation is rarely straight forward, the inner core often tending to cave-in, or collapse once the drill bit is removed. However, much can be learned during this operation which may affect consolidation. Knowledge of the cavity within can influence the level of aggregate in the grout, since an indication will be given of the proportion of lime mortar to masonry. Such indications will be given by the ease of drilling, or otherwise; difficult drilling, with continuous slipping and damaging of the drill will indicate a higher density of stone in the core, for example. Where water flushing accompanies drilling, some indication of cavity size will emerge. A final view into the drill hole may be taken with a torch, or endoscope.

A major problem in ensuring the efficacy of grouting, whether a gravity or injection method is employed, is in balancing the quality of flow of the grout with the number of holes drilled in the precious fabric. Achieving a high flowability will provide a more convincing reach within the core, but may mean introducing greater quantities of water into the mix, which will reduce the

effectiveness of the mortar and water suspension. This ultimately lowers the ability of the grout to fill voids, its primary purpose. Following drilling, the flushing of the cavity with water prevents the grout from thickening as water is drawn from it, and the flow performance is then consequently improved. An indication is given by the returning water of the porosity of the masonry, as well as where leaks might occur. The purer the mixture of the grout, in other words the greater the proportion of binder to aggregate, the superior the flow, but the poorer the properties of cavity filling. A range of recipes for varying conditions is useful, and in the case of injection, the pressure must rely heavily on the skills present and cannot be standardised for reasons of safety to the fabric. Generally, a constant and light rate of flow is the desired action.

Where masonry conditions cannot withstand normally acceptable loads, including limited tensile forces, 'stitching as subsequent reinforcement' (10) may provide a solution. Such strengthening is always grouted in place and connected to both outer skins of the masonry, extending through the core and preventing spreading at the cross-section of the wall. The reinforcement bar is usually threaded stainless steel between 8 - 20mm in diameter. The grout bonds the anchor points to the outer masonry, simultaneously helping to protect it from corrosion.

Prestressing Masonry

In the case of an 'engineered' solution to masonry problems, the imposition of a separate rigid structure using different materials, poses a danger in creating tensions at points where forces are transmitted. 'Discontinuity in the flow of forces, alterations in the existing structural systems and local differences in rigidity could lead to shifts in load transfer that inevitably become visible as cracks.' (11) In other words, no matter how powerful a new system may be, much relies on the points of contact with the ancient structure, specifically where forces are expected to be passed. An alternative consideration in repair of old masonry is to prestress those areas likely to endure tensile forces by inserting threaded bar with anchor ties and imposing the optimum loads expected, prior to the masonry taking up its position in the building. This is solely recommended for local areas of degraded masonry.

A Note on Handling New Stonework

It is a general misconception that stone is extremely difficult to damage. In fact new stonework is easily damaged if it is not handled skilfully. As well as becoming mechanically damaged, new stone will be highly susceptible to staining and damage by rain and frost. Sensible storage is therefore essential to the ultimate quality of the job, being off the ground with the stones stacked separately on even timbers, so that the air can circulate around it. This will preferably not be in contact with, or near, rusty ironwork, or any timberwork which is likely to stain, such as oak. Where new stonework is handled, there cannot be too much 'softening', which may be squares of old blanket or carpet, polystyrene, or quantities of packing straw. The latter observation transfers to the process of lifting with slings, when the weight may bear on the vulnerable arrises of the stone. Softening cannot be recommended too often, with slings having canvas sleeves. If slings threaten

to damage the fragile arrises, wooden packing can be deployed to force the slings outward and away from fragile corners. Specific tools designed for the lifting of individually worked stones, using a prepared hole in the stone so that the arrises are untouched are called lewises and come in a variety of designs and sizes.

Case Study: Replacement of Two South Transept Pinnacles

An Outline of the Work

In the winter of 1989/90 the impact of gale force winds against the Cathedral created a catalogue of damage, including the tearing of lead roofing sheets from their fixings and the loosening of some exposed masonry features. Two pinnacles on the great south transept could be seen 'dancing' in the high winds, relying solely on their centre dowelling to prevent them from total collapse. As an emergency measure, both pinnacles were dismantled down to approximately three courses above the springing point at the junction with the shaft. Reconstruction was not commissioned until three years later, when it was convenient to enter the work into the long-term programme. In the event, it was decided to modify the design of the pinnacles and to employ combined traditional masonry and modern engineering solutions to reinstate stability to these structures. It was felt important to keep within the original ethos of construction. On examination of recorded evidence and by inspecting the pinnacles of the south and north transept, the view was formed that the pinnacles were of 18th century origin (Fig 5.6).

Conditions Discovered

These pinnacles and the corresponding ones on the north transept had received the attention of the works staff in the late 1960s, although there was little documentary evidence of that intervention and of what the work had entailed. There was, however, a distinct change in the physical conditions in the top four or five courses; they appeared to be advanced in their rate of weathering and were conspicuously lighter in colour. The architect at the time, Dr John Baily, posed the notion that the 'white banding around the upper stones of all pinnacles indicated that vibrations had been set up in windy conditions sufficiently intense to remove surface particles and lichens from the stone.' (12) Whether or not vibrations had occurred at sufficient frequencies to incur such a change in state is difficult to support or deny, but these courses were without doubt affected differently from the rest of the pinnacles and they were loose in the extreme. On dismantling, the centre dowel arrangement was anything but conventional, either in masonry or engineering terms. An iron dowel had been encased in lead, but only in short sections (Fig 5.7). Where the sections met, a socket arrangement had been contrived and it was evident that this had fatigued and worked loose, so that the mortar bedding joint had then broken its seal. Ultimately, the mortar had been ground to a fine dust and blown away in strong winds, progressively loosening the uppermost courses which had been rendered unstable. This pattern could be seen to have occurred in all the higher pinnacles of the great south transept and concern was expressed regarding the other pinnacles.

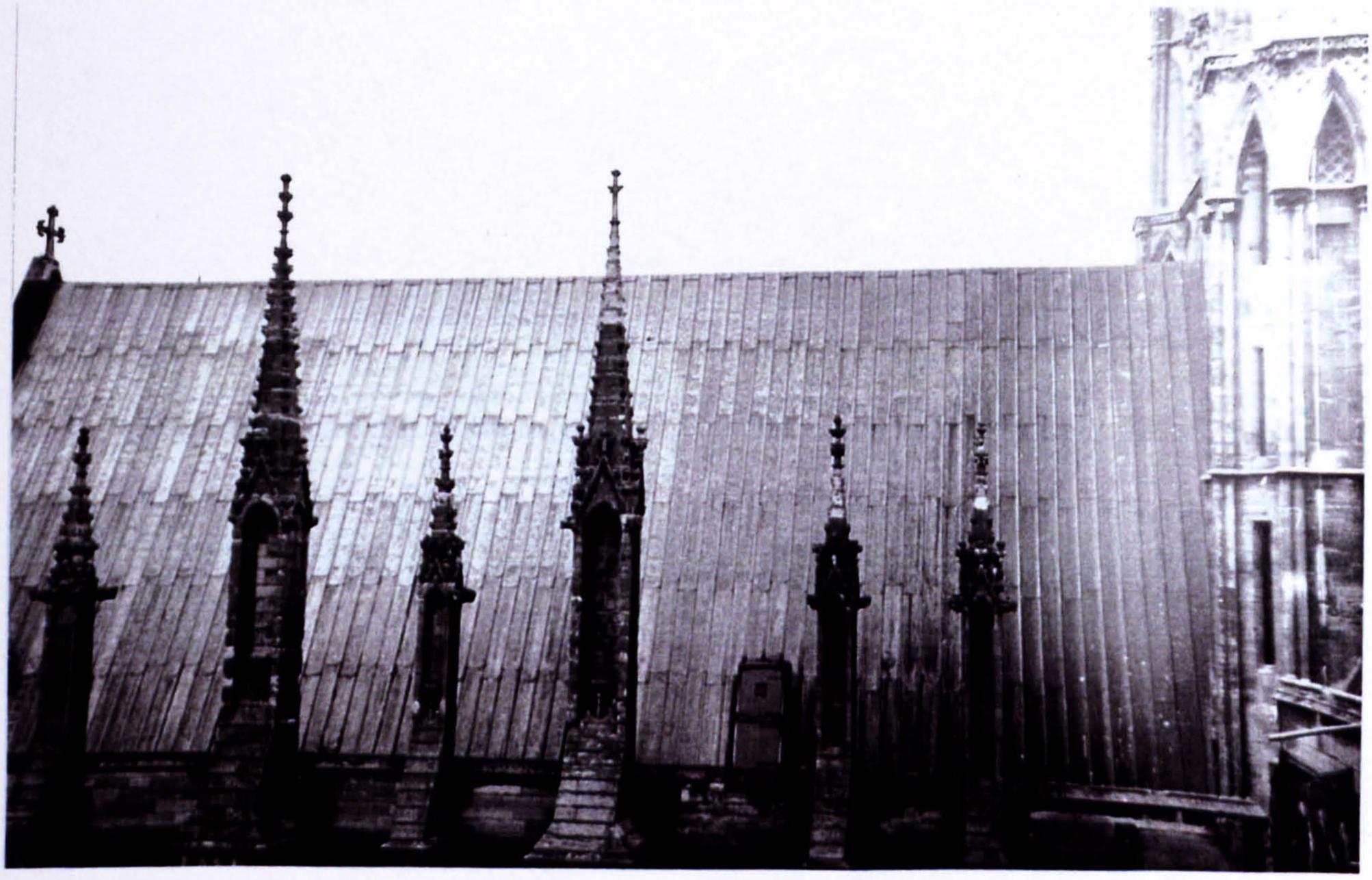

Fig 5.6 The North Transept pinnacles were replaced in the 18th century. These mirror the pinnacles on the South Transept.

Fig 5.7 South Transept pinnacle dowel. This 18th century fixing is broadly imitative of medieval fixings, with ferrous metal dowels encased in lead. The dowel was weakened by being installed in interlocking sections, and the iron was not totally covered with the lead.

A further curious feature was the method previously adopted to bring the stone courses to a sufficient height to maintain the design rhythm of the crockets. This entailed a 2" (50mm) slip, being effectively stuck onto the bottom bed of each stone. In places, this had separated, with a consequent weakening of the slender structure. Much of the gablet face had also been refaced and in fact it was quite difficult to establish the true pattern of courses and therefore the strength of the structure. Added to these weaknesses was the inherent design disadvantage of the height to width ratio, which it was felt indicated that the modifications to the pinnacles was typical of work carried out during the Gothic Revival. Both the Architect and the Consultant Engineer, Brian Morton, felt that pinnacles of these proportions would inevitably fail.

A Modified Approach to Replacement.

It was decided to reconstruct the pinnacles with three modifications, rather than explicitly on a 'like-for-like' basis, and to enlist engineering aid in bringing stability to the pinnacles. These changes would be as follows:

- To reduce the slenderness ratio by restoring likely medieval proportions to the pinnacles.
- To dispense with the slip in the course height, and to use new single stones for courses
- To introduce a 'post-tensioning' system in place of the weak lead-encased dowelling system.

With these three improvements it was felt that there would be a much reduced likelihood of failure since a greater resistance to wind-loading would be present. In particular, the post-tensioning system, proposed and designed by the Consultant Engineer, would convert the structure from a modular to a monolithic state, providing sufficient rigidity to go beyond the calculated point where the masonry might tend to rotate as had happened before. Stone from the Cathedral quarry was to be used and the work carried out by the Cathedral Works Department.

Improving the Stability of the New Pinnacles

The height of the pinnacles was 5.5m (around 18 feet), which extended from a base of 1.3m (4 feet 3 inches), and was a slenderness ratio that was calculated by the Engineer to lack stability. It was decided in some way to reduce the overall height, and 'at the same time an attempt was made to discover the proportional framework of the original pinnacles.' (13) A modified design was worked out between the architect, engineer, and foreman mason. It was decided to retain the height of the pinnacles themselves, to increase the area of the top bed of the top pinnacle stone, but to slightly reduce the finial length. This would provide an increased area of contact between all stones, adding to the stability of the structure, but maintaining design consistency with the adjacent pinnacles. The crocket levels of all the pinnacles on that transept would still correspond, but the actual height would be slightly reduced in the new pinnacles. A full scale setting out diagram was drawn up by the foreman mason incorporating the modified proportions and coursing (see Fig 5.3 p218 which shows part of the new pinnacle drawing).

Working the New Stones

All the stones were quarried and sawn at the Cathedral quarry (see Appendix C *Case Study: Reopening the Cathedral Quarry*). The height of the stones required for the pinnacles would be almost the maximum available at around 300mm (12"). As has been pointed out, the design of the pinnacles was elongated at the time the pinnacles were rebuilt and the distance the crockets were spaced apart dictated the bed-heights of the stone. The individual stones were worked to the full scale setting out drawing. The same team of masons that quarried the stone, also worked the mouldings, carved the crockets, and fixed the new pinnacles in the conventional manner, with traditional materials, but with minor engineering modifications to the fixing design (Fig 5.8).

A Post-Tension System

For simplicity a ready-made system was adopted for the post-tensioning, which entailed a 20mm bar being threaded through thirteen of the twenty courses of stone. Under the bottom bed of the lowest course and on the top bed of the highest course, base plates were anchored to the stone; a series of intermediate screw-fittings linked the bar at every third course. Once the bar was in place and effectively functioned as a dowel, prior to the finial being set in position, the end-plates were stressed using a torque wrench set at twenty-five pounds per square inch (Fig 5.9). The void surrounding the dowels was then thoroughly filled with lime-based grout, making the structure rigid. The thirteen courses could then be relied upon to perform monolithically, with no likelihood of further movement, having been provided with sufficient resistance to the strongest likely gale.

Conclusion

Addressing the structural problems presented by the pinnacles raised several unusual issues. The fact that the pinnacles were not part of the original Cathedral design, but were a later change, and that they posed a threat to the safety of the public and to the fabric, justified design modifications being introduced as part of the solution. In other circumstances, although this might eventually have been possible, a more formal procedure would have been necessary under the Care of Cathedrals Measure 1990. Normally, where such an element would be replaced on a like-for-like basis, in this case it was considered that it would only be a matter of time before the structures failed again and traditional masonry construction, in combination with an engineering solution, at the same time conforming to conservation understanding, was felt to be appropriate. Once the new pinnacles were set in place, a light cleaning was permitted of that area to modulate the starkness of the new stonework into the original which was partly rainwashed. The final result was felt to be sympathetic in context with the surrounding building [1] (Fig 5.10).

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[1] The opportunity was taken to employ a conservation abseiler, to inspect the other pinnacles along the same parapet. Their rigidity was confirmed (some minor localised pointing was carried out by the abseiler) and with this knowledge the scaffold was removed.

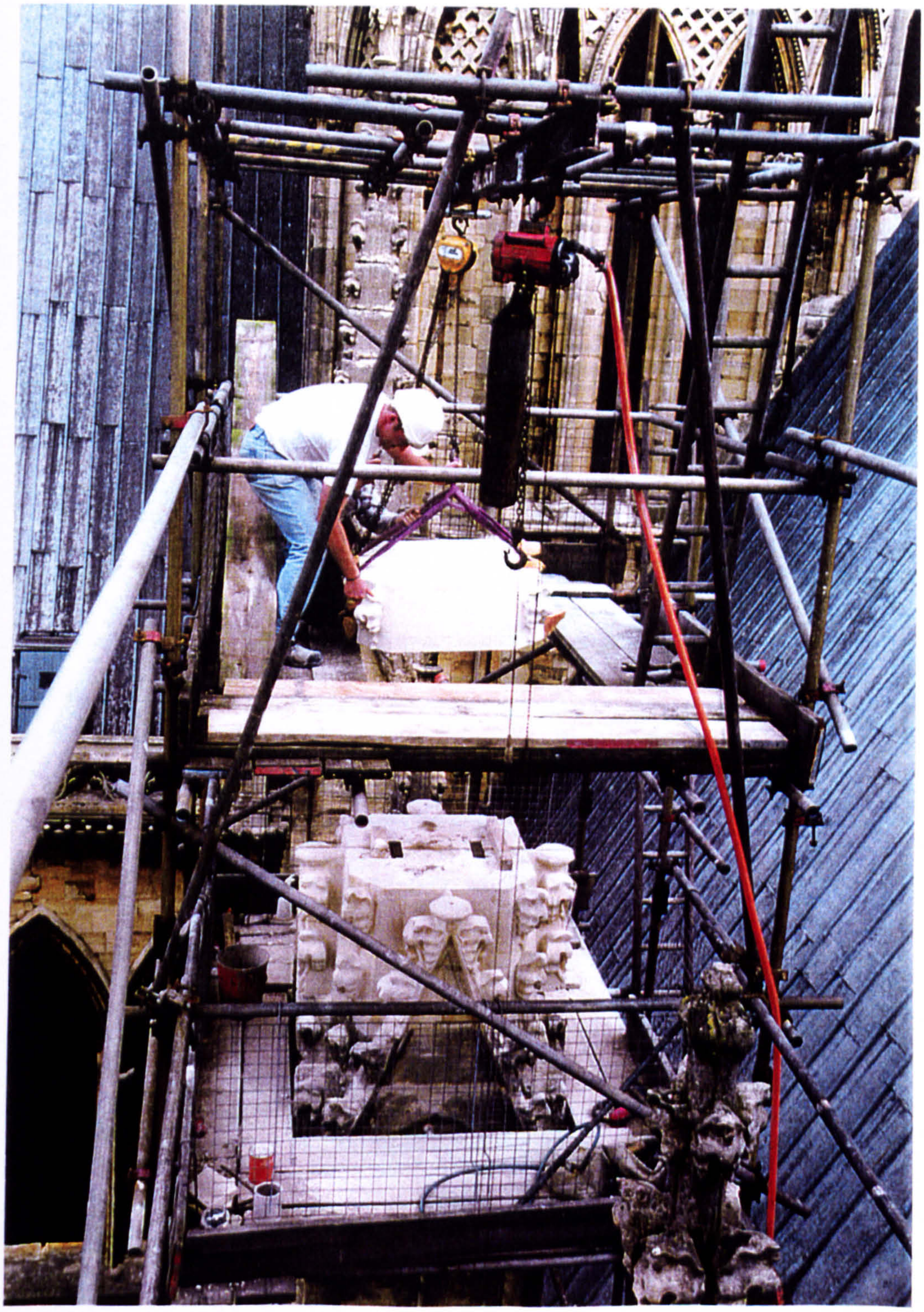

Fig 5.8 Masons fixing the new pinnacle stones in the traditional manner. (Lincoln Cathedral Works Archive)

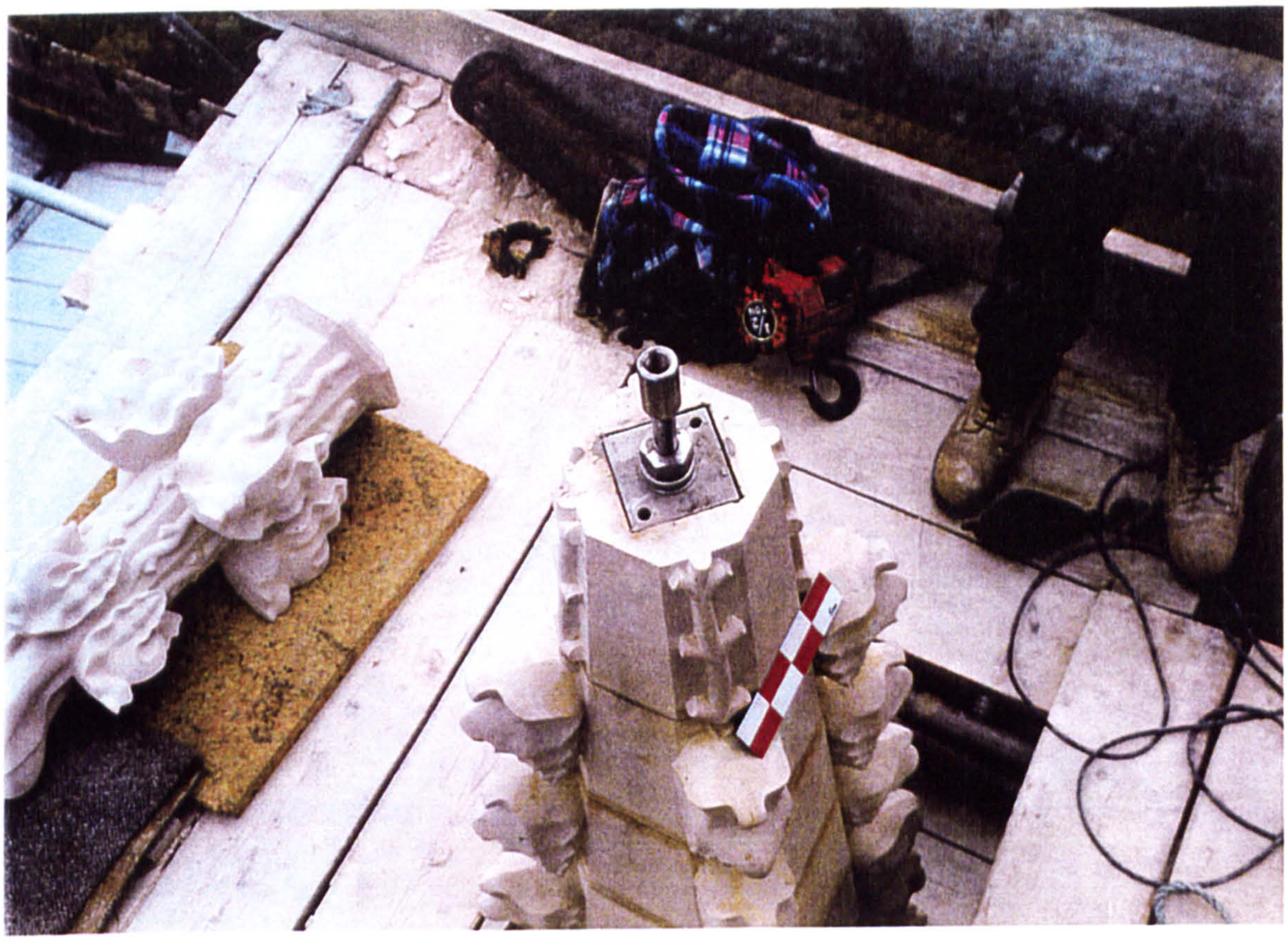

Fig 5.9 Post tension system in South Transept pinnacles (Lincoln Cathedral Works Archive).

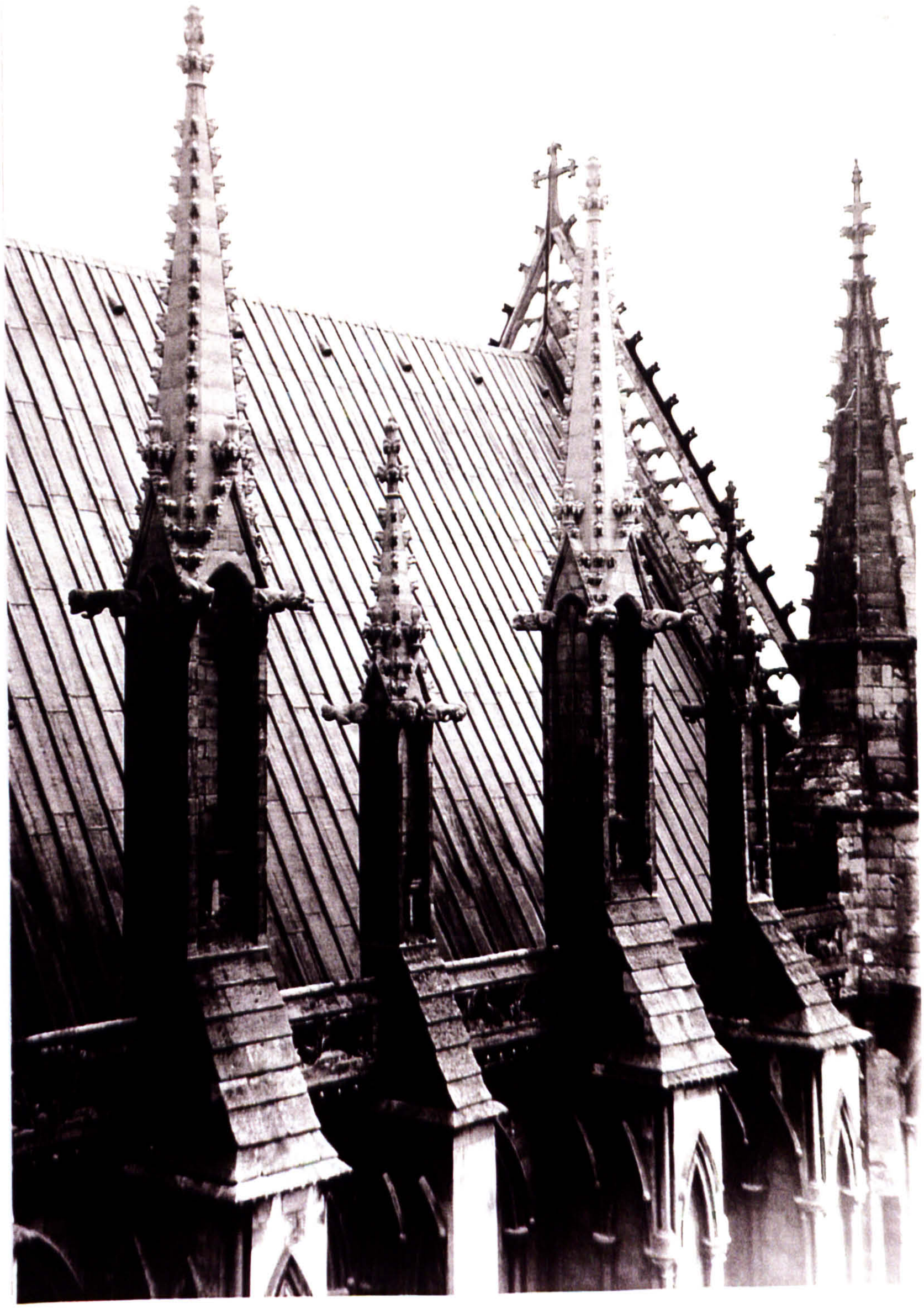

Fig 5.10 Completed South Transept pinnacles

5.3 Conservation Practice

Introduction

A point was reached some time after the second world war when it was no longer possible to ignore the exhortations of the various action groups, pressure documents, and legislations, that had drawn unequivocal attention to the excessive damage done to the nation's historic buildings discharged under the name of restoration and conservation. It became clear to those directly concerned that traditional trades and methods alone were inadequate to the task of care. Even as recently as the 1970s and 80s, some excessive restoration projects have given cause for considerable alarm. In the case of cathedrals, the extent of repair and replacement has been almost arbitrary, due to their status of 'ecclesiastical exemption', based on the fact that these sites are used for religious service. In the event, a new discipline began to emerge out of methodologies belonging to various other strands of conservation, which were primarily dedicated to the conservation of fine art and museum artifacts. The need for comprehensive recording, coupled with the ample opportunity to exploit the upheaval that maintenance works regularly presented in terms of offering greater access, led to the discipline of archaeology moving its attentions from almost exclusively below-ground excavations to concerns relating to historic structures. In addition to the scholarly desire to fill in the gaps of man's history, it became rapidly clear that an appreciation of the performance of the monument or building in times past, as well as an understanding of past interventions, was essential to the efficient practice of the upgraded levels of care and maintenance. The methods of observation and recording of the archaeologist may overlap with the recording duties of the conservator, but the analyses derived from the respective records are entirely different in process and result.

The introduction of conservators into the arena of building care marked a clear statement that cathedrals, churches, and other historic monuments were to be regarded as works of art. There is a point in the field of practical maintenance where the abilities of the mason ends and it is at this stage that the conservator's skills are introduced. The influence of a discipline such as conservation, however, was destined to be greater than the mere practical benefits of the conservator's skills, with good ancillary practices permeating other trade areas. Recording assumed greater relevance and a higher sense of value was consciously placed on the fabric than might previously have been held. It has often been possible to criticise masons for valuing newly executed work more than the surrounding ancient fabric, with a more personal investment being felt to have been made by the mason. Whilst masons ensure that the results of their own labours are carefully transported to the scaffold to be fixed, others may be occasionally careless about the way this is carried out. The methodology of conservation can be perceived as the conscience of the team, counter-balancing any singular principle of approach to problems such as decay or fracturing. Where replacement was once the sole approach, repair or consolidation might now also be a consideration, and always with comprehensive documentation accompanying work of any description. It is clear in such a case that the closer masons and conservators share sympathies with the work, the more seamless will be the operation of caring for the building.

Ethical Parameters in Conservation

Despite the sincere intentions of action groups represented by their various declarations throughout the past century, as well as the plethora of charters that have emanated from many international gatherings (see 4.1 *The Evolving Perception of Care*), it is still a singular fact that conservation today operates with no mandatory code of conduct. It can at the same time be recognised that several documents are salient in their grasp of the practical considerations of the maintenance and repair of historic objects, and it is from such guidelines that conservators have gathered some consensual way of moving forward. Without such conduits for the channelling of ideas relating to practical behaviour, conservation would amount to no more than a do-it-yourself activity, although it is recognised that difficulties exist within the spectrum of conservation. Those difficulties, combined with the transient foundation of fashion and opinion, are at the crux of why any acceptable principles must be broad in structure or multidisciplined, and why perhaps they have not finally emerged. Whilst being applicable across the board, they must also not threaten the nature and intuitions of the many respective areas of craftsmanship. Several principles are already universally accepted, and are defined by their commonality in the many documents emerging from the long search for acceptable rules.

A draft document has been issued by the United Kingdom Institute of Conservation (UKIC), entitled *Guidelines for Conservation Practice*, (14) which attempts to establish principles held in common..

> 'The guidelines are drawn up in a manner that makes no distinction between the many media of which artistic or historic works are made, or between individual works of creative art, mass manufactured goods or the results of nature.' (15)

The particular difficulties of carrying out maintenance and repair in relevant cases are covered broadly in several simply stated rules, none of which would find conflict with the more significant charters such as those already discussed, nor within the manifesto of the SPAB, established more than a century before. Once an object can be ascribed as having the status of cultural significance, as previously described in the *Burra Charter,* a position is established where the conservator must be able to apply the appropriate treatments within a more or less objective framework, reinforced by an understood code of conduct. Here the UKIC *Guidelines* advise that only appropriate techniques and materials should be employed, according to 'the best current knowledge' (16) available, with two provisos, that these 'will not endanger the true nature of the object' (17) and, that it 'will not impede the future treatment, or the retrieval of information through scientific examination.' (18) At the same time, such treatment ought in no way 'to modify or conceal the original nature of an object during restoration'. (19) Prior to and during treatment an 'adequate examination of the object, both to record its condition and to establish the causes of its deterioration,' (20) is commended, with rigorous recording made throughout of the techniques and materials employed, to be ultimately stored in a permanent safe archive.

These guidelines are commonly acceptable in the context of conventional conservation training, and accompany the conservator constantly in pursuit of the work of staving off decay and prolonging the life expectancy of the object. Certain rules of thumb, identifiable within the UKIC *Guidelines*, serve to assist the formulation of good policies and sound results. Since good conservation is often the result of a collaborative effort, accepted procedures are both necessary and inevitable. For example, all intervention is expected to be the minimum necessary, with the maximum amount of original material retained. Where treatments are applied, the concept of reversibility and the ability to re-treat are paramount. The applied sciences employed within conservation progress continually, and impetuous and irrevocable treatments ought not to be allowed to preclude the possible use of future improved applications. Where replacement details are proposed, these can be ethically acceptable by being also reversible, but need to harmonise with the original work in colour, texture and scale, and be identifiable in the future. Similarly, previous repair should be examined where possible and recorded, all records being safeguarded for future reference (See 5.1 *Recording and Archive*).

Conservation of Stonework

Great difficulties have been experienced in defining the methodology of the conservation of stonework, and also in prescribing safe parameters within which such work may be carried out. Where the skills and the judgements of the mason are held in high esteem, presumably because he is perceived as being capable of interpreting the needs of the building and providing a highly acceptable solution, those of the conservator are less easily appreciated. It may be a cliché to point out that the more proficient the conservation operation, the less visibly appreciable it is to the onlooker, and perhaps even to the paying client. In actual fact, the conservator brings skills to the site that are time tested in associated areas of conservation, as well as knowledge of material sciences, and it is the contribution to the analysis of the building's problems that are relatively new. Much of the skill of the conservation of stonework, for instance of fine carving or sculpture, lies in determining the appropriate treatment, and sometimes recognising that no treatment may in fact be best. Many factors of conservation rely on the 'after-care' of the object and considerations such as monitoring need to be taken into account, perhaps returning periodically to check treatments. The question will inevitably arise whether a carving would benefit by being removed permanently indoors where the environment may be carefully controlled, but where it ceases to perform as part of a living structure and becomes instead a museum artifact, or whether there are reasons for it to remain on the exterior of the building where it will continue to decay. Both extremes may be instrumental in the correct prescription of treatment.

Any conservation treatment will beg the question whether it is reversible or not, but it must be recognised that any treatment will effectively initiate a new direction of health, or attempt to limit deterioration, and will in so doing change the state of the object. Reversibility infers a return to the original state of the material, which due to time and the rigours of weather etc, may be an

unrealistic expectation. 'Techniques and materials which will not impede further treatment are generally those which are reversible.' (21) Although this statement is very broad in its assumption, particularly in the context of a built structure, for practical purposes it can be considered a working rule. However, where decorative stonework is considered unstable and extremely friable, a deep penetrating consolidant may prolong its life to a limited degree. This recourse would be a last resort in an extreme case and could be termed 'irreversible'. In fact, good conservation procedure might best begin from the larger 'preventive' perspective, such as shielding stonework from the worst effects of the environment. A next level might then be routine monitoring and general conservation maintenance through to designated programmes of conservation, including cleaning, consolidation, repair etc. In establishing degrees of intervention, reconstruction and reproduction of lost features might be considered the final level, implemented only in extreme circumstances following a disaster such as earthquake or war damage, or where an original sculpture is conserved but removed and a copy carving put in its place to reinstate loss of structural stability. Reproduction of lost elements will depend on the quality of evidence of missing areas; if there is none it cannot be considered ethically proper.

Activities and Techniques

The range of duties that may be expected of the conservator is broad and in the context of a building will overlap with other disciplines, since the conservator will usually employ a holistic view. The conservator operates within the terms of an understood code of ethics, as has been discussed, but the responsibilities of the conservator are indivisible from the continual process of ethical decision-making to the point of being unable to proceed without the ability to make reasonable judgements. It may arise that decisions are made on the basis of scientific analysis, such as the chemical make-up of pollution encrustation on an object, or the nature of an area of polychromy. At the same time, the conservator's aesthetic judgement will be called upon, for instance in the application of colour-matched mortar repairs, where many samples may need to be made before any are used. The following list describes a typical though be no means exhaustive range of activities involved in the conservation of stonework, some of the activities being inseparable from others. The headings are guides only and do not always fully represent the subject. since they serve here to describe the range of duties expected and do not attempt to form a manual or instruction.

Examination

All effective conservation treatments depend on a high level of perception throughout the entire course of action, which in turn needs to be comprehensively documented. An initial review of the surrounding circumstances of the work will usually be expected to produce a condition report. In this document, the nature of the surrounding circumstances of the problem will require identification and this may necessitate either a wider survey being carried out or a specialist view

being given by the relevant professional, such as a geologist or engineer. The main preoccupations of examination might be summarised as follows:

- To establish the conditions of the object
- To identify the nature and source of the problem
- To determine what can be done to alleviate these conditions
- To initiate relevant analysis and research if necessary

In a building the size of a cathedral, the cause of a problem may be some distance away from the problem itself. For instance, a blocked gulley or downpipe may lead to water backing up and seeping through the core of the stonework. Soluble salts travelling with the moisture may find their way into precious monumental works at ground level, and it is then insufficient to contend with the problem only in the monument, with the source unattended. What may seem to be strictly a task for the conservator may require attendance from other skills and calls attention to the necessity of the discipline of conservation to interface with traditional skills and *vice versa*. Once the conditions are as far as possible recognised, a treatment recommendation can form part of the intial proposal. A limited amount of analysis can be carried out by trained conservators, such as mortar analysis, identifying soluble salts etc., but in certain cases, it may be necessary to commission analyses for the purpose of identifying pollution levels or the nature of contaminants. and there are commercial companies that undertake such work. The need for specialist information may lead to the necessity of a specific course of research being undertaken by a university science department, or other such agency with access to sophisticated laboratory equipment.

Recording

A wide range of documentation processes can be adopted for the purpose of describing both the found condition of the object in question and the nature of treatments proposed to be administered The specialised condition appraisal, to which reference has been made, may comprise several media, such as photography, drawn diagrams or sketches, or the rectification and utilisation of measured survey drawings such as photogrammetry (see 5.1 *Drawings, Written Observations,* and *Photography*). Comprehensive written reports can be of great assistance, explaining the methods adopted by the conservator during the operation. In certain circumstances, the opportunity may arise where three dimensional photography would be useful, but good quality monochrome prints and colour transparencies are normally adequate. The supplementary use of colour prints may also be useful, for example in the presentation of the work. Documentation should accompany all stages of the work, and is as important as any other aspect of the work since the future care of the object will need to be informed of past treatments. The following list of considerations are typical of essential recording procedures:

- To prepare comprehensive condition reports

- To support textual information with clear diagrams
- To utilise the skill of photography for recording
- To establish the practice of continual recording throughout all work
- To commit a final treatment document to a safe archive

A final treatment report will be instrumental in providing critical knowledge to conservators who may need to apply treatments in future and ought therefore to be provided with the security of an archive, from where it may be safely retrieved. Monitoring of an object following treatment may be necessary to safeguard it against the continuing actions of the environment and of the residual pollutants that may be present within it. In this respect, no treatment can be viewed as final. Any treatment applied may be the best available, though may not totally meet the needs of the object. A long-term continual view of changes in the object may need to be made, and treatments may vary according to accessibility, depending on how often it may be feasible to revisit for monitoring. All such monitoring will form part of the complete condition record.

Cleaning

It is a common desire that buildings be clean, so that they more authentically represent the intended expression of the architect, the original choice of materials and qualities of craftsmanship being more clearly evident. At the same time, there is little doubt that cleaning will encourage the longer life of the building. External limestone will benefit by removal of the inevitable black crust that clings to it. On being cleaned, the actual state of repair of the building is made more easily appreciable. Where repairs have been carried out, a clean elevation will help to visually blend the old and the new materials. Whatever the reasons are for initiating cleaning, it must always be considered an essential conservation decision, and initial investigation could declare the need for certain precautions. For example, there may be a need for localised strengthening, or certain methods of cleaning may best be avoided in particular circumstances. If it is true to state that a 'major objective of conservation is to increase the chemical stability of the object being treated,' (22) It is important before cleaning to define the dirt. This will enable an evaluation to be made on whether the removal of dirt will be to the gain or detriment of the object. Overcleaning is not uncommon and can cause damage to the stonework and considerably accelerate the rate of decay. In certain circumstances, pollutants may have supplanted the natural binding matrix of the stone, so that an attempt to remove pollution might cause greater damage. It is important to define the nature of the dirt, which can either be the result of matter in the wrong place, or of a chemical change in the material itself.

In deciding upon a system of cleaning it might initially need to be determined whether a wet or dry application is preferable and this can limit the choice considerably. Several cleaning methods are amongst those in general practice and it is worth briefly outlining some of them. The following are not in any particular order of preference or efficacy:

amongst those in general practice and it is worth briefly outlining some of them. The following are not in any particular order of preference or efficacy:

- Solvent cleaning: This depends on identifying a solvent that can dissolve the dirt but will not disrupt the substrate. At the same time, a solvent must permit the carriage of dirt particles away from the object without redepositing traces on the surface of the stone. A grading of solvents moves from acetone, through industrial methylated spirit (IMS), dichloromethane, to certain acids, and may include additives such as degreasing agents, or solvent mixtures. In making such a choice, a chief consideration would be safety to the operative and the object.

- Water washing: Although water is strictly speaking a solvent, water washing is generally referred to as a separate cleaning method. It is normally cheap and plentiful and has few health and safety objections.[1] In terms of cleaning large expanses of masonry, such as external façades, it is fortunate that water is the appropriate solvent for black crusts.

- Combined water/abrasive cleaning: At present there is only one such system commercially available in Britain, which is known as the 'wet slurry' system. These combine an abrasive agent, such as calcium carbonate, being ejected in a compressed air jet with water in a spiralling motion. Different nozzles produce jets in a variety of sizes, and the pressures may also be varied according to the dirt layer. The spiralling action of the jet on the surface of the stone has the effect of scouring away the surface dirt, and is useful on ashlar and running mouldings. Over large areas of masonry, there may be a tendency for this system to leave a visually patchy surface, so great care must be taken to keep a long-range view during the operation (Fig 5.11).

- Air-abrasive: The air-abrasive method is a dry method of stone cleaning that utilises compressed air with abrasive particles. Most common of the air-abrasives systems used in the cleaning of historic buildings is the micro air-abrasive. Larger systems have been widely used in the past, though not always with positive results, and have the disturbing name of 'sandblasting.' Some refined versions of these are still available, but these should not be confused with micro air-abrasive systems which are operable at very controllable levels, ie working down to 5 psi. Cleaning relies on the removal of dirt by the cutting action of minute abrasive particles, such as aluminium oxide dust or glass beads. Micro air-abrasive systems are suitable for carved work rather than expanses of ashlar. A disadvantage of the air-abrasive method is the dust created, which obscures vision, and causes a nuisance to the respiratory system (Figs 5.12 and 5.13).

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[1] It is important that contaminated water does not feed back into the fresh water system, so a system of 'one way' valves is necessary to preclude this, as well as being a legal obligation.

Fig 5.11 Cleaning ashlar with a wet slurry system (Lincoln Cathedral Works Archive).

Fig 5.12 Micro air-abrasive system. Note the personal health and safety apparatus required (Lincoln Cathedral Works Archive).

Fig 5.13 Micro air-abrasive cleaned carving detail (Lincoln Cathedral Works Archive)

- Poulticing: Cleaning of stone can be effected by using a poultice, which may work in more than one way. This may be by drawing the dirt into the poultice itself, so that it comes away as the poultice is removed. More often, the poultice is used as a solvent carrier to soften the dirt layer, so that the dirt can then be removed by other means. An example of this is the AB57 poultice, which includes ammonium bicarbonate, mixed with a thick (thixoptropic) adhesive paste. Mixtures such as clay, paper pulp, lime, or cellulose, are pressed firmly around the stone and covered with plastic film to maintain the moisture content, a feature that marks a disadvantage of the process, since the cleaning action takes place out of sight and any patchiness will not be seen until later.

- Laser: The acronym laser comes from: *light amplified by stimulated emission of radiation*, and is a cleaning system employing a beam of light. A Q-switched ND Yag system has been found most suitable for marbles and limestones and its effectiveness relies partly on the stone being lighter in colour than the dirt. When applied to the surface of the stone, a dramatic temperature rise occurs at the centre of the lighted spot. A differential exists between the absorbent state of the black surface of the dirty stone and the reflective state of the underlying clean white surface, the encrustation being receptive to the properties of heat rising dramatically in temperature, whilst the white stone beneath remains relatively unaffected by it. The resultant process can be described as the 'selective vaporisation of an optically absorbing substance'. (23) Due to the small area of energy impact, which is referred to as 'ablation', the laser is most suitable for cleaning sculpture or carving. Distinct advantages are offered by the laser, such as being able to see the cleaning operation in progress. This offers a safeguard against damaging rare traces of polychromy, or friable areas of stonework. At the same time, there is no unpleasant dust created, or waste matter, other than a faint vapour which needs to be adequately extracted. Although the laser is at the latter stages of research and development, it is highly likely that it will emerge as a successful cleaning method for finely carved objects of stonework (Figs 5.14 and 5.15) (See Appendix K *Laser Cleaning the Romanesque Frieze: An Investigation*)

The decision to undertake the cleaning of stonework, whether it be an entire building or a single feature, can depend on several issues and it is always essential to balance the benefits of cleaning against the possible pitfalls. Doubts about the possible consequences of any action may represent a clear message that no action may be best. There is often a clear logic associated with a choice in cleaning technique, with either the scale of the work to be cleaned or the nature of the dirt, dictating the circumstances of method. Systems that create a large dust nuisance will not be applicable indoors, nor will water washing. The type of material to be cleaned may deny certain treatments, as in the case of alabaster which is water soluble. Combinations of materials, and attendant features such as pigment traces, will also need to be considered, where a particular treatment might cause an adverse reaction.

Fig 5.14 Laser cleaning system with special eye protection and air extraction.

Fig 5.15 Part of a Romanesque Frieze fragment cleaned with laser

Desalination

Some techniques of cleaning using poultices, such as paper pulp or sepiolite, a naturally occurring mineral (de-hydrated magnesium trisilicate) can reduce salt levels in stone, a process referred to as desalination. Poulticing is generally used for sculpture or carvings and requires several applications. On removal their salt content is measured until it is ascertained that levels in the discarded poultice have notably reduced and reached equilibrium. At this stage it can be deduced that a quantity of salts has been extracted from within the stone, or at least from a few millimetres below the surface of the outer face. If it is carried too far the process may begin to activate salts from deep within the stone, which were previously not causing a problem. On the continent, more radical methods of desalination are sometimes employed. For example, whilst work was being carried out on Notre Dame le Grande, Poitiers, in France, many stones from the west façade were individually treated, since salt readings of some areas were inordinately high.[1] These stones were immersed into a bath of de-ionised water for a period of two hours. On removal, the stones were pasted with a 25mm thick cellulose pack using a gauze binding, wrapped tightly in elastic bandage, and left in an airy place for up to one week. The poultice was then removed and the stones were dried out in a thermographically-controlled hot air cabinet. Tests proved that a dramatic reduction in salts had occurred. In this case, the source of the salts was historic and had been permanently stemmed, but in cirumstances where the salt problem is allowed to remain, such an operation might be considered a waste of resources.

Consolidation

Consolidation of stonework is a rearrangement of the failing structure of the material and is a course of action that may be pursued as an alternative to replacement, and is primarily applicable to localised areas of high value rather than large areas of masonry. Trial tests precede all applications, which also benefit from a sustained programme of monitoring. It is important to note that treatments to natural materials may delay the processes of degradation, but will not necessarily halt them and these limitations should serve as a precondition to the aims of consolidation.

Following an assessment and attempt to improve environmental conditions, so as to limit access to the agents of decay, it is necessary to determine the level and extent of consolidation. The principle aims of consolidation are to establish cohesion throughout the stone without impeding 'breathing' so that this will allow the passage of moisture and provide a level of added strength and self-support, ideally allowing the stone to expand and contract. Any signs of discoloration should

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[1] The area in front of the west front had traditionally been used as a market place over many years, and successive generations of a salt-selling family had occupied a position immediately in front of the church, stacking their bags of salt against the wall. Not only the stones were contaminated with sodium chloride, but also the surrounding ground, all of which needed to be treated until salt levels were safely low enough to replace the original masonry.

be avoided, as should any other unsightly effects. Consolidants in regular use on limestones are as follows:

- Lime water: After an initial coating primes the friable stone, between thirty and fifty separate coatings of limewater are made over a period of days, two applications at a time and with a period of a few hours between each. Clean sponges are used to gently wipe off the excess fluid on the surface of the stonework, care being taken to remove any white residue, or lime 'bloom' which may begin to accumulate on the surface. The lime water, which is calcium hydroxide, once it has penetrated the pores of the degraded stone, begins a process of carbonation, turning back into calcium carbonate, and consolidating the stone. The west front conservation programmes of both Exeter and Wells Cathedrals were based on the lime method, which was developed by Professor Robert Baker from methods he had seen employed in Italy. Obtaining proof that decaying limestone physically benefits from consolidation by limewater application has, however, proved elusive. Although it is claimed that there is a positive contribution, the application of large quantities of water cannot always be regarded as beneficial to salt contaminated stones. Where it has been felt that beneficial changes have occured, this has not been scientifically confirmed. Dr Price was compelled to conclude, following tests: 'on the basis of the laboratory experiments described, there is no conclusive evidence that multiple applications of limewater serve to consolidate friable limestone.' (24) (see Appendix E *The Lime Method*)

- Acrylic resins: These include Paraloids (methyl methacrylate co-polymers) and Primals (acrylic dispersions) and are generally used for small areas of local consolidation. They rely on a solvent carrier which leaves the resin to set in the stone when the solvent evaporates. They cannot penetrate very far into stones and solvent evaporation inevitably draws much of the consolidant back towards the surface. However, in theory they are the most reversible of available consolidants, although they are not suitable for external use, due to the fact that they are not resistant to the sun's rays or frost and break down within a few seasons.

- Silanes: Amongst the most commonly selected consolidants are the products known collectively as organosilanes, commonly referred to as silanes. These products are compounds of silicon. Silanes are applied to stonework in the form of silicon based monomers, chemical compounds consisting of single molecules and possessing an extremely low surface tension. This solvent-based carrier ensures that deep penetration takes place before consolidation occurs. The basis of the consolidation action is polymerisation, the chemical union of the monomers, forming larger ones of the same compound, effectively creating a cross-linked silica lattice, which lines the pore walls, the main advantage being that polymerisation occurs deep within the structure of the stone. The presence of water in the stone or atmosphere aids polymerisation by acting as a catalyst. The chemical state of consolidants permits deep

impregnation into the stone, enabling them to be employed generally rather than locally. Since water is the principal agent in the decay of stone the hydrophobic nature of silane effectively prevents the growth of mould, which in turn prevents the accumulation of dirt and attracted moisture. Due to the fact that they can create a moisture barrier it is essential that a stone to be silaned can be isolated and treated all over. Although silanes offer added strength to the decaying stone, they are brittle and present low resistance to mechanical shock. Valid fears exist that silanes may break down over time. Other disadvantages are the rigorous necessity of health and safety provision and their irreversibility, making their use a last resort treatment. (see Appendix F *Silane Consolidants*)

Once consolidation is started it needs to be completed in a single operation, as it is possible that a superficial, or interrupted, impregnation will create a harmful interface and act as a barrier to the free movement of moisture. In due course this will set-up a series of separate physical actions, reacting to changes in moisture level and temperature. The primary concern is the long-term welfare of the stone and where possible the opportunity to reverse the proposed action at a later date, or to modify it by the introduction of further treatment should be provided.

Dismantling and Reassembly

In certain circumstances, for example where individual stones are seriously delaminating, the conservator may have no recourse but to skilfully dismantle the separate fragments of a stone in order to reassemble it in a more stable manner. (see 4.3 *The Death of Lazarus and Dives in Hell)* The aim of this operation is to eliminate uncontrolled fissuring and to re-establish even contact in the separate fragments of the stone. A fragile piece of sculpture or carving may need to be faced up in a fibrous tissue before being handled during removal from the building, whilst often hard mortars are painstakingly cut away and ancient dowels severed. Once removed, the separate sections are cleaned and alien matter removed, they may then be stuck back together with resins, employing non-ferrous dowels to reinforce the contact. This adhesive must only be applied in spots, so that a continuous impervious barrier is not created. This is especially critical if the carving is intended to be replaced on the exterior of the building. Dowels can be used in a number of ways, either to provide rigidity in a joint, or to take up load-bearing where adhesion is poor in projecting stone.

Colour-matched Mortar Repairs

Gaps left after reassembly or small cracks and missing areas may be filled or capped with mortar repairs. Matching colours will come from the aggregates of stone dusts and sands. Such mortars may be bound with lime or resins, depending on material compatibility with the stone, any consolidation already carried out, and whether the repair is internal or external. Many samples are prepared with a carefully documented recipe of the mix for reference. These will vary subtly in colour, based closely around the general hue of the stone, and may contain varying grain size for

texture. Sensitivity is required in matching the modulated appearance of the natural stone (Fig 5.16).

Lime mortar repairs, once they are pressed into cracks and crevices, must be kept damp so that they cure slowly. These are the most compatible materials for external limestones, slowly carbonating into calcium carbonate, possessing the same properties as the stone itself. These repairs work sacrificially, wearing away rather than the stone and, where salts are present, acting as long-term poultices, drawing the salts from the stone. Materials such as translucent marbles or alabasters may require a tinted polyester resin repair, although such repairs would only be appropriate indoors.

Some Relevant Observations

Conservation is a multidisciplinary activity in terms of understanding and working with materials, and attempts to bring together the most appropriate advice, techniques, and materials, within the perceived range of values of the object. In the context defined by this study of caring for a monument, or more specifically Lincoln Cathedral, the concept of preserving the 'true nature' of the object may seem occasionally to be in conflict with conservation practice. Maintaining a large building invariably involves the replacement, or a change in the nature of some architectural elements. Many plain ashlars, for example, are chopped out and replaced with new stones in order to maintain the structural integrity of the building. This action may not itself elicit much controversy, since the balance of the decision is unlikely to be in dispute, the stones expressing little of the individuality of their executor, but where stones are decorative, the balance of opinion may tend to move away from removal, even though the structural question is equally urgent. In the case of Lincoln Cathedral, where the style is mainly 13th century, with a small area of twelfth century masonry in the centre of the west façade, the possibility of removal of these rarer though equally plain stones is likely to be of more concern. Additionally, within that twelfth century façade resides the Romanesque Frieze consisting of nineteen sculpted panels. Removal of these explicitly for their own preservation's sake has activated great argument (see 4.3 *The Lincoln Romanesque Frieze: A Case Study Shaped by Practice*). Within this apparent turmoil lies an inevitable and spiralling scale of argument, revolving around removal of parts of the fabric and replacement with newly worked stones. All work should be carried out bearing in mind the design qualities of the building and the constructional traditions originally employed. This includes the choice of materials, with only the most compatible used, together with appropriate skills, ensuring that the building can be reapproached for repair in the future. Discipline is assured in the debate by adherence to ethically sound and objective rules. Admittedly, these may be more apparent to those charged with the task of prolonging the life of the building than the layman.

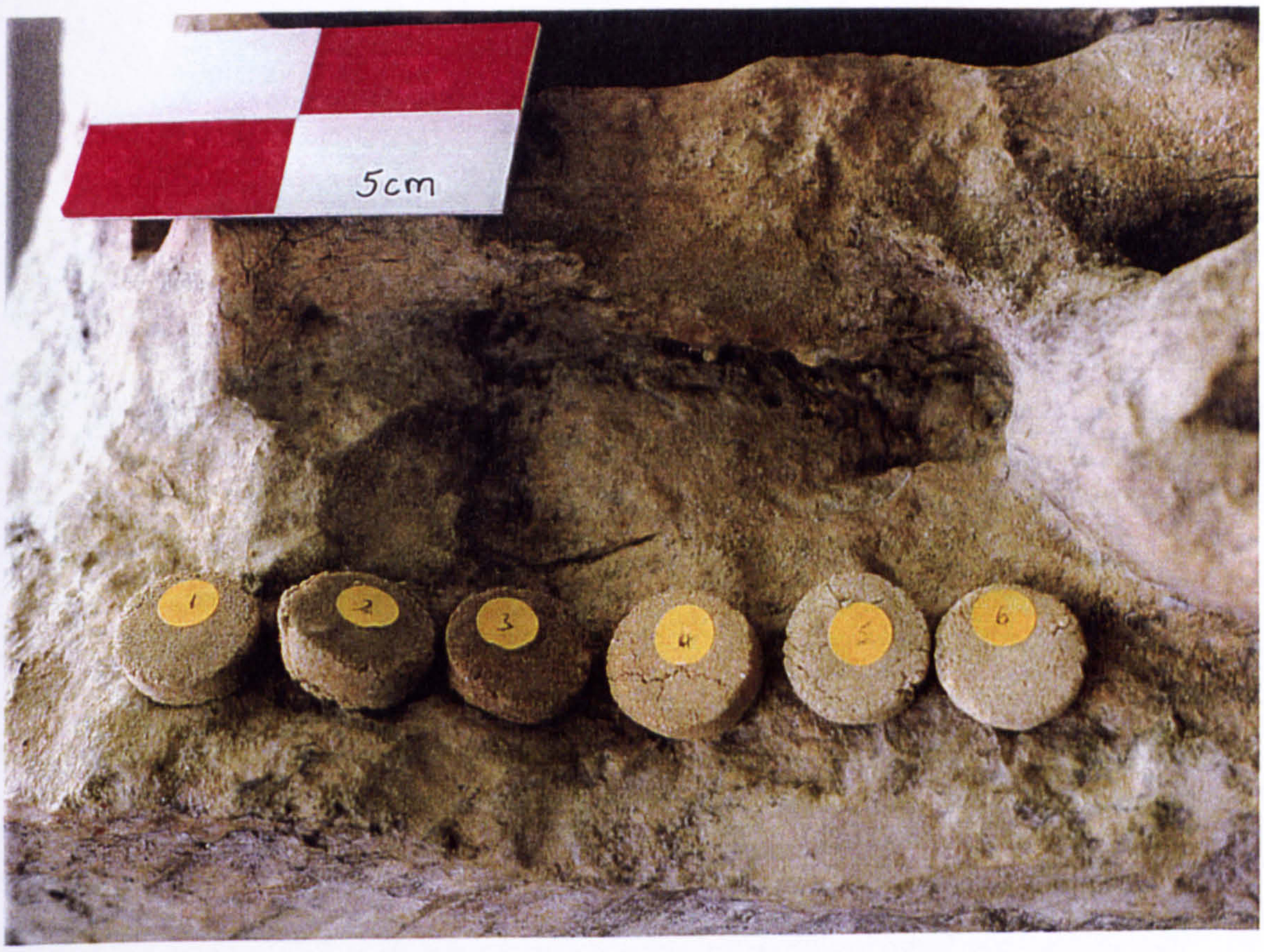

Fig 5.16 Colour-matched mortar repair samples (Lincoln Cathedral Works Archive)

Whereas it is the understood duty of the stone mason to execute areas of replacement as determined by the architect, including the actual preparation and working of the stone and fixing of it, the role of the conservator is mainly preoccupied with repair of those individual stones which may be considered more valuable, such as carvings and sculpture. In the broad sense, William Harvey describes the term conservation as follows:

> 'Its object is to maintain present appearances and old associations while removing the element of danger and imparting the largest practicable measure of permanent stability to the existing structure.' (25)

As has already been pointed out, however, the conservator brings to the work more than mere skill, but a methodology which insists on a measured approach, and involves the examination, analysis, and diagnosis of specific problems. A thorough understanding of types of materials and their characteristics is essential in this endeavour, both in the stone, its decay mechanisms, and the applied material science of any treatments and their effects. Attendant to all work is the continued creation of accessible records in the routine form of working diaries and more formally in condition and treatment reports. In carrying out these complex tasks, the conservator crosses the existing boundaries of other established practices. These other areas are principally, administration (to some degree), archaeology, art-history, material sciences, museum practices, and the traditional building trades. The great challenge comes in successfully applying these disciplines coherently whilst contending with real problems of failing stonework. The conservator, through an understanding of ethics, maintains an awareness of the high emotional and cultural value of the object being worked on.

Case Study: Cleaning Black Crusts from Limestone Façades at Lincoln Cathedral

Introduction

This case study will examine the changing attitudes towards cleaning the exterior fabric of Lincoln Cathedral during the past hundred years or so, and will follow the development, not only of techniques, but also the reasoning behind choices made. The dirt on the façades of the Cathedral do not vary greatly in consistency, being relatively even black crusts (see 2.3 *Factors of Decay*), although there is some variance according to orientation on the building. Areas that receive regular cycles of wetting and drying are generally less densely encrusted, whereas northerly facing elevations which tend to be more damp for a greater part of the time normally possess greater thicknesses of black encrustation.

Historically, much controversy has surrounded the practice of stone cleaning , the results of which can so noticeably affect the aspect of an entire city or a single prominent building. In the 19th century what constituted cleaning and what could be described as irrevocable intervention became a matter for serious discourse, with action groups struggling to define the practices. Throughout the present century, matters progressed little until relatively recently, the first half of the century

witnessed the perpetration of considerable damage to historic buildings, due to a naïve understanding of the effects of certain processes, such as chemical treatments, water washing, or abrasion. Often, the choice of cleaning technique, although it might have been correct in relation to the dirt and the stone itself, suffered from the extent of the application and the type of expertise engaged to carry out the work. As recently as the 1960s, the practice of sandblasting highlighted the dangers of aggressive 'quick result' methods of cleaning, and visible losses of surface detail drew attention to the need for moderation and the accompaniment of recording. It is only in the last two decades that the view has developed whereby stone cleaning is not simply an option for anyone to engage in business, but is a science-based specialist area and just as relevant a process of intervention to the welfare and longevity of building fabric as caring for the stained glass, timberwork, or the masonry in general.

At Lincoln, these developments can be traced from last century to the present day, when stone cleaning is carried out within the conservation view. Within this view, no process or technique is considered entirely on its own merits, but forms an option along with a range of choices towards the maintenance of the building fabric. The cleaning of stonework, taken as a part of the conservation plan, is executed solely by skilled conservators who are trained, not only in relevant cleaning techniques and the associated chemical changes that are engaged during the process, but whose perceptions are prepared for the presence of contingent problem areas, such as ferrous fixings, fractures in the stonework, and the presence of polychromy. Most important, is the ability to define the dirt and clean to a level which is not damaging the surface of the stone. This is more complex than it sounds and may often mean exercising considerable judgment of what constitutes clean and therefore leaving areas of dirt which would damage stone if removed (Fig 5.7).

Defining the Dirt

Dirt is broadly definable in two classifications. Foreign matter can be described as those deposits which have later become mixed with the particles of the material and were not originally present. These can be laid over the surface of the object in the form of dusts, the waste products of birds and insects, carbon particles and the greasy remnants of unburned hydrocarbon fuels. Environmentally produced foreign products can almost always be assumed to contain some level of acid, which may precipitate the second classification of dirt. The products which have been created by a chemical alteration between the original material and other materials are created through a process of deterioration. Such reactions can be precipitated by environmental pollutants, such as air-borne acid gases, and salts from the sea or produced by industry. Oxidisation is a typical example of the forming of matter through chemical reaction (see 2.3 Chemical Factors of Decay). The varying nature of dirt can pose a serious problem to the conservator, who must exercise considerable judgement in determining the level of cleaning. In the case of black crusts, these will combine both classifications of dirt, and guidance in deciding when or how much to clean will be gained by concentrating on the difference between dirt which is comprised of foreign matter from that which has chemically combined with the substrate.

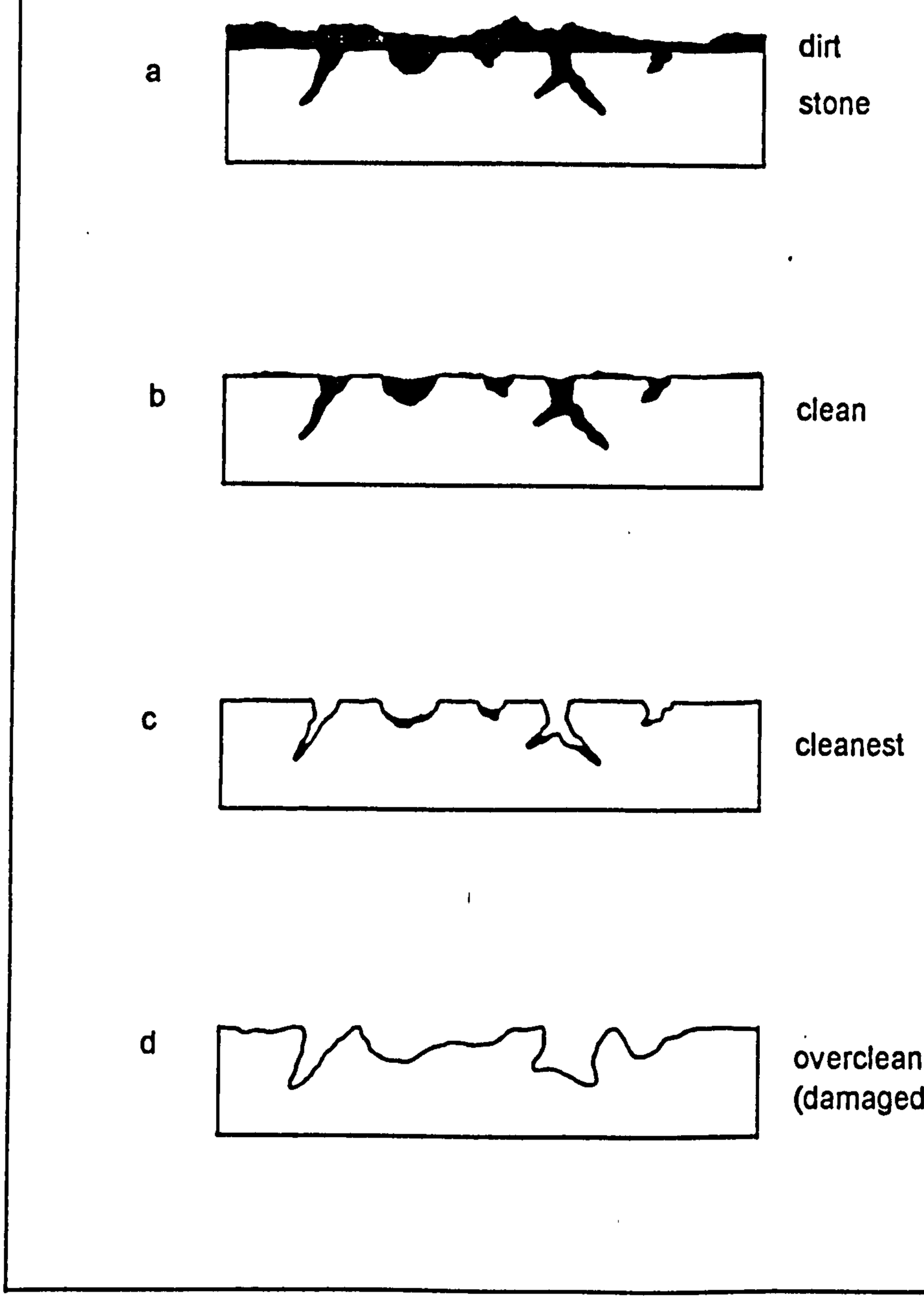

Fig 5.17 Defining the dirt and determining levels of cleaning that are safe for the stone. Option c) would be the optimum clean in this case.

A Note on the History of Pollution and Cleaning

It is likely that the cleaning of monumental buildings has taken place since they were completed. In the 13th century the atmosphere of London was so polluted by the domestic burning of coal, that a proclamation was issued prohibiting its use. Ironically, the cathedral and church builders themselves, through the intrinsic necessity of lime burning, must have borne some responsibility for the problem. The population growth, the corresponding growth of industry, and the forming of urban communities with generally improved standards, all assisted in encouraging the serious problem of atmospheric pollution. The opening up of the waterways allowed greater mobility for industry and encouraged urbanisation. Lincoln in the 13th century had become an important inland port and boasted a population of around six thousand, (London's population was approximately eight thousand at that time). Intense growth and the creation of densely populated towns, combined with the bringing together of industry for fuel, transportation and labour, resulted in severe concentrations of heavy pollution. At the very centres of these communities were focused the majestic cathedrals and churches currently being erected, or extended. The newly exposed masonry, extensively enhanced with vivid and expensive pigments, must have suffered sufficiently to exhort action, both in preventative measures and in practical restoration. Treatment might have necessitated the re-touching of pigments, some of which had been imported from as far as Afghanistan (lapis-lazuli), and the washing and scrubbing of masonry.

In rural areas, the incessant burning of stubble in the fields, and of solid fuels for domestic heating and industry, brought about the discoloration of cathedral façades. In the Forest of Dean, in 1282, there existed around 60 forges, processing an annual total of between 150 and 180 tons of locally mined iron. Charcoal was the fuel used, burnt in the forest from fallen and new timber. In the same year, 'there were known to have existed 900 charcoal burning hearths alone, in only four of the woods of the King's demesne'. (26) Coal-burning as a fuel for the iron smelting industry had by the close of the 13th century brought prominence to the coal mining industry of Newcastle. Many emerging industries in the 13th and 14th centuries used coal to fire their furnaces or kilns, even in areas where major ecclesiastical buildings already existed: 'it is perhaps significant of the new technology that it was coal, still comparatively novel as a fuel for such a purpose, that was chosen for the firing of the tile-kiln at Boston, operating in the first half of the century.' (27) The nuisance of smoke became commonplace, and fines and other penalties were a regular occurrence, particularly in the case of cathedrals. A sum of money was provided by King James I for cleaning and repair work to St Pauls in the beginning of the 17th century 'because it was so badly damaged by coal smoke.' (28) A thousand pounds was given to York Minster in 1632 by King Charles, together with the instruction that no further domestic dwellings were to be constructed nearby, so keeping down the nuisance factor of coal-burning. Some developments began to emerge in washable building materials, such as salt-glazed tiles, bricks, terracotta, and polished marble, but even these were to be no match for the pernicious smoke.

Cleaning at Lincoln Cathedral

The Practice of Scraping

In 1865, 'persevering attacks' were made against recent restorations to the fabric of Lincoln Minster, and namely against the architect John Chessell Buckler (1859-1870). This led him to vindicate himself 'as the director and superintendent of the restorations in question.' (29) Buckler's defense took the form of a published account of his own actions at Lincoln, and his method of staving off attack was to compare his performance with the actions of others, both at Lincoln and elsewhere. Against the protestations 'that he was doing no more than cleaning the masonry.' (30) Buckler was drawn into a major ethical controversy that was to last for some time. This came at the height of the Gothic Revival, and was to play its part in questioning the principles, and motives, of many active architects of the day, during a time: 'when considerably more medieval architecture was lost though restoration than demolition.' (31)

Rather than merely forming a defense, Buckler's written work amounts to an attack on those whom he referred to as his 'neighbours', fellow architects, such as Sir George Gilbert Scott, and his own predecessor at Lincoln, James Essex. It is clear from Buckler's defense that the original accusations refer to the common practice of 'scraping' and 'refacing' masonry. This technical malpractice is self-explanatory, literally involving the act of abrading back the faces of stones, sufficient to remove dirt and ancient polychromy. A further practice was to chop back the face of the stone so that it required a facing slip, similar to modern cladding. In this way, the original profile of the masonry was redefined. The master mason of the day, Sandall, described how he had been instructed to carry out cleaning according to accepted practice: 'a scum collects on the surface of stone, and this we wash and scrape off, but the surface of the stone is not injured; it is quite impossible to scrape it away without violence.' (32) Scott wrote a strong letter of protest to the Dean and Chapter of Lincoln in 1859, objecting to the practice of scraping, which he insisted had been a long established practice at Lincoln, though should now he hoped be considered out of date. Buckler retorted obscurely in his own defense, alluding to the 'original surface of the mason work,' (33) and that new stonework had been roughened by the traditionally executed finishing process. In a history of Lincoln Cathedral, Kendrick writes:

> 'The "scraping" process to which the exterior of the minster was subjected under the late John Chessell Buckler of Oxford is within the memory of many. It caused much angry discussion and bitterness at the time, and resulted in the publication of a book, in which Buckler undertook to justify his work on the minster.' (34)

The successor to Buckler as architect of Lincoln Cathedral was John Loughborough Pearson (1870-1897). Perhaps mindful of what had transpired, he cleaned from the main transepts eastwards in a manner so tenuous as could best be termed restrained.

Twentieth Century Attitudes to Cleaning and Preservation of Detail

It can only be speculated how much medieval pigment has been removed from the historic façades of Lincoln Cathedral over the centuries due to the practice of scraping, and how much carved detail has been inadvertently lost due to inappropriate methods of cleaning. Certainly, in the 1920s and 30s, during the time of the Special Repair programme there seems to have been little respect paid to the surface of sculptures. Routine weekly reports from the Clerk of Works to Chapter during that period refer to 2" (50mm) diameter holes up to 6' 0" (1.8 m) long being drilled through twelfth century sculptures,[1] with gallons of Portland cement grout pressure pumped into them. This area embraces the southern run of Romanesque Frieze panels and includes the *Daniel in the Lion's Den* panel. In no contemporary document is there a drawing of the Frieze panels, either individually or as a complete run, to illustrate their current condition or to display where drilling or grouting was being carried out, and it is unlikely that any record was kept of polychromy or of any other subtle detail. In some areas of the Frieze, unsightly Portland cement was at this time smeared across cracks, with no clue of what detail it covers. It can be concluded that the cleaning that accompanied this major programme of structural work paid scant attention to such detail.

In 1932, Schaffer, in his study of the weathering of building stones, suggested that 'an annual wash by hosing may normally be regarded as sufficient, but more frequent application may be an advantage.' (35) The arbitrary nature of this approach, as with any cleaning process, may be potentially destructive. Szerelmey, leading stone contractors in the 1950's and 60's, in their publication on the care of stonework, freely recommended the use of steel and bronze wire brushes, to be used in conjunction with water washing. 'Of these the steel wire brush is the best from the workman's point of view.' (36) If steel wire brushes proved inadequate, the writer goes on to say, 'the only method is to use a fast spinning carburundum disc which actually puts a new face on the stonework.' (37) As recently as the early 1980s, this method was specified for cleaning blackened stone surfaces on National Trust properties.[2]

In 1961, some thirty years after the Special Repair campaign, reports from a further cleaning programme of the same area begin to exhibit more caution in face of the value of the Frieze panels. The Clerk of Works at that time, J.A. Higgins, writing a report to Chapter, had the following comments to make:

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[1] Reference is made to ' Norman work on West Front, to south side of SW Doorway, from 28' 6" to 35' 6" up, ' which corresponds to the area of the southern run of Romanesque Frieze panels. GODFREY, R. 25 May 27. Report to Chapter, *Lincoln Cathedral Works Archive*.

[2] Working as a stonemason for the National Trust in 1980 - 81, the author witnessed this method of abrasion being employed extensively on the stonework of Hardwick Hall, where it was presented as a standard specification for cleaning sandstone façades.

> 'The initial washing of the panels, now in progress, is removing the heaviest of the grime encrustation and it is planned to treat the whole series in this manner before undertaking the final cleaning and repair of the separate panels. In dealing with the repairs we should do no more than secure the loose fragments, at the same time cut out the disfiguring cement pointing and replace [it] with a synthetic stone pointing which will match up with the surrounding masonry.' (38)

By this time considerably more value had been placed on the sculptures, but still a lack of understanding persisted in making the programme of work threatening to the welfare of the panels, although the work was well intentioned. The method employed to clean the panels was conventional water washing and it was clear that the panels were not intended to be manned during cleaning; a record states that the architect, Lawrence Bond (1957-79), 'wishes to make an inspection of this work.' (39) another report goes on to state disappointingly that 'a mason will then resume work on the sculptured panels of the West Front.' (40) In addition to wrongly applied skills being in control of cleaning major works of art, it is perhaps even more alarming that specialists trained in constructional matters should be carrying out preparatory repair work, rather than someone trained in the conservation and maintenance of stone sculpture. Photographs from before this campaign show details which are now irrevocably lost.

Reports during later work to the south porch door of the Choir, known as the Judgement Porch, involving the same team, prove that little had been learned since the excesses of the previous century, since old abrasive techniques are once again resorted to:

> 'The washing of the masonry at the entrance to the Choir proved quite satisfactory as far as the removal of the dirt and grime was concerned, but unfortunately it exposed unpleasant patches of ancient paint, which Mr Bond decided ought to be removed. We found that this could only be done by careful scraping and the use of abrasives.' (41)

These reports date from January 1970 and gone are the precautions relating to the safety of cleaning in the good summer months, it can be presumed that water washing was carried out during that winter, and therefore in sub-zero temperatures.

Modern Thinking and Practices of Cleaning

Cleaning of the limestone façades of Lincoln Cathedral is now regarded as a conservation procedure and the range of technical options is viewed similarly to an array of tools in a box, no single tool being felt capable of addressing all aspects of cleaning. In the case of the west elevation of the Cathedral, this has been cleaned over the past seven years by conservators as part of a complete conservation programme, with the archaeologists and surveyors, conservators, and masons, all working towards a single aim. Discussions between the Fabric Council, the architect, and the conservators, have established what constitute correct levels of cleaning for Lincoln stone, and bear in mind that over-cleaning is tantamount to destruction or damage of the stone surface. It is now considered inappropriate to damage the surface detail of stonework in any

way, as the preservation of polychromy, ancient tooling, and previous treatments, all contribute to the archaeological totality of the building.

In the case of large areas of plain ashlar, water washing with a timed nebular spray and bristle brushes takes advantage of the soluble properties of Ca SO_4, and makes it a finer tuned operation than employed in previous times. A fine mist is aimed in the direction of the wall, following thorough inspection and recording, and does not saturate the stonework. Where there are carved details, these are wrapped in polythene so that water cannot penetrate. Whilst it may be that these details are later cleaned in a similar manner, or at least using a method that employs water, closer individual attention to their condition must be given. An additional 'wet slurry' system of cleaning, (Lincoln uses the JOS system) enables a water and mild abrasive mix (calcium carbonate is used at Lincoln) to be projected on to the stonework in a spiralling jet at fairly low pressures. This can be used through one of three nozzle sizes and is useful in a variety of situations, from ashlar and mouldings to simply carved and sound details, such as dog tooth. It is not suitable for finely carved work or areas that are fragile. Particularly recalcitrant areas of black crust can be loosened either mechanically, with scalpels and fine chisels, or by the employment of a variety of softening poultices.

When cleaning of friable sculpture is carried out, a dry method of cleaning is employed so that no agitation of soluble salts occurs at the surface of the substrate which might cause disruption and damage to the stone. Dry micro air-abrasive systems of cleaning allow the conservator to maintain better contact and vision during cleaning. The jet of abrasive (aluminium oxide is used at Lincoln) is more concentrated than the smallest wet slurry jet and more suitable for fine detail, offering greater control of the removal of the black crust. Although the air-abrasive offers control, the powder can obscure vision of the stone surface, and the dust nuisance is sufficient to require protective masks and breathing apparatus to be worn, with further obscuring of in vision. A method currently in the advanced stages of research is the Q-switched Nd:YAG laser, which although not intended to replace these conventional methods, is indicating positive signs of a more sympathetic clean of delicate stone surfaces and is also beneficial in that it is self-limiting. Laser cleaning offers almost total visibility and the dust nuisance is minimal, although it is necessary to wear safety glasses to protect against the intense light pulses, and fine gaseous emissions as the black crust is vaporised necessitates air extraction Following successful trials at Lincoln on both ashlar and carved fragments, a Romanesque Frieze panel was cleaned (see Appendix K Laser Cleaning the Romanesque Frieze: An Investigation) (Figs 5.18 , 5.19, and 5.20).

Fig 5.18 Detail of Lincoln Cathedral West Front before cleaning (Lincoln Cathedral Works Archive)

Fig 5.19 Detail of Lincoln Cathedral West Front after cleaning. A variety of methods were used on ashlar, mouldings, and finely carved details as appropriate (Lincoln Cathedral Works Archive).

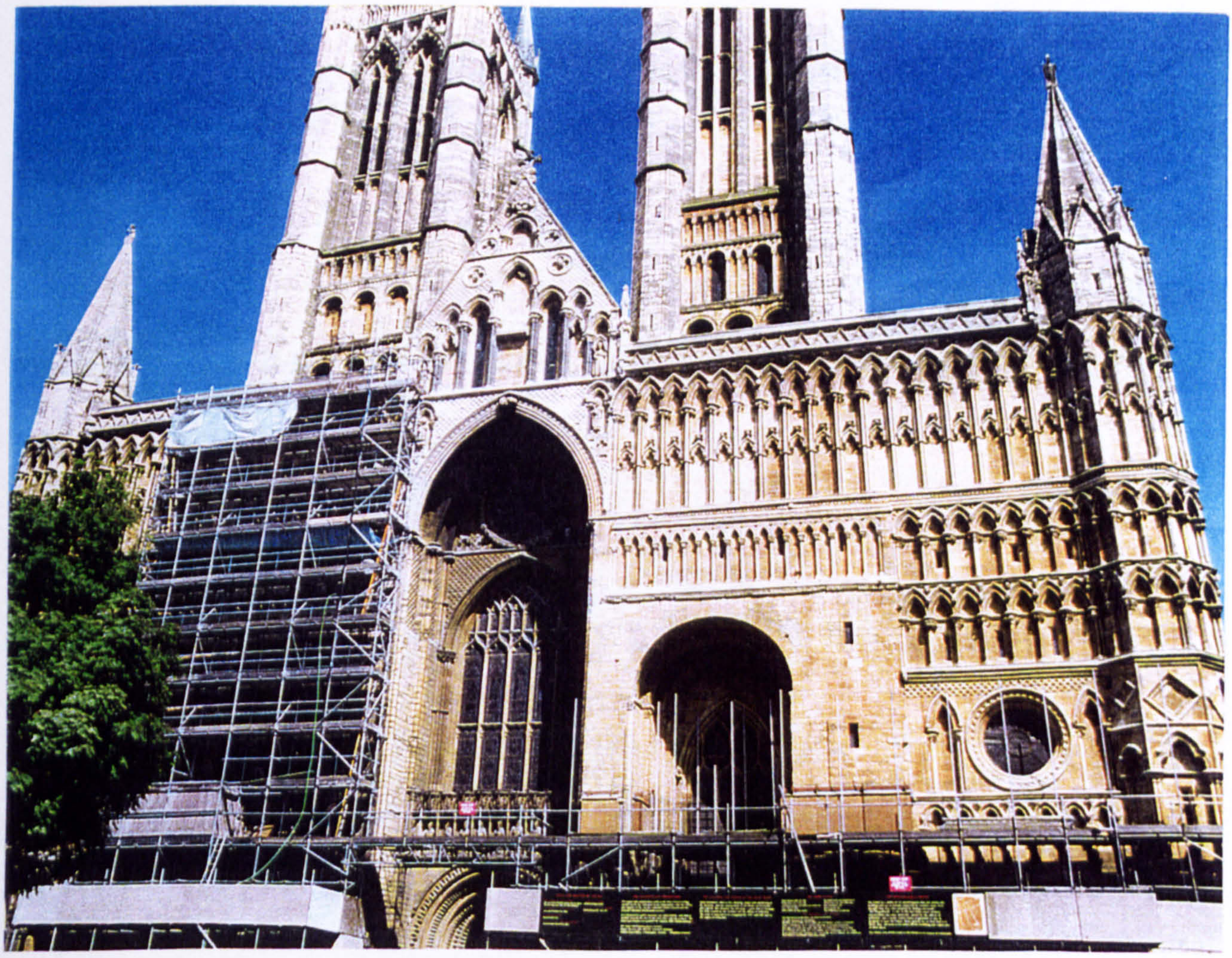

Fig 5.20 Lincoln Cathedral West Front cleaned south flank (Lincoln Cathedral Works Archive)

Conclusion

This brief outline of attitudes and practice of cleaning at Lincoln demonstrates the changes in awareness both in the nature of the material being cleaned and of the dirt itself. In Buckler's time, the problem of dirt on the masonry was confronted in an aggressive way, the results being damaging to the ancient stone. No understanding was sought of the nature of the dirt, or how it may have penetrated the substrate through chemical change, or how destructive it might be to remove the outer face of the stone. In general, there can be little said that compliments the work of Buckler in relation to cleaning, as his recommended actions were likely to have accelerated decay rather than staved it away. At the time of major engineering repairs in the 1920s and 30s, during Sir Charles Nicholson's time as architect, little or no care seems likely to have been exercised during cleaning. Considering the plethora of documentation that was produced during this period, there is little that is relevant to detailed action to the fabric. Although some effort appears to have been made towards a more analytical approach to cleaning during the architect Lawrence Bond's time, moderation does not seem to have accompanied such understanding. The saturation of large areas of masonry, including statuary and carving, must have resulted in loss of detail. Many label stop heads were replaced at that time on the higher levels of the west façade, and it is tempting to suggest that ill-considered cleaning may have contributed in no small way to the demise of the original work.

Certain factors of caution are necessary during cleaning and these have considerable bearing on the quality of the final results. It is important to cultivate a familiarity with the particular technique being employed, so that a particular choice of cleaning system meets the need of the dirt problem and is compatible with the stonework. No system will compete with the full range of dirt issues. For example, the wet slurry system of cleaning was initially felt to supersede water washing, during cleaning of the west front, but the results were sometimes patchy and a combination of both systems proved of greater value than either system on its own. Without appreciation of the range of technical cleaning systems available, and their relationship to both the dirt and the stone, it will prove difficult to limit the cleaning process to that which is strictly necessary, ie to remove the pollutant crust and to reveal the original qualities and intentions of the architecture. It is easier to go too far than to expertly assess and execute a restrained clean. Overcleaning assists the processes of decay, by piercing the hard skin formed naturally on limestone and exposing the softer areas behind the face to further attack from weather and pollutants, and leaving the surface of the stone more vulnerable to further penetration by pollutants. At the very least, an exaggerated clean will cause the area cleaned to be viewed separately from other areas, eroding the integrity of the architectural scheme.

5.4 Training Opportunities for Stone Masons and Conservators

Introduction

There have been considerable changes in the nature of skills applied to the care of historic buildings in the past two decades in England, which have had repercussions on the traditional skill of stonemasonry, and the emerging discipline of practical conservation of historic buildings, originally intended to complement the former. A stage has now been reached where the success of such complementarity needs to be questioned, and it would be beneficial for the traditional stonemasonry trade[1] to assess its role within the industry of historic building care. What adjustments has the stonemasonry industry made during recent major changes in the perception of historic building care, where even the defining terminology of the operation has changed from restoration to conservation? This point itself has fundamental implications for the stone trade, whereby the shift is from policies of large scale replacement of masonry, to the staving off of the agencies of decay, and the maximum retention of historic fabric where possible. From within the trade itself, there has been little or no real sign of recognition that such shifts have occurred. Certainly, no acknowledgement is made in recently altered standards of competence, which form the basis of training accreditation. In this respect, it is not unfair to suggest that training standards have followed the trade in its insularity, and have consequently and palpably declined. Several questions beg to be asked, for instance would the masonry trade in its ideal traditional form be adequate to modern conservation needs, and is the trade, in robust defence of its traditions, unable to adopt necessary changes in thinking to perform a complementary role in conservation?

The discipline of practical conservation has achieved prominence amongst the panoply of skills active in the field of caring for historic buildings, having been introduced into this area in England by pioneers such as Alban Caroe, Professor Robert Baker, and others. The continued presence of the conservator in this work is justified by a legitimate contribution to historic building welfare. At the same time, some difficulty resides in such a young discipline having no peer group or elders to whom they can identify or match themselves, so that the next stage in its positive development may determine a reliable set of circumstances from which real training needs may materialise. Whilst it may be true that University and College courses can adequately convey the history of ethical development, or the applied scientific technology of conservation, they are unlikely to be in a position to understand the clear practical demands of the workplace. It may be, through institutions such as the UKIC or ICOMOS, perhaps in liaison with relevant college departments, that simple and unequivocal definitions can be made of historic building conservation, in terms of craft or profession status, to enable the discipline to enter the next stage in its evolution

The Stone Industry: Training and Shifts in Emphasis

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[1] Separate distinction is made between the traditional banker / fixer masonry trade, as opposed to the many other facets of the stone industry which, for example, supplies headstones, fireplaces, paving, dry-stone walling, general walling, and general construction requirements. All of these, with the possible exception of the last category, which is almost defunct, operate independently from the mainstream of the trade which is banker / fixing masonry.

Up until this century, the life-style of the mason was a traditionally restless one, being a journeyman trade and travelling to a variety of sites for work. There was often no way of altering this unless a long term project was engaged upon, and an early commitment was made to a succession of new experiences and ideas. In gaining this measure of experience masons gathered knowledge of stone types and their respective characteristics, such as the variations in beds of a single stone and how this might translate in working, and its performance on the building. With this understanding came advice regarding technique, gleaned from fellow masons on site or elsewhere, such as the preparation of suitable mortar types and how they worked in certain circumstances. Little of this learning could be regarded as 'standard,' since stone as a constructional material varies so greatly depending upon its provenance and intended purpose, and the abilities to handle it were as innumerable as the individuals encountered along the way.

Until recently, the most effective method of training masons, as well as other crafts, has been considered to be through the direct transfer of knowledge and skills, or training through example. Such a system presented a model, not only of achievement, but also of the ingenuity and method of reaching solutions. An expertise in cutting the stone might also extend to the most suitable method of setting out a task, not only in the case of individual stones but of entire structures, of procuring materials and labour, and administering financial accounts. Thus training amounted to more than merely learning the trade, but was a way of arranging projects, of organising the work, and managing appropriate resources, and was in itself the development of resourcefulness.

Training in this way transferred more than mere trade skills (by which is meant that knowledge which is defined in a particular craft), but encouraged an understanding of materials, structures, and design, and developed an intuitive relationship between all aspects. It was in tune with the flow of new circumstances and fresh needs, and it was capable of continual adjustment. In this respect, continual development was experienced not only within the individual stonemason, but also throughout the trade. Since the second world war, however, a decline has been experienced in systems of traditional apprenticeships, with employers abrogating theoretical aspects of training to technical colleges. The duration of apprenticeships was correspondingly reduced, initially from seven to five years, now to three years, with further pressure to reduce it to two years. Some full-time training courses are now offered at colleges, for instance at Weymouth College in Dorset, which offers one or two year courses in stone masonry and stone carving. Training has moved from the triangular relationship of master and building, with the apprentice drawing lessons from both, to the standardised reiteration of object lessons taken from the written word of manuals, text books, and codes of practice.

Throughout the second half of the present century the use of solid stone in new building has declined in favour of synthetic materials and cladding. In cases where architects have prescribed stone for new buildings, significant developments have utilised the digital processing of stone by machine, and the results are often less than satisfactory. Cheaply priced stones from abroad,

specifically France, Spain, and even China, have been imported in bulk and are now readily available, a factor that seriously questions the viability of investing in local materials. The commercial stone industry in England has fallen into a decline since the 1960s and, as a consequence, traditional skills within the mainstream industry are not as highly prized as they once were. The emphasis has moved away from the quality of hand skills towards mass production, and the employment of machine operatives and semi-skilled labour, who do not possess the understanding of the mason. The majority of trained stonemasons who remain in the trade, chiefly find employment in the maintenance of historic buildings, although the reduction in industry-supported training means that relevant training in this field of work is severely lacking. Poor financial backing has led to centres being threatened by cuts, and the closure of courses and centres.

In historic building work, dangers may arise in the temptation to employ less specialised labour, as skills diminish. Figure 5.21 shows dressed walling carried out on the ancient Lincoln city wall, where appropriate skills have clearly not been employed. This ignores the more complete understanding that masons have of natural building materials and of the complexities of traditional masonry structures. In such instances, the first casualty is often preparatory setting-out, which is not evident in the finished product. However, acquiring moulding profiles and their correct interpretation is a form of practical archaeological analysis, and provides assurance of the integrity of the work as a concentrated focus for the quality of design of replacement features. Sensitive and effective masonry repair is dependant on knowledge of the originally applied geometry and stereotomy, and omissions in setting-out will be costly in terms of quality, with work needing to be done again.

Current Training Patterns for Masons

As competition for work and profits becomes stiffer for the masonry contractor, so the incentive for trainees to survive training programmes is more important, but a corresponding trend is that employers are able to devote less funding to training. Up until 1992, the City and Guilds of London Institute supported conventional training for apprenticeships with two levels of qualification, the Craft Certificate, and the Advanced Certificate, the first of which occupied the apprentice for the first two years of training, and the second was completed (optionally) during the third year. The climax of both classes of qualification was a written examination and practical test, based on a worked piece of masonry. The new system of National Vocational Qualifications (NVQ) introduced in 1992 has been established so that failure need rarely occur. It is a modular based system, with credits awarded for knowledge and abilities previously gained. An NVQ is simply a measure of competence, with a number of units required to reach each level, for example NVQ II requires five units. NVQs I, II, replace City and Guilds Craft certificate and NVQ III replaces the Advanced certificate. Eligibility to move on to level III depends on achieving level II, although the time taken

Fig 5.21 Inappropriate masonry skills employed on the medieval city wall of Lincoln. Note the poor bonding, with straight joints, and the sloping level of courses. This area of masonry was pointed up with hard mortar.

to reach these levels can be adjusted to the pace of development of the apprentice. Courses are designed to take the apprentice to NVQ II in two years, with a further year to reach NVQ III.

The Modern Apprenticeship scheme is an industry-linked system, which was made available from September 1995, and offers financial inducements to companies to invite young people into training and apprenticeships. It operates at two levels, for school and college leavers who are around the ages of 16 or 17 years old, with a second tier called the Accelerated Modern Apprenticeship, enabling the age group of 18 and 19 years old to enter the scheme. Standards for modern masonry have been established and maintained by the Construction Industry Training Board (CITB), a body that takes its lead from the commercial sector. The CITB initially researched the needs of the industry, prior to modernising the standards of competence, and setting up the Modern Apprenticeship schemes. The CITB actively vet and test potential apprentices for eligibility to the scheme, and test the commitment of employer and apprentice.

Three main centres of training in stone masonry in England are at:

- City of Bath College, Avon Street, Bath, Avon BA1 1UP.
- Weymouth, Newstead Road, Weymouth, Dorset DT4 ODX.
- York College of Art and Technology, Tadcaster Road, York YO2 1UA.

These colleges offer practical courses in stone masonry and do not essentially vary greatly, although they perhaps reflect regional differences in approaching local stones, their terminology also varying slightly. For instance Weymouth College tutors may possess experience of working with the local Portland stones, which are crisp and shelly and tend to 'pluck' during work. Bath stones on the other hand are soft stones and can be worked using 'drags' and 'coxcombs',[1] rather than conventional chisels. Yorkshire sandstones require an entirely different approach, as well as greater health and safety provisions due to their pronounced silica content. Amongst the main disciplines taught on these courses are setting-out and hand skills, such as working straight and curved mouldings, lettercutting, a limited degree of architectural carving, with sawing technology, and around 30% of course time is devoted to site procedures, which includes scaffolding safety and other associated matters of health and safety.

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[1] The quarries and mines of Bath produce soft limestones which are worked in a similar manner to many French stones, using fire sharpened chisels, which may be drawn out to a finer edge, and sharp wood chisels. The range of tools a French mason carries will include stippling (Bouchard) hammers, axes and drags, the latter being common to Bath stone masons. These are serrated plates of tempered steel which are drawn across the surface of the stone repeatedly to provide a flattened surface. Drags can be shaped like a coxcomb, and are useful for shaping a hollow or scotia, or in any shape that would make their manufacture worthwhile.

Les Compagnons du Devoir: A Model in Traditional Training in Stonemasonry

A model exists in France today which exemplifies the training of young masons in the skills and ways of traditional stonemasonry. Trade guilds wielded great social influence in France from the 13th century until the mid-19th century when they entered a decline. It was only in the middle of this century that interest in them was rekindled, and they again assumed prominence in providing training of craft skills in many subjects. To date, les Compagnons du Devoir has helped over 3000 aspirants to full guild, or 'compagnon' status. In total, the Compagnonnage takes on up to 100 apprentice masons every year. Following a two or three year formal apprenticeship with a fixed employer, starting at around school-leaving age, the young mason if elected to go forward by the compagnonnage, embarks upon a 'journey'. This may take five or more years, depending on the progress and development of the individual. Whereas the journey was originally made around the Ile de France on foot, building on experience as the trainee moved from one employer to another and differing circumstances, the journey may now extend to all Europe, and even the USA. An established network of houses, or lodges exist, referred to as 'cayennes', where the journeyman may lodge and attend evening classes tutored by voluntary craftsmen. The guilds maintain a high level of discipline, both in standards of workmanship and personal conduct. Towards the end of the journey, a proposal is made by the trainee, for a 'masterpiece', which will need to be organised and executed entirely by him. Once accepted, the project is then executed over six months, then assessed on completion by a council of full members of the compagnonnage. The masterpiece must be a complex project, exhibiting the competence of the mason, as organiser, and master craftsman.

An Observation of the Compagnons at Lincoln

Only around 20% of those young people embarking on the journey will succeed in completing it, and the level of commitment is evident in the calibre of the tradesmen of the Compagnonnage. Over the past three years, journeymen trainees have been invited to work within the Cathedral Works Department at Lincoln and this has been a qualified success. The qualities of independence and initiative cultivated by this method of training are impressive, as are the skills shown of both banker and fixing work. The local limestone possesses unique characteristics and the working of it is different from many other stones, but the French masons have approached this with relish. At Lincoln, a consideration is given to relating conservation with traditional craft skills and this has caused some confusion to the Frenchmen. No interest has been shown in absorbing any of the skills of the conservators, but this falls outside of the compagnon concept and description of the craft. All Lincoln masons attend conservation training modules, either locally with De Montfort University or short courses at the Institute of Advanced Architectural Studies of York University. It would be fair to conclude that the application of attention and skill is of an extremely high order in the Compagnon, although they show a reluctance to take on new ideas, perhaps the hallmark and saving factor of all traditions, although it should be stressed that no tradition survives without absorbing and accommodating fresh concepts relevant to changing perceptions and needs.

Conservation: Training or Education?

It can be argued that the concept of modern architectural conservation, particularly in respect of cathedrals, was born at Wells Cathedral in the 1970s. It had been apparent for many decades that of the 290 Doulting stone figures on the west façade many were in exceptionally poor condition and required attention. On being alerted to the serious state of the west front, and several of the figures in particular, by the architect Alban Caroe, the Dean and Chapter appointed a Committee to oversee the work. It was quickly found that the deterioration of the figures had almost certainly been accelerated by a rich mixture of Portland grout which had been used to fill the voids behind the sculptures.[1] Work was undertaken under the immediate supervision of Professor Robert Baker, appointed as consultant. The entire project lasted almost eleven years, and became renowned for its employment of the lime method developed by Baker (see Appendix *E The Lime Method*). The team of conservators, many working at Wells for the entire project, were trained on site, with no formal instruction in conservation theory or practice other than that provided by Baker.

It has more recently become the norm that conservators receive their training through the formal auspices of a university or college department. Amongst the first of these to include practical conservation of stonework was Weymouth College, which was initially set-up under the inspiration and guidance of Geoffrey Teychenne, but was quite quickly absorbed into the Conservation Sciences Department of Bournemouth University, where it has undergone several re-inventions. A few exceptions have been made to this off-site method of training, such as at Nimbus Conservation, under the directorship of David Odgers, a chemist who trained as a conservator at Wells Cathedral. At Nimbus, trainees worked on a one-to-one basis with a trained conservator, attending Weymouth College for an entire year. This training combination proved effective, and gained the company a reputation for high quality work, but it was inordinately costly at a time when continuity of work could not be assured. At Lincoln Cathedral, in the early 1990s, a conservator was trained on-site [2] by working alongside a trained conservator on a basis of direct transfer of skills, which was supported by modular courses, at York University, the Orton Trust, and the Society of Archivists. Visiting conservators, such as John Larson, Roger Harris, and Keith Taylor, were commissioned to carry out separate training days. A Science for Conservators correspondence course (42) was completed through the Conservation Unit, providing a fundamental applied knowledge of material science from which to build. A continuity of understanding of the needs of the building was gained from associating and working with other members of the Cathedral works team, such as the masons and glaziers, and a thorough and reliable training was provided, creating a precedent at Lincoln for future trainees. Although no

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[1] It is worth noting that the architect responsible for this action which was carried out in the 1930s was Sir Charles Nicholson, who was also at that time Architect of Lincoln Cathedral, where Portland cement grouts had been extensively used throughout the entire fabric over two decades.

[2] As yet only one trainee has been trained 'in-house', a fine-art graduate, who was registered with the National Joint Council for the Building Industry for a three year period of training.

accreditation was available, a written summary of experience was provided on completion of a prescribed training period of three years.

Current Training Patterns for Conservators

Formal training is confusing in relation to conservation of stonework, no establishment actually defining that as a principal topic. Four establishments are prominent in the general study of conservation, courses concentrating on specialist areas such as archaeological conservation, wallpainting, and stained glass are regarded as peripheral to this study. These are as follows:

- Bournemouth University: School of Conservation Science, Fern Barrow, Dorset BH12 5BB.
- City and Guilds of London Art School, 124 Kennington Park Road, London, SE11 4DJ.
- De Montfort University:

  School of Applied Arts and Design, Lindum Road, Lincoln, LN2 1PF.

  School of the Built Environment, Centre for Conservation Studies, Leicester LE1 9BH.
- University of York (Institute of Advanced Architectural Studies), King's Manor, York, YO1 2EP.

There are two specific levels of formal training available in conservation, which follow the conventional educational patterns of undergraduate and postgraduate. Broadly speaking, the undergraduate courses tend to be directed at the practitioners, whilst postgraduate courses, which tend to offer more theory than practice, are aimed at architects, planners and conservation officers. The only full-time course that provided a designated focus on the conservation of stone was an MSc course at Bournemouth University. This was called *Architectural Stonework Conservation*, although that course has now been broadened to include other building materials, apparently in search of greater numbers, and is now called *Architectural Materials Conservation.* Undergraduate courses at Bournemouth and De Montfort University Lincoln offer a mixture of practical and theoretical study. The City and Guilds of London Art School embraces the subject of conservation as an art discipline and offers a course called *Conservation and Restoration Studies,* with the chance of gaining a Graduate of the City and Guild Institute (GCGI) award which comes with an honours pass and is equivalent to NVQ V, or a college graduate diploma, although degree status is currently being sought. It is worth pointing out that the courses at Lincoln and the City and Guilds both insist on a comprehensive portfolio with all applications, and City and Guilds set tests for colour blindness, which might affect the ability to carry out colour matched repairs. De Montfort University offers post graduate studies in Conservation and Restoration studies at Lincoln, and MA studies are offered at the Conservation Centre in Leicester and at the Institute of Advanced Architectural Studies in York. Successful practical course modules have been arranged at York, for example in the conservation of stone.[1]

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[1] All masons at Lincoln attend a short three or four day module, *Study and Conservation of Stonework* at York, which provides an insight into ethical considerations, conservation issues, and management. Other short courses attended at York have been the *Study and Conservation of*

A Note on the Accreditation of Conservators

Any differences in the perception of the two fields of activity of masons and conservators are not lessened when it is learned that a proposals for accreditation are being discussed for conservators at professional level. This will identify categories of membership of the UKIC on a two tier basis that will relate to *Knowledge and Skill*, and *Professional Attitude*, allowing for progress between the two categories, which will be termed as 'associate' and 'fellow' status. The UKIC has written of this proposed 'professional' membership, which it concedes will affect the larger part of its membership, that 'the assessment process will be carried out by UKIC largely as a review of written material submitted by the candidate and the referees.' (43) It may be relevant at this stage to state that the practical conservation of historic building fabric relies on a great deal of application of physical labour, many conservators being tempted to identify themselves more with traditional craftsmen than other professionals. In terms of combining the dual skills of mason and conservator, this development moves not towards the concept of complementarity, but away from it. In terms of the assessment method quoted, confirmation will be given that conservators are more academically concerned than with the objects in their care. These proposals are overtly concerned with status, rather than giving a commitment of care. A recently published comment on these proposals went as follows: 'UKIC has got to define in unequivocal language that its aim is to serve and satisfy the public. Any mention that accreditation is for the benefit of its members must be suppressed.' (44) A further comment is made in this quoted article, which will contribute to this comment as a concluding view: 'accreditation is only feasible on one level which only recognises single practitioners' total and unreserved competence and their complete acceptance of responsibility for every facet of every conservation / restoration project undertaken.' (45)

Concluding Comments on Training and Competence

There are obvious differences in the relationship to the work between masons and conservators, even though the aims are directly related. Masons begin their training often straight from school, whereas most conservators are either graduates or post graduates by the time they commence work. Whereas the mason may have gained his sense of ethical value, piecemeal, or informally, as part of his training and working activity, the conservator will arrive on the first day of work with a carefully argued system of ethical values. If the difference between the two disciplines is identified broadly as repair and replacement, both definable as active intervention, there may be no difference in ethical stance between them, each carrying similar responsibilities.

In fact, there may be reasons to suggest that masons would benefit by being at least as aware of ethics as conservators, since destruction paradoxically forms part of the mason's methodology of care. It is clear, however, that no attempt has been made to absorb the values and approaches of conservation, let alone incorporate them into the deteriorating training programme of the masonry

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Metals, and the *Conservation of Interiors*, etc. Some modules incorporate practical opportunities to work stone, wood etc, with competent tradesmen present to provide guidance and instruction.

conservation, let alone incorporate them into the deteriorating training programme of the masonry industry. In ideal traditional circumstances, to some extent represented by the Compagnons of France, whose regard for the principles of traditional masonry is exemplary, it must be questioned whether the traditional mason is adequately equipped to meet the revised needs of work to historic buildings. The French system, into which these masons will presumably fit, appears to be one of complete division, with masons and conservators speaking different trade languages, resulting in two separate operations, with no evidence of them sympathetically working together.[1] In the case of the English masonry trade, it can readily be seen that it does not match the ideal, and training of traditional masonry standards is lamentably low, for reasons that have been stated. There are only a handful of masons in England now who could, for example, confidently set-out a Gothic elevation, an ability which would itself demonstrate a familiarity, not only with the medieval structure, but also with the thinking of the medieval mason and of how constructional solutions were reached. The masons' knowledge lies in their fundamental grasp of the structural geometry of the building being worked on, from which a sense of re-approach may develop. There is little evidence of an intimate understanding of materials in use in masonry work, with the exception of stone itself, which has become a commodity. It is as essential to the mason as the conservator that reactions do not occur between materials used. In today's commercial stone industry the craftsman is employed to carry out solely those duties which are too costly or difficult to produce by machine. Only in relation to historic building care is it demanded that the mason's skills come close to embodying the expertise and ingenuity of the mason of long ago. It is in working in that original environment that recognition is available of the characteristic spirit of experiment of the medieval builder, whether resolving a tricky structural problem during setting-out, or pushing the design of a moulding to its limits (perhaps due to the determined use of a newly made chisel), or the developments and refinements of constructional technology. These profound discernments were the sphere of action of the medieval mason, the results of whose labours now requires a corresponding awareness, ingenuity, care and attention.

Research establishes that the majority of students accepted on post graduate conservation courses are academically trained, perhaps in economics or geography, and are accepted on to courses on the basis of the quality of their academic status. It is a matter of some concern that, following the experience gained during a single academic year, students are then invited to enter the world of conservation, form small companies from which they will practice their newly gained

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[1] On a recent visit by the author to Poitiers, Notres Dames le Grande, and the Cathedral of Tours, in France, there appeared to be little co-operation between masons and conservators. On the west façade of Notre Dames le Grande, mortar had been allowed to slop across recently laser cleaned sculpture, and no proper consideration was made for the sensitivity of different operations. For instance, where masonry had to be replaced, the scheduling of areas where work was to be done was not made to coincide with delicate conservation work on the Romanesque Frieze, resulting in tensions on site. At Tours, whilst conservation of the glass was being carried out in the Choir, with attendant work to the tracery, similar problems were evident, with a lack of tolerance evident between trades, possibly endangering the overall safety of parts of the fabric.

skills on the fragile ancient structures of the nation, themselves often the hosts of a complex network of problems. This may reflect well on statistics relating to the amount of graduates placed in industry, but does not bode well for the historic buildings themselves. In an infant discipline such as stone conservation, it is important that it moves through the appropriate stages in its development smoothly, so that a gathering sense of its own identity will be based on substance rather than air. Proposals that it should be regarded as a profession[1] rather than a craft may effectively debar it from efficiently co-existing with others who pursue the same aims, to ensure the long life of historic buildings. There are no reasons why a person cannot set themselves up as a 'consultant' or professional advisor, although any credit for competence will be based on a practical track record, which comes from uncomplicated application of the work. As the only purpose-trained discipline involved in cathedral care and maintenance, a reliable level of appropriate response will be necessary to sustain it amidst its peer trades. Once the discipline determines its role within the team, natural feedback will inform the training institutes what is required. Whilst there is indecision within the discipline, college courses will strive to change until they hit the appropriate level.

[1] The proposals recently made at a recent meeting of the UKIC were addressed to members of that body, and not only those members whose chosen subject was stone objects and structures, but the comments made in this study apply solely to those conservators who seek work on historic masonry buildings. There are many issues that separate this group out from conservators in general, the principal one being that they intend to join ranks with crafts that are already established, at the same time seeking to work in an area of established craft traditions.

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Part 6.0

Summary, Conclusions, and Recommendations

Part 6.0 Summary, Conclusions, and Recommendations

6.1 Summary

Objective knowledge of the constructional methods and materials that a building comprises will aid examination and assessment in the case of failure in performance. In *Part 1.0 A Structural Foreword*, a review is presented of the make-up of the building and its materials, as well as the agencies of deterioration at work. In *1.1 A Brief History of Lincoln Cathedral and the Development of Skills*, an historic appraisal of the building into which is written a brief account of the development of skills. This outline helps to define the site, as well as those significant processes employed in its original construction, and includes winning stone from the ground, refinements in approaching the building to repair and conserve it, and advances in the skills of setting-out, all of which are still practised by modern masons and conservators.

An understanding of the mechanics of the structure is necessary for effective maintenance, even bearing in mind the availability of specialist engineering services. In this respect, some areas which might traditionally be regarded as the province of the structural engineer are focused on in this study as the responsibility of the mason, the duties of whom must include an awareness of structural engineering. It is the mason who must advise and take into account the specific conditions of the stonework through his understanding of the intricacies of construction in general and the workings of the building in particular, as well as his intimate and intuitive knowledge of the stone and the mechanisms of its failure. These areas of knowledge form an insurance against the agents of decay, significantly influencing the performance of the building. Maintaining structural integrity at a local and general level will ensure the direction of forces through the main elements, as well as providing adequate weathering provision. Such monitoring as is needed of the performance of the building will inevitably benefit by being intelligible at workshop level, so that the implementation of regular surveys, which are often facilitated by regular staff and responded to by them, is effective.

A broad review of the main components of the Gothic structure is presented in *1.2 The Medieval Structural System: A Review*, which looks at particular structural aspects or elements where remedial action is likely to be required. Perhaps foremost of these are ground conditions, changes in which may cause movement in the masses of the building, and common points of local failure such as the haunches of buttresses, arches, and cracking vault webs. Specific urgent needs in local areas, however, ought never to be allowed to obscure the actions of the overall structure. Solutions to structural abnormalities may, if they are viewed within the larger context of the building, be more easily determined. In *1.3 Failure in Gothic Buildings* describes the need for large-scale understanding of the structure and the ability to monitor it as changes invariably occur. The effort and expense this entails inevitably requires justification, though this should easily be defended by the advantages of early warning of any serious irregularities, as cyclic and anomalous patterns of movements will be distinguished. Working from the general to the particular, it is

obvious that there is little gain in securing the most intricate piece of carving to the upper reaches of a façade if the foundation or lower masonry is in serious need of attention.

As well as describing the geology and properties of limestone, *Part 2.0 The Weathering and Decay of Limestone* sets out the main routes of decay - physical, chemical, and man-made. These areas are all worthy of major study, and it is by no means claimed that these subjects are dealt with fully. The discipline of caring for the physical well-being of a large historic building needs to embody the study of material decay, yet such understanding can at no time be regarded as finite. Poor design features can also be the cause of decay, which may even be caused by inferior past repair, for example if poor mortars or ferrous fixings were used.

Many examples of poor practice have been found on the fabric of the Cathedral during a long period of continuous maintenance work, and some of these have been referred to in *Part* 3.0 *Lincoln Cathedral: Its Pathology and Care*. What is more, there appear to have been sustained periods in the past when work was so inferior as to suggest that entirely inappropriate measures were applied. In some cases the most fundamental principles of masonry practice have been totally ignored, with large areas of stonework replaced that could never be expected to perform properly within the total structure, or to remain durable for any substantial period of time. There are many examples of vertical joints being placed immediately over other vertical joints, causing inadequate bonding of stones and leading to inevitable separation, or 'drifting', of stonework. Added to this, many instances of the wrong choice of material combinations have caused localised acceleration of decay, including hard Portland cement mortars and ferrous fixings.

More specifically, the large-scale repairs and reinforcements have been examined in a case study in *3.2 Case Study: The Special Repair Programme (1922-1932).* The sheer extent of the installation of rigid concrete beams have initiated long-term changes in the building's ability to perform as originally intended. The work discharged under the auspices of the Special Repair Fund, and under the same caretaking regime up until the early 1950s, makes it is quite difficult to predict with any confidence how the building will endure any significant changes in local conditions. It is commonly acknowledged that Gothic structures do not function within a calculated structural margin but are generously over-engineered, and so are able to accommodate long term change through the redistribution of forces through their structural elements. There is no 'actual state' of the building in engineering terms, since this has the capacity to change more or less constantly, for instance under stress of wind loading and other external changes, including significant maintenance intervention. It is a matter of critical concern that the further this reinforcement is traced - much of it is buried within the masonry - the more extensive its presence is revealed. Inevitably, it must be asked how far the structural properties of the building will be adequate to accommodate changes which the builders could not have anticipated.

By the late 1970s the Dean and Chapter were persuaded by their architects, Robert Maguire and Keith Murray, to address the entire issue of planned maintenance, and resolved to establish a more considered and professional method. Although maintenance of a sort had been continuous throughout the century, a backlog of important structural work was apparent, such as loose and eroded roof coverings, many pinnacles in poor condition, and the visibly dangerous state of masonry on the north nave.[1] Small falls of stone had also been reported from the west front, and an inspection by mobile hoist [2] revealed masonry that was dangerously close to falling; consequently a structured programme of works was felt to be needed. It was also made clear to the Dean and Chapter by their advisors, who included members of the CAC, that the Cathedral had many fine and important, but vulnerable external sculptures, and Chapter were passionately reminded by Professor Zarnecki, who was then revising an earlier publication, of the particular significance of the range of twelfth century Romanesque Frieze panels across the west façade. These had visibly deteriorated since his earlier examination of them in the early1960s.

The Dean and Chapter began to formulate a coherent policy of work to the Cathedral fabric. *Part 4.0 Towards Effective Conservation Policy* is an outline of that effort, with descriptive references made to many significant historic and contemporary influences, and it was a gallant if not comprehensive attempt to set out an approach to address the concerns of the time. It was decided to hold a *Consultation on the Statuary and Sculpture of Lincoln Cathedral* in October 1983 where the emphasis of such influences could be examined. A recommendation of this conference was to go forward on the basis of 'policies of conservation', rather than any single all-embracing document or set of rules. In the following year, a report was debated by the General Synod of the Church of England[3] in which concern was expressed regarding the governance of cathedrals in relation to their historic buildings and contents. In anticipation of legislation, in 1985 Chapter at Lincoln produced a Care of the Fabric by-law outlining the intention to form three major committees. These were to be a Masters' Committee, which would be an in-house body making tactical judgements in proposed programmes of work; a panel of specialist advisors known as the Fabric Council, which would maintain a view of the wider picture, and a Preservation Council to act as a fund-raising body and to administer funding ring-fenced for this purpose.

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[1] Work to the masonry of the north nave, which is in an extremely poor state, with insertions of iron wedges between masonry course evident in abundance, was begun in 1996. In places it was possible to see daylight through deep masonry joints, and finials could be seen hanging from rusty dowels. The parapet and clerestory walls had been visibly pushed outwards by the weight of the roof and the masonry needed to be rebuilt to as near the original position as possible.

[2] A 'Snorkel' hydraulic hoist used by the local fire brigade was put at the Cathedral team's disposal for a short period in order to carry out this inspection. Pieces of carved masonry could be seen to be close to falling and earlier repairs appeared to have failed.

[3] General Synod of the Church of England approved a document entitled *The Continuing Care of Churches and Cathedrals*, submitted by the Faculty Jurisdiction Commission. This report examined existing legal and administrative systems of caring for associated historic buildings and their contents, and improvements were proposed for legislation.

A further conference was held over an extended weekend in the summer of 1988, the purpose of which was to address the specific problem of the Lincoln Romanesque Frieze. The symposium was called *Romanesque Sculpture in its Architectural Setting*, the sub-text of which was to seek ethical and technical advice in conserving the eighteen sculptural panels. Describing the debates which took place during the conference, 4.3 *The Lincoln Romanesque Frieze: A Case Study in Policy Shaped by Practice* outlines the background to the work that was to follow. This section provides an account of the more hard-hitting points of view that emerged during the symposium, some of which were controversial. The symposium effectively launched the conservation programme of the Frieze, which in turn led to the establishing of a permanent conservation department within the Cathedral Works Department. By 1991 the new *Care of Cathedrals Measure 1990* had been added to the statute book, and was shortly followed by a Government funding scheme for repair, operated through English Heritage. The two systems imposed new layers of regulations and conditions relating respectively to approval procedures and conditions for grant-funding acceptance. As a result of this well intentioned Measure, arguably more able to suppress than encourage the development of a responsive conservation policy, much confusion and dissent was to accompany the submission of various drafts of conservation policy, which were thought to be unspecific and open to interpretation. The widely held opinion at Lincoln was that a programme of work such as the conservation of the Romanesque Frieze was so complex and dependent upon unknown factors that a definitive policy document could not pre-empt any knowledge that would be gained through conservation practice. A high level meeting with the Commissioners of English Heritage saw some concessions afforded to this view.

There follows in *Part 5.0 Towards a Practical Discipline* a description of those practices that are applied to the care of a masonry structure like Lincoln Cathedral. These begin with the practice of archival recording, setting up the procedures by which all would contribute to the long-term record of the condition and care of the monument. This is followed by descriptions of traditional masonry practice and the emerging discipline of conservation. Analysis within these sections focuses on how the skills are employed practically, exposing the breach that exists between them. A short review concludes the section with *5.4 Training Opportunities for Stonemasons and Conservators*, in which working relationships are examined. This leads to *Part 6.0 Summary, Conclusions, and Recommendations*, which draws conclusions from the research area and identifies failures in the past, and presents weaknesses in current assumptions in the direction of maintenance care of masonry structures. Specific recommendations are made which extend proposals towards improved skill applications.

6.2 Conclusions and Recommendations

Introduction

One of the main aims of the original proposal for this study was to define the new discipline of conservation, so that it could be made to work more suitably alongside the traditional skills employed in cathedral care. In attempting to do this, considerable scrutiny was given to those traditional trades that have been around for a very long time, such as stonemasonry, carpentry, and plumbing etc, the array of skills typically found in a cathedral works team. It quickly became apparent that, although the conservator did not fit too comfortably into the conventional cathedral team, often coming from a different training background, the skills extended under the banner of conservation were valid and here to stay. It became obvious that certain aspects relating to conservation training were out of touch with the industrial atmosphere of a cathedral works department, but also that the traditional trades themselves would need to consider change in order to move along with more progressive attitudes..

During the long history of Lincoln Cathedral and the repairs that have been carried out on it, allegiance to proper craft procedures has been allowed to deviate on many occasions, and the workmanship bears testimony to this. In *3.1 A Legacy of Repair*, some examples are given of such practices on Lincoln Cathedral and elsewhere. Immediately after the second half of this century, traditional skills began to be taught once again, but following several recessions, which particularly affected the construction trade, materials and skills once more became diluted. In the last thirty years, the care of historic monuments has developed as a separate endeavour, and a great deal of intellectual energy has been expended in defining national policies and codes of conduct. English Heritage, as a custodian of monuments, has varied from employing a team of direct labour, to advocating contract labour, eventually settling for neither. This has had a most unsettling effect on the core skills applied to historic structures, a situation which has not been resolved since EH became holder of the national cheque-book for cathedral grants. Suggestions to engage in contracting have been made to certain cathedrals where a permanent team was in attendance, presumably in order to facilitate greater expenditure. Little attention was paid to the local culture of care, so important in the long-term conservation view.

Conclusions drawn from this study span a range of problems associated with cathedral care, focusing on changes endured by the ageing building, comparing today's performance with that of yesterday, examining routes of policy-making, and determining the attitudes and understanding of those individuals who must physically contend with the agencies and effects of deterioration and decay. Much depends on training and the support received for it. As national policies vacillate, for example between funding for heritage or health, the uncertainty generated is damaging to both options in the long-term, with confidence faltering and the more able individuals being less attracted to the work. Modest, long-term policies, appropriately acted upon, might be less likely to attract opposition, with levels of care being available to support the nation's structural heritage.

6.2.1 Concerning the Special Repair Programme (1922-1932) and the use of 'Panaceas'

Research was undertaken into the works to the masonry fabric of Lincoln Cathedral during the Special Repair. A wealth of documentation was found to have been generated during that time, and during the continued presence of the Clerk of the Works Robert Godfrey (from 1916-1953), whose role was enhanced to include Surveyor of Lincoln Cathedral. Documentation relevant to that period has been examined, and supported by field study throughout the entire fabric of the Cathedral, where possible. The current research has revealed that the intervention into the masonry structure was far greater than previously conceived. The conclusion is drawn that the extent to which the fabric of Lincoln Cathedral was subjected to reinforcement of the kind described in *3.2 Case Study: The Special Repair Programme (1922-1932)* was excessive and unjustified. At the same time, it is concluded that much of the contemporary documentation is ill-prepared and unrepresentative of the true state of the structure and of the intentions behind much of the work. The professional view of the Architect represented in reports to Chapter over the decade prior to the campaign, showed little concern in respect of the stability of the structure. This conflicted with Godfrey's view almost immediately on his appointment as Clerk of Works (Godfrey had been employed at the Cathedral since 1902 as a plumber). Further to this, no reference was found relating to prepared policy or proposal for the Special Repair, for presentation to Chapter, and the conclusion is therefore made that no coherent policy was prepared, and respective control was therefore severely reduced. As a consequence of this research it is possible to conclude that irreversible damage has been perpetrated to the structure of the Cathedral, the full consequences of which may not be revealed until inevitable changes in environmental conditions exact appropriate adjustments from the medieval structure. In respect of findings during the conservation of the Romanesque Frieze, it is now determined that damage was carried out directly to the sculptures, which has seriously exacerbated their decay on the façade and accelerated their structural deterioration. It is finally concluded that the process of drilling and pressure grouting with Portland cement was pursued as a cure-all, or panacea, throughout almost the entire area of the Cathedral at clerestory level, a recourse which carries no recommendation in conservation practice. Whilst it is accepted that engineering solutions may be valid (the introduction of resistance offered by the tensile steel in reinforced concretes can help to stabilise movement), treatments appear to be more beneficial when restricted to localised areas. These works would always benefit by being accompanied by appropriate investigation, and continual supervision of a structural engineer who is trained in relevant aspects of historic building structures. The example of the Special Repair confirms the ethical premise of minimal intervention.

Conclusion Summary:

- Much of the documentation generated during the Special Repair (1922-1932) was ill-prepared and did not justify the programme of work. making it generally unsafe to rely on the accuracy of the records of this period.

- No evidence exists of a coherent policy proposal, or plan of action, making control of the work unreliable.
- Irreversible damage to the medieval masonry structure of Lincoln Cathedral was caused due to the excessive treatment during the Special Repair programme, the full consequences of which are as yet unrealised.
- Direct damage was caused to panels of the Romanesque Frieze, which endangered their structural presence in the fabric and accelerated their decay.
- Drilling and Portland cement pressure grouting was adopted as a 'panacea' which conflicts with conservation practice.
- Engineering solutions can be valid, if accompanied by appropriate investigation and supervision.
- The ethical premise of minimal intervention is confirmed.

Recommendations

Although much damage to the fabric due to the Special Repair is irrevocable, it is recommended that the entire intervention, which extended from 1922 until 1952, be definitively researched and plotted, so that a comprehensive reading of structural implications is available to the crafts team and engineers. This may entail sifting through all records and reports of that period, beyond the period that this study has been concerned with, and matching findings with empirical research on the building. In reality, this may entail the lifting of areas of replacement masonry in order to ascertain the direction of reinforcement concrete beams. Whilst it is conceded that this work is problematic, it is recommended that any findings from the Special Repair should be considered a fundamental part of the long-term monitoring programme which is in place over the entire fabric of Lincoln Cathedral.

This line of research was followed in order to determine the skills and techniques that were employed during the Special Repair programme, and it was established that pressure-grouting with Portland cement was used as a panacea throughout the entire structure. In view of such alarming findings, it is recommended that support and encouragement is extended to carry out a major review of cathedral structures, where a similar history of past repair exists.

When this study was embarked upon, the intrusion into the fabric was not clear, nor were the implications to the building structure as a whole. A direct link has now been made between the deterioration of some of the Romanesque Frieze panels and the brutal effects of drilling and pressure-grouting. Severe acceleration of damage to Romanesque Frieze panels can be ascribed to this programme of work, and it is recommended that these

important factors are borne in mind during the formulation of policy in the current conservation programme, and other programmes in the future.

It is recommended that the notion of panaceas is dismissed from the lexicon of conservation options and considerations. This concept may be expanded to include treatments which are ostensibly benign, such as the lime method (which was devised for a particular stone type, Doulting limestone, but may not be applicable to others). The level of skills in a team, or the nature of those skills, may also be regarded as a panacea, with the likelihood that they will be employed continuously, irrespective of need. Rigid policies of conservation which deny the inclusion of fresh knowledge, can also be considered a form of panacea. Policies, techniques, and skills need to meet the demands of the building accurately, and be tailored to suit.

6.2.2 A Question of Professional Competence and the Quality of Specifications

Professionals such as architects and engineers often exhibit confidence, but may be lacking in significant training in specialised issues in caring for historic buildings. Past campaigns of repair indicate that even eminent professionals were responsible for poor maintenance practices, as illustrated in *3.2 Case Study: The Special Repair Programme (1922-1932)*, 5.2, *Case Study: Replacement of Two South Transept Pinnacles*, and *5.3 Case Study: Cleaning Black Crusts from Limestone Façades at Lincoln Cathedral*. The conclusion has been reached that where reputations were made due to the exhibition of qualities within a certain field, such as architectural design, the skills and understanding required in other branches of the same discipline, namely maintenance conservation, have not always been available. Incidences of badly executed repair, often with little or no ethical reference, may have been carried out with the best intentions, but it can be concluded that specialist knowledge relating to the maintenance and repair of historic masonry structures was lacking. In such cases the ancient building has acted as an experimental base upon which professionals have practiced their theories. Even today, when legislation insists that a proficient architect is engaged, specialist training in conservation and ethical values are not included in normal architectural qualifications, and this is a serious omission

A sample of opinion was sought from within the breadth of the conservation industry, represented by various large companies from the commercial sector, a retired University lecturer in engineering, members of various cathedral FACs, and several staff members from four major cathedrals, York, Gloucester, Salisbury, and Lincoln. Without exception, those consulted supported the notion that a failure in communication existed between architects and engineers, and the team performing the work.

Where breaches of understanding arise between groups commonly involved in conservation, researched opinion concluded that errors or failings inevitably occurred in accomplishing work of

merit. Most serious of criticisms was the poor quality of specifications, which were prepared for the utilisation of craftsmen by professionals who, it must be concluded, often possessed a limited practical understanding of the work. Questions arise regarding objectivity and the application of stock advice, where subtle realisation of detail and minute discoveries hardly ever reached the professional level and were invariably lost from the larger view. Similarly, the conclusion is drawn that local cultures of building care may be inadvertently ignored within standardised specifications, the details of which are often conspicuously lifted from textbooks, effectively stereo-typing variants of traditional practice.

It must be concluded that conflict arises in the case of the architect's impulses to contribute creatively towards work of conservation, difficulty emerging when what has been described as the 'design ego' of the architect is not restrained. Whilst it is inevitable that there will be occasions when the architect may be required to exercise his aesthetic judgement in distinct matters in the development of what must be considered a 'living' building (for instance in the case of restored copy carving work), any temptation to allow design prejudice to enter the conservation equation will run counter to ethical precepts of conservation. This will collide with the received understanding and practices of the conservator. The line where conservation yields to the temptations of restoration, and ceases to contribute to the cultural significance of the building, is defined in the Burra Charter (1) as the point where conjecture begins.

Engineers may be inclined to regard the constraints of working within traditional parameters as lacking in structural logic, since the pursuit of ethical solutions may deny the purest of engineering remedies. There are parallels between the two professions, since engineering as well as architecture can produce creative solutions, and be equally threatening to the traditional ethos of the structure. Opinion sought from a sample of practitioners within the profession draws the conclusion that, aside from short courses such as those run at York (see *5.4 Training Opportunities for Masons and Conservators*), engineers receive no specific instruction in masonry structures, or their problems, during formal training. Conservation processes are rarely touched upon by engineers, unless pursued as a separate study. It is recommended from within the profession that engineers pursue a conventional career, 'gaining experience in regular problems of foundations, concrete, etc. and apply this understanding to the medieval structure.' (2)

Conclusion Summary:

- In the past, professionals such as architects and engineers have been culpable of excessive programmes of repair to major architectural works, often without historical or ethical reference to the building or the traditions within which it was constructed.
- Architects and engineers are often lacking in specialist training in the specific areas that they are actually commissioned to advise in.

- A large historic structure cannot be expected to perform as an experimental site for the development of professional skills.
- Although current legislation insists on the presence of a qualified architect to supervise maintenance of cathedrals, no qualification is demanded of specialised understanding.
- A gulf in understanding frequently exists between the conservation team and the professionals, which is often based on the practical inexperience of the latter. As a result of which, frequent difficulties in communication can be difficult to overcome.
- Architectural and engineering specifications are often standardised and do not acknowledge the idiosyncrasies of local conservation or constructional cultures.
- Any temptation that the architect may feel to engage his design impulses will run in conflict with received ethics of conservation and must be restricted, although it is recognised that the aesthetic judgement of the architect will on occasion be called upon.
- Engineers and architects may conceive that the best of solutions emerge from outside of the original traditions of construction and subsequent maintenance of the historic building. Adaptation of such solutions are best regarded as last resorts, rather than the initial treatments to be recommended.

Recommendations

Although it is recognised that it is not within the scope of this study to contribute specific suggestions to improve the training or education of professionals, such as architects and engineers, it is recommended that the quality of contribution made by those professional areas to the conservation of historic masonry monuments are reviewed and treated as a special area. In this respect, it is recommended that further investigation be embarked upon to isolate areas of weakness in professional understanding of medieval structures, in particular cathedrals. Inadequacies in training and experience may lead to a reduction in confidence in professionals and the breakdown in communication with practitioners. The cost of poor performance from those engaged to lead maintenance activities may be demoralising to craftspersons and costly to the building, both physically and financially.

The recommendation is made that additional levels of competence be necessary to qualify for the post of cathedral architect or engineer. Such a qualification could display an ethical understanding and technical awareness of general and local traditions of workmanship, materials, and a state-of-the-art technical appreciation of conservation. The implementation of additional learning could be perceived as specific Continual Professional Development (CPD) and would assist in closing rifts that exist between craftspersons and professionals, whose aims should be common. This would militate against architects imposing their will on the design state of the historic building.

These recommendations are consistent with the continual demand for improved skills and intelligence in the practice of cathedral care, and acknowledge levels of understanding as shown in *Part 2.0 The Weathering and Decay of Limestone*, and *Part 5.0 Towards a Practical Discipline: A Review of Conservation Methodology*, where it is an expectation that the conservators knowledge should be highly detailed. If this is accepted, as it undoubtedly is in the case of the mason's craft skills, then a recommendation must be made that craftspersons and architects assume more of a partnership. *Part 4.0 Towards Effective Conservation Policy* demonstrates the success of policies shaped by practice, a state that would be greatly facilitated by a common willingness to share team membership.

6.2.3 Approvals, Conditions, and the Quality of Care

It has been established that the system of management of works has developed differently at Lincoln than at other cathedrals, due mainly to an historic arrangement created in the early part of this century and beyond. During that period an immoderate measure of confidence was invested in the office of Clerk of the Works, which went on to incorporate the role of Surveyor to the Fabric, though not architect.[1] The office was held by the same individual for thirty seven years, a lasting consequence of which has been to bring the office closer to the decision-making front than at other cathedrals. The culture survives at Lincoln, with the works body closely involved in matters of policy,[2] an unusual factor that has created tensions as new layers of authority have been introduced.[3] The conclusion is reached that, due to the expectation of fixed routes of communication, the conditions imposed with offers of grant-funding do not take advantage of the full range of local views available. This runs in conflict with a declared intention in *Repair Work and Grants from English Heritage 1994*, where it is stated that grants will be offered where work will 'normally be carried out using traditional methods and natural materials appropriate to the building, its history, and its condition.' (3) Where maintenance procedures are interpreted as not complying with the principles or views of EH, it is further concluded that pressure to conform may cause a dilution or loss of local characteristics of repair, which may themselves be responses to local materials and traditions as reflected in the original construction process.

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[1] Godfrey was actually received as a Fellow of the Faculty of Architects and Surveyors in 1927.

[2] Individuals and teams within the Works Department have been invited to take part in the formulation of policy. For example, the experience and views of respective foremen, mason, glazier, joiner, or senior conservator, are sometimes instrumental in preparations and presentations to the Fabric Council, as well as applications to the CFCE or EH for grant-funding. These individuals, and others, may be invited at any time to speak before the FC or other committee meetings which may be called, or attended by grant awarding agencies.

[3] These came about initially as a result of the Care of Cathedrals Measure 1990, which is regarded as positive legislation, bringing in tandem the accompanying grant-funding system channelled through the auspices of English Heritage.

The following list details typical examples of conditions which may influence maintenance methods and results in this respect:

- physical design character of the building
- performance mechanisms of local materials
- historic culture of maintenance and repair
- peculiarities of regional environmental circumstances
- structure and strategy of maintenance management
- the level of quality, development, and qualification of the 'in-house' team

In certain circumstances, the limits that apply to grant-funding do not allow for the development of policy at the rate that careful exploration might reveal changes in initially perceived circumstances (see *4.3 The Lincoln Romanesque Frieze: A Case Study in Policy Shaped by Practice*). Newly uncovered patterns of deterioration of stones or other physical evidence, perhaps relating to the larger structure, might be sufficient to dislodge earlier presumptions. Instead, a comprehensive specification is required with applications for funding, which should state from the outset a strategy for the work, a forecast of costings, and a timetable schedule. It is concluded that, despite recognition that public money must be accountable (and that a great deal of it has been channelled towards cathedrals), the demand for a presumptive document at the commencement of a complex project, to be adhered to throughout, may in certain cases be unrealistic. Planning preparation for projects such as routine maintenance of roofs and large expanses of plain masonry cannot be treated in the same manner as complex items of carved stonework, sculpture, or other works of exceptional significance. The full physical circumstances of some projects may not be immediately available for survey, defying the ability to make superficial condition assessments followed by treatment recommendations. At the same time, conservation can be most effective where policies come together consensually, drawing widely from the knowledge and understanding of all involved in the work.

The government has made grant aid available to cathedrals,[1] to be administered through the auspices of English Heritage, the official agency through which the government seeks advice on the preservation and maintenance of historic buildings. An EH Cathedrals Team has been created, with the appointment of a Cathedrals Architect who works in the field assessing applications for grant assistance. It is the role of the Cathedrals Architect not only to assess the validity of grant applications, but also to control the quality of the associated work as funds are requested to be released. Therefore, EH act dually as paymaster and arbiters of craftsmanship. Some of the funding dedicated to cathedrals has been invested in the initiation of a *Strategic Technical Research Programme*, (4) which explores a broad range of issues felt to be of concern to

[1] The government initially pledged £11.5 million over the years 1991-94 and added a further £8 million in 1993 for the years 1994-96.

cathedrals, further encouraging solutions which are devised away from the individual site. It is concluded that large bureaucracies tend not to be innovators, usually moving too slowly and being too distant from the field. Left to operate in its correct capacity, without becoming caught up in the complexities of decay etc, EH could perform a real service. It is also concluded that these three principal functions, to administer grant aid, evaluate the quality of a wide range of work, and to provide solutions to complex regional conservation issues, are in danger of conflicting with the integrity of conservation throughout the country.

Conclusion Summary:

- Due to the expectation of fixed routes of communication, the conditions imposed with offers of grant-funding do not take advantage of the full range of local views available.
- Where maintenance procedures are interpreted as not complying with the principles or views of EH, pressure to conform may cause a dilution or loss of local characteristics of repair.
- Conservation of complex and / or significant areas of the historic structure cannot be expected to conform to bureaucratically devised systems which cater for the majority of situations. This opposes the integrity of genuine research into intricate matters and militates away from instituting the most appropriate solutions.
- Conservation policies can benefit from being devised by consensus rather than decree, with practice often prescribing the best course of action.
- The multiple role of EH as custodian of monuments, paymaster, quality controller, and disseminator of new knowledge may be too much to expect of a single organisation and could lead to conflict (the additional role of training institution has recently been abandoned).
- Where development is not only encouraged but demanded, in skills of accuracy and attention to detail, it is then essential to provide space for those skills to perform

Recommendations

In the interests of appropriate care being continuously administered to the cathedrals of England, it is essential that a capacity for development is assured in all concerned areas. With direct reference to *4.3 The Lincoln Romanesque Frieze: A Case Study In Policy Shaped by Practice*, obvious reservations were held by EH with regard to the formulation of policy and the core abilities to physically handle the conservation of the Frieze. (This fear initially concentrated on the possibility of damage occurring to panels on being removed from the fabric, although when this was demonstrated to be without substance, anxieties moved to other issues.) It is recommended that initial scrutiny be made of cathedral works teams, with reference to proficiency of performance, including presentation of documentation, continuity of understanding, and adaptability of needs through training. The respective competence of cathedral works teams could be assessed and endorsed. In the case of poor levels of ability, these would then become exposed, to be corrected by the respective cathedral works team, with assistance from other bodies,

such as CFCE and EH. It may be felt necessary to inspect the continuous level of performance from time to time, as determined by the EH Cathedrals Architect.

In the case of the above being implemented, recommendations and specifications could be established through processes involving joint effort, drawing on positive contributions and discourse from within the endorsed 'in-house' team, as well as other outside agencies, such CFCE, EH, the SPAB, and others. Conservation policies, developed by consensus rather than imposition, would incorporate flexibility and allow for the continual introduction of new knowledge. Grant funding ought not to be provided on the basis of willingness to comply with rigid EH policies and preconceived methods of conservation, which may or may not be applicable. This would then free the respective and relevant research projects from the pressures of implementation (sometimes prematurely) as justification for their existence; the wisdom of results, published in the normal way, would then be available to be drawn on at will.

6.2.4 The Question of Practical Skills in the Care of Historic Masonry Structures

Introduction

Recent changes in cathedral maintenance, instituted by the Care of Cathedrals Measure 1990, impose active demands on the skills responsible. Many of these demands are met in the medium of the conservator, who has reference to related disciplines, such as archival activities, archaeology, and museum practice. Conservation is conceived to meet current thinking in cathedral care, although confusion surrounds the discipline in the lack of clear definition of its duties within the cathedral team and its, as yet, poorly conceived identity. Stonemasonry, long occupying a central position in matters concerning traditional construction, also faces a struggle with its identity in terms of new challenges to be met as it confronts the next phase in its long and prodigious evolution. Parts *5.2 Masonry Practice* and *5.3 Conservation Practice* outline the respective practices of the stonemason and the conservator, which in turn follow the over-arching discipline described in *5.1 Recording and Archive*. The ultimate aim is that these disciplines will function complementarily towards the aim of engaging the problems of the historic masonry structure. If left to their own devices, development may occur in these disciplines along divergent paths, resulting in quality maintenance being diminished. Mutual acceptance must operate between disciplines, with prejudices overcome. For example, the conservator may regard the mason's means of resolving problems as somewhat ruthless, since this often embodies destruction within the act of repair. Conversely, the mason may regard the conservator as opposing the traditions of his craft, with repair supplanting the conventional philosophy of replacement.

6.2.4.1 Recording

A most significant aspect of recent developments in conservation is the insistence and ability to record what is found and what has been done. In the vast majority of past repairs, knowledge of

treatments previously carried out would have been invaluable. Where resources are not available to carry out adequate recording, unless threatening structural imperatives exist, it would in the majority of instances be preferable to suspend commencement of work until funding was available. In the context of the term conservation, the necessity of recording is implicit. Carried out in an everyday working manner, recording can be simply carried out and at low cost. Difficulties often lie in persuading or enforcing trades to comprehend the value of recording and adopt relevant procedures; this may require a fundamental change in perception of the work, which could be a positive conclusion. It can only be of value if technical aspects of the work are more than superficially familiar to the recorder, and may suggest the case for at least some conservation training. Recent raising of awareness in the work in general is inclined to expose weak areas of performance, which in the case of recording need to be quickly addressed since incomplete or poor documentation can be costly in terms of finance as well as to the building. The conclusion is reached that recording in all aspects of conservation practice is the linchpin between all trades, and the responsibility of all associated disciplines.

Conclusion Summary

- Knowledge in recording benefits current repair, and will benefit future care. The duties associated with recording are accepted as the responsibility of all employed in the work.
- Recording work is best carried out by one who is familiar with the technical processes that may have been employed in the past and that are in use in current work.

Recommendations

It is recommended that an awareness is inculcated in all trades involved in conserving the historic fabric, of the cultural significance, or practical usefulness, of detail as it is revealed during work. This understanding would best be imparted during formative training as part of the theoretical and practical ethical instruction. This would include the training of masons, carpenters, and plumbers (lead workers), and all other trades destined to work on important historic buildings.

6.2.4.2 The Mason

During the period that historic buildings have enjoyed a resurgence of interest and a substantial increase of investment in their maintenance, it is a disturbing irony that a corresponding slump in masonry standards has occurred. In masonry training, there has been a reduced commitment from the commercial sector. Greater emphasis has been placed on the applied discipline of conservation, but the discipline of masonry continues to have an essential role to fulfil within the concept of conservation. The transfer of training standards from City and Guilds of London to National Vocational Qualifications (NVQ) has been a failure in accommodating this, catering less for revising craft skills than for introducing a tick-box system of cramming greater numbers across lower thresholds. The time has now come to alter the axis of masonry learning, since the

applications to which the trade must attend have recently moved on. Almost every mason formally trained today is destined at some stage to apply his skills to the needs of historic building conservation.

Confusion has emerged due to the scramble for contracts and the inability to interpret the terminology applied to the direction and funding of work, and a further factor is the poor esteem the masonry trade currently has of itself and its role in conservation. Prior to current controls in building care, masonry replacement was the accepted practice and masons were the acknowledged practitioners. The mason is neither builder nor conservator and his role in the upkeep of historic buildings is often begrudgingly accepted as a necessary evil, due to the necessity of replacement of original architectural elements. In turn, masons have fatalistically accepted that pride of place may have slipped away from them in favour of conservators, and the likelihood of establishing complementarity between the two disciplines has consequently declined.

It can justly be levelled at the masonry industry that it has considered it expedient to reject a greater number of new ideas than it has been prepared to accept. Feelings of impending demotion of position, brought about due to changes in the application of skills, have not been confronted by any effort towards revitalisation. Referring to poor representation from within the trade, Hill and David make the following comments:

> 'It is also the fault of the masonry trade itself, because its members have been reluctant to put pen to paper for the education of outsiders. Instead, this has been left to others who have had some contact with the trade. Architects, archaeologists, conservators and others have all dealt with the subject in varying detail over recent years, and almost all have failed to do justice to the subject.' (5)

There can be little surprise that few comments emanate from the trade itself; that has never been the accepted method of the craftsman, who expected that the way to his work would be facilitated, leaving only the practical aspects to be addressed. Yet how could a proud industry, whose primary resource is the ground it stands or builds upon, allow the import of so much foreign stone, its own prosperity undermined without comment by the mass introduction of possibly inferior and incompatible materials? It is no longer the case that it is the work only that counts; it is now expected that a good job is articulated as well as executed. A factor may be that the manner of the conservator in his presentation may be easier for architects and other professionals to accept, the language and craft of the traditional mason being relatively esoteric and deliberately inaccessible. The conservator, usually post-graduate trained, approaches the work from an academic base, with theory and ethical premises built into his terminology. Communication, understanding, and access to proposals is therefore more available to the professional who also arrives at his position mainly through academic study. Therefore it can be concluded that the task of establishing a basis for complementarity between masons and conservators involves bridging gulfs in attitude and communication.

In past times, it was the custom for the stonemason to spend his working life journeying from job to job, amassing a corpus of experience which formed the wisdom of his approach. This encouraged the perpetuation and excellence of the craft. In more recent times, society has organised itself in a more permanent manner, with fixed addresses and the expectation that work would somehow appear close to home. During the last decade and a half, however, the concept of permanence of employment has been to a large degree eroded, and it is once again becoming common to put in the effort of travel for work. A model has been provided in the description of current expectations of trainee masons working within the Compagnons du Devoir of France, who travel widely in pursuit of the experience commensurate with high standards in the trade.

It is essential that the mason, like the conservator, has an articulate grasp of the ethics of conservation which automatically complements his skills. Where the architect can be expected to appreciate the design frailties of a building, the mason must also be able to detect such potential failure so that he is in a position to proffer practical solutions. The mason, as engineer, is charged with understanding the constructional performance of ancient masonry structures, and the mechanisms of demise.

Conclusion Summary

- During the recent resurgence of interest and investment in historic buildings, masonry standards have conspicuously declined.
- Current trends in commercial masonry are not encouraging to the development of skills. The continuity of quality stonework depends on sustaining the culture of the craft, nurturing the intuitions of craftsmanship, and encouraging craft development.
- Masonry training shifts initiated in 1993 failed to absorb and influence major changes in national policies of cathedral conservation. Continued outdated instruction does not produce appropriate standards of competence, even though most currently trained masons are destined for employment in this area.
- Confusion exists in the competition for maintenance contracts in historic building work, with masonry companies losing work to conservation firms. This factor has led to further reductions in standards and diluted attempts to close skill gaps.
- Although the masonry trade has suffered from a loss in confidence, it has not proved itself able or willing to revitalise the industry.
- Whereas conservators are clearly able to express ethical opinion within the context of their skills-base, masons are generally not equipped to do so.
- Contrary to the past tradition of a 'journeyman' approach to securing work, society is now organised on a more static basis, restricting opportunity in site work. Since the early 1980s, however, it is again becoming common to engage in travelling for work.

Recommendations

In order to sustain the culture of stonemasonry, it is now incumbent on it to form a developing component in conservation practice, and to assimilate current principles and obligations that govern the protective upkeep of the fabric of historic buildings, and cathedrals in particular. These principles are manifold, but are recommended in the Burra Charter (1988), (6) which does not conflict with the Code of Ethics of the UKIC, (7) nor with the perceptions of A.R. Powys in his writings on the *Repair to Ancient Buildings* in 1929. (8) It is recommended that such ethical reference should clearly replace the notion that ethics are always 'passed on' from master to apprentice during training, since traditional links can no longer be relied upon. A clear definition of ethical guidance, with historical reference to the craft of stonemasonry, would point the direction towards a new stage in its development. The practical stonemason is a builder by training, but a place amongst the range of skills of a cathedral workshop depends on the modification of approach to meet the demands of the building. The contribution of the stonemason forms only a constituent part of a system of applications, known collectively as conservation. It is recommended here that masonry training establishments, such as those referred to in 5.4 *Training Opportunities for Masons and Conservators*, introduce into training schemes a rigorous regime of ethical instruction and discourse.

As a corollary to such ethical awareness, it is further recommended that National Vocational Qualifications for stonemasonry are revisited and rectified to include and interact with standards in conservation practice. These must acknowledge a modified approach to the work, with a revised nomenclature relating to maintenance of historic buildings. The implementation of these measures will help to revitalise and instill confidence back into the masonry trade. Until current training reflects the actual nature of the work that trades are expected to practice, natural methods of transferring skills and experience by example will be unavailable, resulting in an increased reliance being made on manuals and instructive texts. This will dilute the intuitions of craftsmanship, reduce the quality of contribution to the nation's historic building stock, and endanger the future of cathedrals.

The notion of 'journeyman' is recommended to re-enter the current descriptive trade vocabulary. A review of the stonemason's work must include an increase in continual professional development (CPD), since a successful alliance with the conservator will increase the burden of the mason, rather than reduce it, which will increase the value of the work. Where once it was the mason's role to design, specify, and construct, masonry practice is now a subdued reflection of that , principally working stones on the banker and fixing them into the building. In the defining terms of the CITB, in *Skills Survey:*

Stonemasonry, 1994, (9) it is stated that there are only two types of stonemason: *4.1 Type of stonemason: Bankers. Fixers.* Any hope of further involvement, or of development, is circumscribed in 4.4 where a sixth activity is listed as: *Main Activity: Other.* The CITB is an industry-led body that reflects the conclusions of the commercial sector. It is further recommended, following the period that has elapsed since the last research of opinion, that CITB or other body, re-evaluate the circumstances of stonemasonry, with a view to facilitating a more apposite definition of its abilities and potentials.

Reference to *Part 1.0 A Structural Foreword* and *Part 2.0 The Weathering and Decay of Limestone* illustrates the complex understanding necessary for correct conservation assessments. This is not solely the work of the conservator and should become the joint responsibility of the mason. Once it is accepted that masonry is an entity within conservation methodology, scope for development will emerge. It is further recommended here, that the subject of *materials science* is added to the curriculum of studies of the mason, so that adept assessments of a building's ailments can be made, and appropriate proposals and remedies will ensue. These will be based on mutual understanding of the mechanisms of deterioration and the behaviour of materials, such as lime mortars and engineering adaptations.

The mason is an engineer; no-one can hope to understand materials and structures with the same level of intimacy as the mason, who often sees the stone through the entire process from ground to building and with some understanding of its decay. It is the stonemason's intuitions that are relied on for selection. Isolated setting-out, followed by removal of one or more masonry components, is inadequate and bad engineering practice. A medieval building for instance, has both a considered and an unknown engineering stability, no enlightenment of which is provided by any masonry training course. Masonry repair is a radical intervention, involving the temporary but fundamental removal of structural elements, during which the equilibrium of the structure is the responsibility of the mason. Intervention into the structure must be accompanied by a knowledge of possible repercussions. It is therefore recommended that *structural engineering* is introduced as a study subject to be included in masonry training, with practical reference to ageing structures and the history and development of structural engineering.

During the past three decades, training periods have been whittled down from seven years to five years, and then down to three years. Recent pressure has called for traineeships of two years, thereby ensuring that greater numbers are regarded as training successes. This militates against the welfare of the historic building. If the level of intelligent contribution is to be maintained and even raised within conservation teams, further reductions in training

are untenable. It is recognised that an increase in training period is unrealistic, but the minimum three year period is recommended to be retained, with an increased theoretical and practical burden added to the scope of training, thus reducing the gap in understanding between conservator and mason.

6.2.4.3 The Conservator

A new methodology of practical conservation has emerged during recent decades which has been influential in changing the descriptive approach to caring for historic masonry structures from 'restoration' to 'conservation'. Practical conservation is a leading initiative, and responds to a history of concern (represented in a series of charters and manifestos), although it cannot be assumed that programmes of over restoration and other malpractices are past events. Many poor quality maintenance programmes are still executed due to a lack of resources or poor qualities in understanding. Following an initial reluctance to accept the new discipline, the traditional trades are now having to accommodate much of the thinking behind it, to the extent of modifying their own approach. This move is reflected in the Care of Cathedrals Measure 1990 (10), as well as relatively new Government systems of grant funding to cathedrals.

Practical conservation borrows many of its lines of approach from other disciplines, such as archaeology, environmental conservation, engineering, and the traditional trades, but has also developed new methods of treatment that help to counter the deterioration and decay of building materials. Conservation methods are applied to historic building fabric under the guidance of rigorous codes of ethical conduct, which form an inherent part in the training of conservators. Other trades, such as carpenters, plumbers, and masons, the accepted skills found in cathedral works teams, are not currently trained to conserve large medieval structures. In this respect, conservation is the only physical application that is currently 'made to measure' for the care of historic buildings. In no other training context associated with buildings is the philosophy from which it grew so comprehensively incorporated.

Training in conservation is often achieved through the attendance of college or university courses, making the basis for training initially academic rather than based on experience. Whereas the mason may have gained his sense of ethical value, piecemeal, or informally, as part of his training and working activity, the conservator will arrive at work with a system of ethical values, carefully rehearsed during lectures and seminars. The difference in activity between masons and conservators can be broadly described respectively as replacement and repair, both definable as active intervention, and there should be no difference in ethical stance between them, each carrying similar responsibilities. The demand on each is therefore equal to uphold the architectural, archaeological, artistic, or historic values of the property during work.

As yet, no educational course is defined solely as conservation of stone, or masonry structures (Bournemouth did run an MSc course in *Architectural Stonework Conservation*, but has now broadened the scope of the course, see 5.4 *Training Opportunities for Masons and Conservators*), and newly graduated conservators usually have little or no site experience. Training must incorporate site activities from the start, the safety of the practitioner, the public, and the object, depending totally on health and safety awareness. Much conservation work relies on the safe movement of precious, but heavy objects, and is far from similar to laboratory conditions.

The conservator needs to understand not only how the surface of the stone has become disrupted, but where the likely routes of disruption exist within the structure. The mechanisms of deterioration and decay are complex and not fully understood (see *2.3 Factors of Decay*), but the causes of certain problems are detectable along obvious pathways within the building. In the case of the Lincoln Romanesque Frieze, it has been seen that the advanced breakdown in the stones, was caused not only by acid pollution, but by the brutal pressure-injection of Portland cement grout through the face of the sculpture and into the core. It is likely that the combination of mechanical and chemical attack induced by the work of the Special Repair (see *3.2 Case Study: The Special Repair Programme (1922 - 1932)*) caused more injury to the panels in seventy years than occurred during the previous seven centuries. Revelations of actions taken during the Special Repair programme could alert conservators involved in the current conservation of the cathedral to the reordering of structural loading, for instance due to the introduction of tensile concrete members the order of load-bearing cannot now be readily predicted. There may be relocated concentrations of moisture behind masonry and a consequent redistribution of soluble salts as a result of grout presence. This warning places specific emphasis on the general lesson of maintaining an understanding of the static and dynamic conditions of a structure.

In the initial stages, by the example of good conservation practice set by conservators, assistance will be given to the traditional trades during the modifications that are now necessary. Along with the essential duties of all trades in recording, there may also be the need to draw attention to significant finds during work, such as medieval putlog holes, etc. In this way, the conservation view will increase the sense of value of the property and the work within the whole team.

In conservation, although judgements can be made of performance, levels of competence are often measured by the grade of degree attained during initial training or education. A chief way forward towards the ultimate integration of the complementary disciplines of stonemasonry and stone conservation would be for the latter to make the decision to carry out conservation with 'practitioner' status along the lines of a craft or trade, or to take responsibility for the commissioning of conservation on a professional basis. In the event of the former choice, the transfer of knowledge and the natural assimilation of abilities might then occur through example and experience, in the form of conventional training arrangements.

Conclusion Summary

- Practical conservation is now accepted as the valid methodology of maintenance care of historic buildings, and has particularly influenced legislation in the care of cathedrals.
- Within the overall discipline of conservation, many separate strands of activity operate, which include new methods and techniques, the training of which involves the rigorous assimilation of a code of ethics.
- In contrast to the traditional trades, the conservator usually steps forward from an academic rather than an experiential background.
- It is important for the conservator to adapt to large sites and associated procedures, rather than laboratory, studio, or other academic area of practice.
- Practical conservation of stonework requires distinct learning and understanding of structures, which cannot be interpreted as artefacts, since they perform holistically and dynamically. Changes in mechanical and chemical stability will affect assessments.
- In the present early stages of change, conservators will act as a 'conscience' within the cathedral team, encouraging good practice and facilitating future developments in approach across the other working disciplines.
- It must be determined whether conservation of historic building fabric intends to go forward as a trade or craft, or as a profession, so that parity or authority can be assured.

Recommendations

A recommendation is made which focuses on safety procedures, since much work practically involves working at height on scaffolds and with automatic lifting equipment. This factor is often taken for granted, but is rarely imparted to conservators as part of training, although the safety of personnel, the general public, and the object, wholly depends on it. Health and safety is rigorously enforced on most sites and is a legal obligation, and it is acknowledged that conservation training places an emphasis on many aspects of health and safety. Industrial sites, such as cathedral scaffolds, are specialised and require legal precautions. A recommendation is made to augment the practical applications of the conservator, confirming removal from the lecture theatre, or laboratory, to the industrial site. It is recommended that conservation trainees are instructed in *site procedures,* such as scaffold safety, and lifting technology, as a formality.

A recommendation is made to introduce to the conservator an appreciation of the structure in its entirety. Where practical conservation training aligns closely to maintenance of precious objects, a cathedral elevation can call for considerable adjustments in approach. It will be necessary to convert the conservator's attentions from small containable objects to large-scale areas. For instance, during the cleaning of a cathedral façade, levels of cleaning need to be viewed over the large area, otherwise the result will be patchy and uneven, likewise knowledge of structural behaviour is essential to the protective care of a

building, and forms a vital understanding relating to likely actions occurring within the masses of the structure. It is recommended that the study of three-dimensional *structural performance, or engineering,* is included in the practical training of conservation.

In defining the role of the conservator, it is recommended that the decision whether it progresses as a craft or a profession is made. This study is concerned with practical conservation, although it does not deny the role of the professional in any capacity, and it is therefore recommended that the conservator adopts the term 'craft' in descriptive reference to itself. It may initially be able to do so through such bodies as the UKIC, who are currently scrutinising accreditation in conservation, and through training establishments, some of which are in a state of flux. In both cases, it is recognised that resistance may reflect the view that this represents a downgrade in career perceptions.[1]

A direct benefit would emerge if conservators were more fully cognisant of the range of treatments from which masonry structures benefit, including conventional options offered by the mason. Extended site training in the form of block-release, or in-house training, would confirm commonality in terms of reference and methods of treatment, extended by the individual discipline. It is recommended that greater site training be made available to the conservation trainee. A significant development to current trends in conservation training would be the opportunity to develop training precedents, by the introduction of apprenticeships, across a range of age groups from school-leaving age to mature trainees.

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[1] Reference to the term 'craftsman' is often made to signify praise. It has been emphasised throughout this study that areas of understanding are necessary to the effective skill of caring for the ageing cathedral, involving an appreciation of the structure, understanding of the agencies of decay, and knowledge of and ability to apply certain methods of staving off the inevitable deterioration to which all physical matter is subject. Craftsmanship is essential to the seamless execution of this, and the less disturbance created visually, or physically, the more justified it is to apply the term. This definition denies the mason justification to rebuild large areas of the building; to the conservator, it must be sufficient to know that the work has been successfully carried out, since the work will often be largely undetectable.

6.3 Methods of Implementation

Introduction

The following section will explore practical ways of implementing the recommendations made in this thesis. These will apply specifically to the circumstances defined within the text, and will relate to those in existence at Lincoln Cathedral. Such methods of implementation will not be exhaustive, but are intended to initiate speculation on how the circumstances outlined in *Part 6.0 Summary, Conclusions, and Recommendations* might be acted upon.

6.3.1 Researching and Plotting Work of the Special Repair Programme (1922 - 1932)

Research

Despite the immediately obvious difficulties of establishing the scope and scale of the intervention of the Special Repair Programme much is available from the plethora of reports prepared by the Clerk of Works of the day, Robert S. Godfrey. It has been shown that these records are not entirely reliable, but the directions given should relate to the specific areas of work on the Cathedral, which would have corresponded to contemporary invoices and time sheets. The reports can be examined in six separate bound volumes, four consisting of the Clerk of Works' weekly reports to Chapter, and two volumes of monthly reports to the Executive Committee of the Special Repair Fund. Sufficient evidence is available within these volumes, and copious other visual and textual documentation in both the Lincolnshire County Council Archive and the Works Department Archive to establish comprehensive and reliable reports relating to the four main campaigns of the Special Repair programme. These are: a) the west front and nave, b) central tower, the great transepts, and St Hugh's Choir, c) the east transepts, Angel Choir and east gable, d) the chapter house and connecting areas.

Once the Clerk of Works' reports have been thoroughly examined for information, with the distinct campaigns identified in terms of locations and scope of intervention, information will begin to emerge which can be described as a cross between an archaeological survey and a conservation condition report. Strategic excavations into the fabric of the masonry would confirm the likely thoroughness of the reinforcement. Fig 3.8 on page 121 shows that steel fixing was introduced below the surface of the walkways at clerestory level, changing the mechanical properties of large areas of the structure. Of significance would be the junctions of the walkways between the transepts and towers, where most damage might occur in the event of major movements within the masonry structure. Sufficient evidence has already been revealed during recent conservation repair work to the west front of the Cathedral to suggest that the extent of grouting is significant. A reference diagram of grouting holes would be a simple commission for student research, and would permit a greater understanding of connected runs of hard grout within the masonry core, indicating where moisture build-up might be likely to occur. Recent work in other regions, where recording has been made, for example on the walls of the south choir and nave elevation, might also reveal useful evidence.

Monitoring

During recent years several attempts have been made to devise a working three-dimensional grid-plan of the Cathedral structure. It is essential that this is now resolved so that a comprehensive visual record of the constantly changing state of the structure can be mapped, and major interventions such as the Special Repair may be included in the structural analysis. A macro-survey is currently being run, with key points such as the three towers and the apex of the east gable being used to monitor major movements within the Cathedral structure. Normal cyclic movements, such as those exacted by seasonal change, are being established so that anomalous movements may be clearly identified. A three-dimensional explanation of new structural actions, such as those introduced by the Special Repair Programme, is necessary when considering the structural equation.

Analysis

Masonry structures such as Lincoln Cathedral defy analytical definition, being hugely over-engineered (their true state might only be determined by physically refining them until failure occurs), and they are susceptible to a more or less permanent re-ordering of their loading arrangements. In order to establish a working estimation of the performance of the structure, as much evidence as possible contributing to past and present behaviour needs to be made available. This will include information relating to the current structural state, local environment, past repair records, and any relevant research data which may be available. Historic data may produce information on past treatments drawn from outside traditional building norms. At Lincoln, the intervention of the Special Repair employed methods and materials which were state-of-the-art at that time, but which flew in the face of conventional constructional methods. This may not ultimately prove to be an insurmountable problem, but the changes in both structural performance and material compatibility must be accommodated. In the case of the engineering arrangement, the masonry system was originally conceived to function compressively, but may have been partially converted into a tensile system due to the large amount of reinforcement introduced into the fabric, and patterns of failure will be manifested in an entirely different manner. Where new materials have become part of the equation, these will need to be scrutinised for possible adverse reactions. Great difficulty will reside in such analysis for two main reasons: firstly, the structure at Lincoln cannot be relied upon to function as seen, due to the way that fundamental changes were inserted into the masonry configuration during the Special Repair; secondly, the variable quality and deterioration of a natural material such as stone cannot be measured. The range of disciplines involved in conservation of the structure must be invited to contribute to the collation of information and views, to include the archaeologist, architect, engineer, mason, and conservator. It is recommended that all reports produced are equally relevant and intelligible to those individuals specifically charged with the long term physical care of the building and its furnishings. When new prescriptions are made to secure structural stability in the future, the availability of comparative examination will help to reduce the danger of failure.

6.3.2 Practical Ways of Improving the Quality of Professional Advice

Introduction

A prerequisite to assessing the value of professional advice and instruction lies in the definition of roles and responsibilities, which often vary at different cathedrals. It is now a legal obligation under the *Care of Cathedrals Measure 1990* to engage the services of an architect (who must carry out a quinquennial review and report) and, unless otherwise agreed with the CFCE, a consultant archaeologist. The engagement of consultants in the disciplines of engineering and conservation is encouraged during the practical execution of work to the medieval fabric. This includes the formulation of proposal documentation, recording of any work itself, and for the preparation of final reports. Inevitable areas of overlap exist between these disciplines, and the needless repetition of work is costly. It is essential that the nomenclature used in recording by the archaeologist and conservator are consistent, with the fact borne in mind that the conservator must record before, during, and following conservation work. Responsibility for a definition of this nature should be ratified by the CFCE. Whilst the relevant analysis belongs within the remit of the respective discipline concerned, methods and standards of recording ought to conform to a recognised standard. Where architect's reports are concerned, these would benefit by including the views of the other professionals involved.

In the case of the architect, there exist variations from his more traditional role, which correspond to differing levels of authority according to the history of the cathedral. An extreme example of this can be found at Westminster Abbey, a building defined as a 'Royal Peculiar', where the design influence of the Surveyor to the Fabric during a recent restoration has been most pronounced. Contemporary conservation codes of practice have been conspicuously ignored, with levels of replacement of stonework and the introduction of new designs of a high order both in terms of quantity and quality. Under the authority of the *Care of Cathedrals Measure 1990*, which has no influence over a Royal Peculiar, it is unlikely that approval would have been given for similar work elsewhere. It has been pointed out that at Lincoln the architect has historically been made to share authority with the Clerk of Works. The latter may be described as the executive manager of the works, an office which has the curious ability to identify itself as both contractor and client. At the same time, it holds control over the budget. Therefore the authority of the architect is often confused and a continual matter for debate. It is, however, through the architect that such authorities as the CFCE and EH insist on communicating, and as a result power is to some extent balanced. The question remains, however, who is responsible for the appropriate decision-making, implementation, and maintenance of standards and integrity of the work.

Under the guidance of engineers a plethora of engineering solutions were inflicted on cathedrals in the early part of this century, often at cost to the integrity of the medieval structures. Of the more recent engineering programmes completed on cathedrals (See 3.3 *Major Interventions and their Significance*), some reference to conservation thinking, such as materials science and recording

disciplines, has been observed, although closer adherence to these principles might have obviated the risk of damage to the fabric that actually ensued. At York Minster, radical underpinning was successful in halting potentially calamitous movement beneath the central tower and the east end, but preventive methods of sealing the masonry from contamination by harmful Portland cements were unfortunately omitted. Soluble salts from the calcium sulphate-rich grout have migrated upwards into the masonry and have subsequently caused continuous harm to the stonework. (Further encouragement to this action was given when the Minster was water-washed in winter soon after completion of the restoration.) The current mandatory understanding that a proposal should be put before the FAC would almost certainly have prevented such a possibility.

The Situation of the Architect

The line of authority in the management of fabric issues to cathedrals is perceived as operating 'under the overall professional direction of the architect' (11). The *Care of Cathedrals Measure 1990* stipulates that all cathedrals must appoint an architect and, where relevant work is to be carried out, a consultant archaeologist - but this insistence does not extend to any other professional. In turn, English Heritage acting either as adviser to the CFCE, or in connection with grant awards, will insist on communicating chiefly through the architect. This makes the architect a key figure in relation to conservation policy and the maintenance of standards of work. It also builds into the system an unwelcome and unhelpful flaw, where all decisions made by the architect will in the end be directly related to his fees. In turn, this serves to weaken objectivity, and the perceived if not actual cost-effectiveness of any architectural decision made under this scheme. Perhaps not surprisingly, this situation is encouraged by the Cathedral Architects' Association (CAA), in their paper entitled *The Role and Duties of the Cathedral Architect*, expanded and revised to coincide with implementation of the *Care of Cathedrals Measure 1990*. The CAA, an association that exists to protect and promote the interests of cathedral architects (who automatically become members upon appointment), states that a permanently employed Clerk of Works should be immediately responsible to the architect:

> 'If there is a Cathedral Clerk of works, instructions to him must be passed through the Cathedral Architect; otherwise the Architect's authority would be undermined and his aesthetic and technical control would be diminished. This procedure may at first sight seem cumbersome but, bearing in mind the national importance of the Cathedral, it should be realised that the Architect's study and professional experience of many problems (including history of art and architecture, archaeology and the philosophy of conservation, together with current practice and technology) means that his judgements are made on a wide basis.' (12)

Often, the architect is not in fact best placed to wield such an influence over specialist practical work, and the claim of practical experience in the technology of conservation is questionable. Historically, the dramatic and often irrevocable actions exacted on the fabric of many cathedrals do not bestow confidence on the architectural profession. In the early decades of this century, at Lincoln, and other cathedrals, such as Winchester and St Paul's in London, irreversible actions

were recommended by architects and engineers, and subsequently carried out by works teams. The introduction of ferrous fixings has exerted abnormal forces on stonework and most cathedrals can cite copious examples of destructive iron wedges and cramps being found in their masonry. Even more alarming was the persistent resort to making flexible masonry structures rigid, using pressure grouting pumps and Portland cement. A series of earthquakes occurred in September 1997 in the Italian region of Umbria, all but completely destroying the Basilica of St Francis at Assisi in which was housed a series of frescoes by Giotto and work by Cimabue. Engineers have subsequently revealed that the campaign of restoration carried out in the 1950s, during which rigidity was increased by the insertion of two concrete roof beams, arguably making the structure less resistant to seismic tremors and the destruction consequently greater.

At Lincoln, at a time when the Clerk of Works had come to identify himself as surveyor (a view actively supported by *The Faculty of Architects and Surveyors* in 1927), the Special Repair was pumping thousands of gallons of Portland cement into the masonry structure, some of the consequences of which are only being revealed today, as identifiable pressure cracks are found in the important structural sculptures of the Romanesque Frieze. The magnitude of that intervention, carried out under the architectural supervision of Sir Charles Nicholson, continues to hinder any reliable engineering analyses or predictions being made of the actions of the structure.

More generally, it is suggested that the duty of an architect is to be placed objectively between the client and the contractor, and to authorise the procedure of work by issuing an Architect's Instruction (AI). Some difficulties arise from this position (at Lincoln partly due to circumstances already stated), in that the term 'instruct' extends the idea of having influence over opinion, added to which is the unavoidable fact of life that the costlier the intervention that is instructed by the architect the greater is his percentage, irrespective of the outcome of his decisions being good or otherwise. The notion of consensus or collaboration is most significant, so that comprehensive dialogue allows the most suitable recommendations for treatment to emerge. In this respect, the halting progress of the conservation of the Romanesque Frieze has determined that the logic of specifications can best be determined by practice itself. A major blockage in the agreement of policy was released only when the conservation practitioners were eventually allowed to present the nuances of the conditions of the sculptures and the reasoning of proposed treatments directly to the EH Commissioners. Although the Architect officially issues the AI, it is argued here that it must be beneficial for him to be considered as a team member, whose prime duty is to maintain an objective view of the work, to assess and collate the views of the team, and be responsible for the direction of coherent conservation policies overall.

Those claims on behalf of the cathedral architect by the CAA are surely open to question; the position of this study opposes the assumptions of the document *The Role and Duties of the Cathedral Architect,* based on the past and present performance of the architectural profession

described in the text. Case studies dealt specifically with the Special Repair programme 1922-1932, and the current conservation programme of the Romanesque Frieze, where problems arose due to lack of professional control. Similar cases at York and Ely are presented and are susceptible to scrutiny. In many cases, the architect's knowledge of art history is sketchy, since it often ranges superficially across periods and styles, and the study and experience of a particular aspect normally depends on individual inclination, ability, and the opportunities presented to the architect. It is over-optimistic to assume that all architects are well versed in such disciplines as archaeology and conservation philosophy. As recently as 1997 the words of the RIBA itself contest such claims in face of the fact that architects accept that approximately 50% of their workload is concerned with the repair and maintenance of existing buildings, of which around one tenth is true conservation:

> 'Yet little or no training in this aspect of their work is given to architectural students. It is hardly surprising, therefore, that architects' share of available work of this kind has diminished in recent years. Outside authorities which offer grant aid for repairs to historic buildings, in particular English Heritage, increasingly call for demonstrable competence of professionals engaged in grant-aided projects. The Department of Environment is understood to be compiling a specialist register of its own.' (13)

Assumptions such as those expressed by the CAA are at the root of many problems where complex applications for approval and grant-funding are required. Indeed, problems emerge at the initial stages of assessment and specification. At a time when the practitioners of historic building conservation are developing successful, evidence-based methodologies, both practically and academically, it is not helpful to overshadow that effort by promulgating the perception that the architect is master of all aspects of the work. Were this ever the case, the knowledge and experience of the architect could no longer be held to be sufficient in scale or scope. The claims of the CAA are unfortunate and seem to cast a net over too wide an area in the unnecessary attempt to prove the validity of the role of the architect and to secure his position. In fact, such claims emphasise the necessity to identify accurately the architect's role. Whilst the CFCE and English Heritage insist on communicating almost exclusively through the architect, with reliance on a document written by architects to define policies, it can be seen that there is greater scope for evading subtle and true conditions of the building fabric and proposed treatments.

Further conflict exists, as previously indicated, in that it is the instruction and implementation of work that determines the architect's fees, and in respect of grant-funded work this is worked on a percentage basis. In this respect, the fundamental conservation ethic of minimum intervention is immediately placed in opposition to the financial interests of the architect, since the least work executed on a building equates to the lower level of fees. Most conservation work is labour-intensive, which is where an in-house team is the least costly, whereas the restoration component of conservation work, which is the least desirable as far as the building is concerned, is the most expensive, but the most remunerative to the architect. Such a system as this is unfair on the architect, who must be provided with a more equitable basis upon which to negotiate his

remuneration. At the same time this arrangement ought not to compromise the architect in terms of his professional integrity, and the quality of disinterest in his advice. In the case of cathedral conservation, where the levels of ability and articulation are steadily rising across the entire range of skills, a separate system of engagement relating to cathedral architects might create a more rational and harmonious relationship within the team. The closer the relationship of the architect comes to resembling the terms of employment of other members of the working arrangement, either as a salary in the case of a directly employed team, or as a fixed fee where contract labour is commissioned, the greater would be the sense of equity and the more effective would be the collaboration. Far from the assertions made by the CAA, Indian Conservation Architect Vikas Dilawari stated recently in a personal discussion: 'It is said in India that the qualities an architect is required to possess are humility and five senses.' (14)

The Situation of the Engineer

In a recent lecture given during a seminar held jointly by the SPAB and the Institution of Structural Engineers[1], it was explained in an introduction by the Immediate Past President, Brian Clancy, that the structural engineer of today is trained in modern calculations, modern design, modern materials and modern contractual arrangements, a situation which has left a 'black hole' where historic building work is concerned. During the same event, it was suggested by Charles Blackett-Ord, a structural engineer himself, that a poor reputation had been gained in the context of historic building work due to the tendency of the engineer to over-analyse. Often, in approaching ancient structures, the engineer had reached the calculation that they should no longer be standing. The engineer is often lacking in an understanding of architectural history, and the common sense reasoning behind material choice and the genesis of technical methods. The rationalist approach of the engineer to structural disorders is generally made analytically through models and calculation, an approach which can invalidate his recommendations, since they may fall outside of conservation ethics. It is stated in the text of this thesis (See *1.2 The Medieval Structural System: A Review*) that it is not possible safely to establish the state of any element of a masonry structure, such as an arch, vault, or even a simple stone wall, without some knowledge of the primary materials, the mode of construction, and something of the maintenance history. The last point may require access to documentation relating to the maintenance of the building. Any treatment proposal must accommodate the archaeological circumstances, and absorb the multiple levels of value associated with the built structure. In approaching structural problems in the conservation context, many modern solutions and up-to-date British Standards might not be appropriate.

The appointment of a cathedral consultant engineer is a critical matter, since almost any intervention into the structure may precipitate a new ordering of its loads, locally or more generally, and therefore an understanding of the potential behaviour of the structure is essential.

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[1]A seminar hosted by the Institution of Structural Engineers on 26 November 1997 was instigated by the engineers jointly with SPAB, and was entitled *Practical Repair of Old Buildings.*

Whilst it may be too much to expect the engineer to become an intimate part of the conservation team, commonality of language and terms of reference is essential in the facilitation of intermittent consultation to ensure a meaningful exchange of relevant information. It has been shown that the burgeoning discipline of architectural conservation (See *Part 5.0 Towards a Practical Discipline: A Review of Conservation Methodology*) straddles a variety of other working areas, such as archaeology, art history, and chemistry, and in so doing is developing a hybrid system of nomenclature. Suffice it to say that the received terminology relating to architectural elements and style, much of it devised by the early nineteenth century Quaker Architect Thomas Rickman, has been adopted by stonemasons and conservators due to the proximity of practice. Past experience and current research is unable to make the same claim for the engineer, who employs terminology from within the science-base of his own discipline. The engineer might now be persuaded to make initial gestures to the developing conservation movement by demonstrating a willingness to bridge the gulf in communication, and to share in a common descriptive reference system.

Given that the maintenance and repair of the ancient cathedrals of this country are now consensually described under the generic term of conservation, it is logical that consultants should be versed in the rules of conduct which the overriding methodology of care embraces. This would extend the benefit of introducing the engineer not only to the parameters of traditional techniques, as well as acceptable modern treatments employed within the field of historic building maintenance (outside of which the engineer may legitimately feel the need to direct the processes of repair), but also the front line of ethical awareness. At the same time, this would offer the advantage of introducing the engineer to current relevant research, of which the conservator must take note since the discipline of historic building conservation is still in the fledgling stages of development. The mere fact of being more informed of conservation thinking would surely dissuade the engineer from automatically turning to incompatible engineering solutions, whilst also inviting him to contribute to associated research. Greater familiarity with historic constructional processes, of which most contemporary engineers are unaware, would hopefully persuade the engineer to make appraisals and judgements based more on the extrapolation of structural behaviour, rather than objective analyses which are less likely to yield sympathetic results.

A sample of opinion, taken from a range of engineers concerned with ancient structures bears out that rather than relying on sound judgement, definitive scientific analysis was most often felt to be professionally safer. Therefore, those materials which can be calculated for strength and longevity are usually selected for the solution of problems over traditional materials, the safety of which relies on empiricism. Where it must be accepted that masonry structures defy analysis, engineers remain hesitant in relying on their feeling for structural form. Again, this is likely to be due to the factor of liability. In fact, such diffidence in relying on intuitive experience and understanding of the performance of materials has become a stumbling block in attaining effective recommendations for the care of old building structures. In personal discussion, the engineer Alan Baxter described

this problem thus: 'Academic engineering is trying to be a definitive scientific study and academics find it very difficult to cope with instinct, feel, history etc.' (15) One example of the choice of materials being made through analytical convenience forms a paradox: the insistence on prescribing steel frames over oak timber frames in roof structures principally due to fire precautions can be erroneous, since in extreme heat steel will lose its structural properties before oak even combusts. In recommending repairs to masonry structures, modern engineers tend to rely on standard tests, such as those provided by the *American Standards for Testing and Materials* (ASTM) (See Appendix A), which give figures for the properties of crushing and the modulus of rupture, and others which identify properties of porosity and saturation (See Appendix B). However, the variables of stone types even in a single quarry is unlikely to be accurately represented, and it is more likely that a local mason would be capable of providing a truthful indication of the worth of a stone for a prescribed purpose. All too little serious research is currently being carried out on the masonry structure, and the result is a reliance on often inappropriate solutions prescribed by engineers. Alan Baxter had the following to say on this subject: 'Engineers are a real problem still in their insensitivity to existing structures. They often over-specify, they frequently do not spend enough time in understanding what is there and many have no 'feel' for how structures, which like masonry, are indeterminate analytically.' (16) It is a fact that many of the structures that have been made too rigid as a result of grouting and other forms of reinforcement have had their future options for treatment dramatically reduced.

How the Professional Gulf in Understanding Might be Bridged

In respect of the architect and the engineer, in their roles of offering advice and instruction, recognition should be given to the fact that only the architect is a statutory appointment for cathedrals. It has been shown that knowledge is necessary of the history and culture of the maintenance of the building, the intricacies of local materials and environments which are responsible for their failure, as well as the current technical and ethical advances of conservation. In the case of cathedral appointments, these issues require addressing at the earliest possible time, so that learning at the risk and expense of the building ceases. A prerequisite to this is the willingness to recognise that deficiencies exist and a preparedness to accommodate the gaining of necessary knowledge. As a first step it would be essential that recognition is given to such gaps in understanding by the relevant leading body of the professions. In the case of the architects, this would be the Royal Institute of British Architects (RIBA) and the CAA; in the case of the engineers, it would be the Institution of Structural Engineers (IStrucE). Endorsement of the need to bridge gaps in understanding by the Cathedrals Fabric Commission for England (CFCE) would broadcast the need to all cathedrals. Since a review mechanism is written into the *Care of Cathedrals Measure 1990*, it is recommended here that such a requirement be recognised and accepted as a clause for future inclusion into the Measure.

Architects

In the case of the cathedral architect, whose suitability is extremely difficult to assess at interview, even with supporting portfolio of work and references, there are a number of courses of action which would begin to close the perceived gaps in understanding, all of which may lead to conforming with an innovation currently being examined for consultation by the RIBA itself. This is towards the compilation of a Register of Accredited Architects in Building Conservation (a similar idea having been already implemented for surveyors by the Royal Institution of Chartered Surveyors (RICS)[1]). This recognises demands for appropriate specialisms within the profession by 'corresponding client bodies and organisations.' (17) At present there is no RIBA system of such registration, the only acknowledgment being by 'self-reporting' of specialist areas, or services, by individual practices. In the words of the RIBA: 'The identification of the individual specialist appears crucial for selection, nomination, and appointment.' (18) At present the RIBA has no agreed or recognised qualifications for building conservation, but an agreed pathway to such accreditation is needed. At the same time, the RIBA recognises that certain structured courses exist in building conservation, which may provide an initial entry qualification. In the event of this system of accreditation being introduced, as far as meeting true needs is concerned, much would depend on the calibre of adjudication with respect to entry on to the register. Understandable difficulties might arise where mature architects felt that their experience provided adequate qualification for entry. In other cases, the publishing of erudite academic papers on esoteric conservation issues ought not to be sufficient to qualify. Much would depend on the response of the client, in this case the cathedrals.

The proposal for a Register of Accredited Conservation Architects is commended here as being of likely benefit to cathedral care, and is recommended to be extended so that it becomes mandatory for cathedral architects, in which case the claims of the CAA could be supported. Entry to the register should be based on both practical and theoretical experience. Once again, it would be incumbent upon the CFCE and its advisors stringently to review such an accreditation before endorsement was given. It is not enough that the profession endorses itself or its own members.

Engineers

In many ways, the position of the engineer is more difficult to contend with, since the problem has not been identified by the professional body itself in the same way as it has been by the architects. At the same time, credit must be given to the engineers for the instigation of the recent seminar on Practical Repair of Buildings, which was held jointly with the SPAB, particularly in view of the large

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[1]A similar system has been introduced by the Royal Institution of Chartered Surveyors (RICS), and has met with some opposition. Accusations have been made that the system leads to 'elitism' and is not a fair method of representing experience, or knowledge otherwise gained. It is worth pointing out that of the Surveyors assessed for competence, more than 50% were referred.

numbers that applied to attend. It may be sceptically suggested that the engineers recognise that funding exists in the maintenance and care of historic buildings, and where this is disseminated by EH, for example, a proportion must be allocated to professional fees. It is understood, following direct personal communication with officers of EH, that a list of engineers is in existence who are not recommended for grant-aided work, based on a lack of understanding of the historic structure.

At the seminar held at the Institution of Structural Engineers, it was of concern that on receipt of a question from a member of the audience regarding the ability to read the changing state of an historic masonry structure, no comprehensive answer was available. In the text of this thesis, the question has been clearly dealt with that due to the changes which inevitably occur due to ground conditions, as well those created in the superstructure by significant maintenance intervention, a continued prediction of the state of the structure must be available. Engineers' recommendations ought not to be proffered as ultimate solutions, leading to a crisis appeal, whereby proposals might supersede all other methods of approach. The question of how engineers might best be instructed in historic masonry structures was put in a personal communication to the leading structural engineer, Professor Heyman of Cambridge, who answered that he recommended that engineers adapt their understanding of modern materials to historic buildings. It is the contention of this thesis that the possible cost of experimental training on historic structures may be too high. Where significant fees are being paid, the service should be accurate and experienced. Knowledge of traditional materials and constructional process would assist the engineer in this pursuit, as would a familiarity with modern conservation ethics and techniques.

There are several practical steps that can be implemented by the engineering profession, all of which require the IStrucE to recognise that the engineering fraternity wishes to be involved in historic building maintenance. This will require extra specialist knowledge which may be gained through part-time courses which deal exclusively with the historic structure and the contemporary methodology of conservation. Such course are wide ranging, and may be recommended under the sub-heading of Continual Professional Development (CPD), which might become compulsory in order to comply with a cathedral appointment.

Conservation Training and Professional Development for Architects and Engineers

Out of a growing number of University postgraduate conservation courses which are aimed at professional levels, such as architects, planners, and conservation officers, which would be equally relevant to specialist structural engineers employed in the context of historic buildings. These courses offer theoretical and ethical instruction, within the context of practical case studies. A selection of courses is described in *5.4 Training Opportunities for Stonemasons and Conservators* (p 273), and a sample of these, though by no means all, which are directed at professional level, are given in the following list:

- Bournemouth University (MSc), School of Conservation Science, Fern Barrow, Dorset BH12 5BB.
- De Montfort University (MA, MSc and higher degrees), School of the Built Environment, Centre for Conservation Studies, Leicester LE1 9BH.
- University of York (MA and higher degrees), Department of Archaeology, incorporating Institute of Advanced Architectural Studies, The King's Manor, York, YO1 2 EP.
- Architectural Association (Dip. Conservation), 34 - 36 Bedford Square, London, WC1B 3ES.

Opportunities for essential CPD can be undertaken by those professionals engaged by cathedrals; a number of short-course options are available which would apply to both architects and engineers. The breadth and quality of attention in maintaining a grasp on current professional issues can be represented by an up-to-date CPD diary. The SPAB introduced the Philip Webb Award, which is a design competition within the context of historic properties. This is calculated to persuade the architectural student as designer to recognise the implications of intruding into original long established ancient design concepts. It is also a way of encouraging vital development within ancient buildings, whilst at the same time appreciating the values inherent within them. A six day course is also run by SPAB called *The Repair of Old Buildings* and is intended for professionals and craftsmen alike, whether at the beginning or middle of their career. It is intended to demonstrate practices of conservative repair. The subjects covered range from the principles promulgated by the Society over the past 120 years, to the study of the principal traditional materials of construction, with the emphasis on restrained treatment which is likely to preserve as much of the ancient fabric as possible. Of value in this course, in the context being discussed, is the introduction of structural aspects of repair, which may describe the consequences of intervention.

6.3.3 Improvements in Systems of Approval

The Situation of English Heritage

It has been suggested in this thesis that large bureaucracies such as English Heritage are rarely equipped to accomplish all of their aims, and that they may benefit by narrowing their field of influence. In the case of cathedral care, the principal aims of EH may be perceived in the following summary:

- to administer grant aid to cathedrals in pursuance of maintenance conservation
- to provided advice on preservation and maintenance relating to historic properties
- to research relevant issues in the field of cathedral conservation
- to extend training facilities in the field of architectural conservation

In addition to these services, EH is a major custodian of ancient monuments throughout England. The question is raised whether these functions are too many in number, and tend to conflict.

State Assistance: Help or Hindrance?

As far as cathedrals are concerned, the provision of grant funding is often a mixed blessing since it is conditional on the positive evaluation of techniques used. In certain cases where 'in-house' skills are employed, outside tendering has been mandatory, and lower quotations forcibly accepted. The programme of Strategic Technical Research, which was established by EH in support of cathedral conservation, influences the technical efforts of cathedral teams to the point that grant funding may be withheld where technical methods are contested. A recent example of this occurred at Lincoln concerning the specification of mastics in glazing - EH maintaining that cements were preferable. An approval was held up for several months. The view that there may only be a single solution to a complex technical issue may be regarded as unsafe. The urgency with which funding and supporting information is required by a cathedral may reduce its powers of negotiation and consequently the integrity of its culture of maintenance. The extension of this type of stranglehold is threatening to the natural evolution of local solutions to conservation issues, itself the essence of vernacular development. Without a more objective basis from which to suggest assistance and technical support, there is a risk that the credibility of EH will be undermined to an extent which precludes a very real opportunity to contribute to conservation on a national scale.

Craft Skills

Where they are allowed to respond to specific circumstances and needs, craft skills will develop more effectively than if they are heavily influenced and controlled by a central agency of conservation. In the words of St Benedict: 'If there are craftsmen in the monastery let them carry on their crafts in all humility.'(19) In 1997 the training centre run by EH at Fort Brockhurst was finally closed down. The reasons for the failure of the centre were given that the response to its 'Masterclasses' had been poor, which may not have come as a surprise to others involved in the training of conservation. The very fact that the centre was funded by government money and run by the state agency for conservation may not have persuaded many that the term 'Masterclass' was automatically eligible. After all, it is only since 1991 that EH (having developed in 1984 out of the Department of the Environment's Public Works Department) has become involved in the conservation of such living structures as cathedrals, having previously been responsible for the stock of derelict abbeys and monasteries around the country, much of which consists of low walls and fragments of elevations. A very particular brand of conservation was developed by EH, which consisted chiefly in capping the exposed corework of partially dismantled masonry walls, repointing exposed joints, and generally maintaining the sites of abbeys, monasteries, and priories. Within five years EH had subsumed the long and varied experiences of cathedral workshops, and the many commercial companies throughout the country, and were promoting themselves as the authority in all areas. An example of the rigid views promoted by EH officers was levelled recently

at masons who, it was criticised, persisted in using trowels for pointing. Pointing-keys, designed by EH are now specified for this task. Such detailed interference is pointless and unconstructive, and will serve only to mute the intuitions of craftsmanship, lower morale, and irritate and confuse the craftsman, thus reducing confidence in other directives from an agency with diminishing credibility.

On Research and Specification

On occasions, following the production of interim reports resulting from current research, suggestions have been made to cathedrals (and others in receipt of grant aid) that findings be employed. As research has developed, the same recommendations may have been rescinded, or altered. Most responsible conservation departments would always carry out tests using local materials as understood by local craftsmen, which must be far more valuable than imposed recipes from a central source. Specifications relating to mortar mixes and the views of EH on the inclusion of Portland cement have varied so widely and regularly over recent years that it is almost impossible to determine at any one time what they are. Many of EH's views are inspired by the Smeaton Project, trials for which are carried out on the most marginal and untypical site of Hadrian's Wall. Mortars are examined in isolation, with little or no account taken of their relationship to stone types, or the nature of the structure the mortar is being used on. A most useful technical advisory service could be offered by EH, which could regularly be visited by architects, engineers, and craftspersons, who could follow the full circumstances of research, perhaps even contributing to it. As it is, the Architectural Conservation Team, which could provide a very real and valuable service to cathedrals, is commonly perceived as merely providing a back-up for the EH Cathedrals Architect who is confronted with many cathedral conservation issues.

Evaluation of Work

Once a grant offer is made and the work is embarked upon, the work is evaluated whilst in progress, and on completion. This inspection is carried out by the EH Cathedrals Architect, who may be accompanied by an EH quantity surveyor. Although there is only one EH Cathedrals Architect, two other architects have been commissioned on a part-time basis to assist with the workload of inspecting the forty-four cathedrals. Many of these cathedrals are undergoing intense and long-term programmes of maintenance, and the responsibility to absorb fairly the detail of each programme of work is weighty. This procedure is, however, carried out in a pedantic and on occasion suspicious manner, in the name of protecting public expenditure. In fact, such attention to the letter of this procedure makes it unnecessarily cumbersome and ultimately untenable. Where established cathedral works teams have proved themselves capable of sustaining conservation of a consistently high quality, with appropriate documentation, and have a proven management and accountancy track-record, it would be possible to devolve responsibility to the respective cathedral on a basis rated on credit. Where outside contractors are employed, a track record based on performance could be established, with the management remaining the responsibility of the respective cathedral authority. Such a system would secure a relationship of

trust, and would relax the insistence that a pre-planned prescription of treatments and quantities of materials to be used be rigidly and unrealistically adhered to as a prerequisite of grant-funding. In the case of complex conservation projects, as described in *Part 4.0 Towards Effective Conservation Policy* this has proved to be necessary.

A Workable Future?

It can be seen that the present system of distributing funds to cathedrals is by its nature likely to produce conflict, and can be adversely influential to cathedral care, as well as the development of skills. The conflicts described previously in relation to the relevant professions are currently upheld by the system, and the forming of black-lists of those professionals whose abilities are doubted, as well as those endorsed, is itself unprofessional and lacking in fairness. Cathedrals were previously maintained in many individual ways, which were often erratic and unreliable, but did at least respond directly to the state of the building. It may be that the cathedrals funding arrangement, which is administered by EH, followed on too quickly after the inception of the *Care of Cathedrals Measure 1990*, with too many changes occurring at one time. English Heritage was provided with substantial funding to be disseminated to cathedrals, but the qualifying conditions often tend to coerce cathedral works teams into methods based on project-management, rather than an all-embracing care provided by established methods. A danger exists in this method of procuring work, in that the idea of successful conservation management may be perceived as the quantity of funding won from EH. In this respect, quality will be forced into second place, with productivity being the prime mover. Additionally, many complex conservation issues, where approval difficulties can be anticipated, might be deliberately avoided. Without independence of opinion, and with no threat of prejudice involving other similarly funded projects, the business of appropriate and qualitative conservation care of cathedrals will be seriously threatened. A funding agency that enforces its own advice and methods, which have to be taken up in order to qualify, is not tenable since such advice may not apply, and in any event carries no liability[1]. There is no guarantee that large-scale projects, initially funded by EH, will continue to be supported throughout the duration of the project. An example of this is the west façade of Lincoln Cathedral, which has been funded for five years, but has been refused funding for the final year of the project. This has resulted in no work occurring on the final quarter of the façade which has at the time of writing been scaffolded for more than two years.

Since EH was established in 1984, its in-house policies have been constantly changing, and job positions within the agency have been in a constant state of change; rumours of internal adjustments abound, an example of which is the threat of regionalisation which hangs over the

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[1] English Heritage make it quite clear that no liability is accepted by them in a document entitled *Cathedral Repairs Grant Scheme for 1997/98 - Lincoln Cathedral,* under the sub-heading *Professional Advice,* 'English Heritage accepts no liability for any professional advice offered by its representatives. Your own professionals remain responsible to you for the works they specify and certify on your behalf.'

agency like a cloud. What is required for effective and sustainable cathedral care is stable and sympathetic support, which is based on familiarity, and is objective and reliable. A personalised funding partnership cannot be formed on the current practice of a solitary EH Cathedrals Architect, albeit with some part-time support. A solitary architect cannot hope to comprehend the true needs of all cathedrals (during December 1997, as many as five separate applications for approval were outstanding at Lincoln, due to the workload of the EH Cathedrals Architect). Central administration of quality control has proved impossible to implement to the satisfaction of all involved in the process, and the system might benefit by the diverting of funds to form a small team of cathedrals architects who operated regionally. In such a case, it might be necessary, and even preferable, to have less actual conservation work executed, the quality of which excelled, rather than a greater amount of work, the character of which is diluted due to the constraints imposed by strict adherence to a dogmatic set of rules. Local cultures of cathedral maintenance would in such an event be more readily accommodated, with information feeding back to the research body, encouraging the research to be more directly connected to the real world of cathedral conservation. Cathedral teams could be more genuinely involved, and would be more likely to seek the support of the research body as being in the vanguard of proper conservation issues. At the same time, the particular philosophy or ethical approach adopted by the EH Cathedrals Architect[1] would at no time be persuaded to hold sway over work presented for approval.

The current system of cathedral architects, and other professionals, having their fees rated at a percentage of expenditure flies against the well-being of the fabric, as well as conservation ethics, and it is recommended that this method is reviewed by EH. Similarly, the insistence that the EH Cathedrals Architect relates exclusively to the cathedral architect summons up the notion of professional conspiracy, with the interests of the profession truly protecting itself. It has been stated that architects may not be best placed to discuss technical matters, perhaps not having received the appropriate training or experience. It is recommended that a more personally-based system might help to promote the skills, experience, and understanding of respective cathedral works team members, many of whom are more qualified, academically and experientially than the architects. A further recommendation is that EH officers should re-evaluate their national role, and question themselves whether their multiple functions are compatible. Of inestimable value to the country is the local colour and culture of its regions, an historic condition represented by its cathedrals. This is reflected in the local responses to their care and upkeep, a feature which is hoped can be encouraged to flourish, rather than be threatened by the levelling influence of standardisation.

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[1] The current EH Cathedrals Architect is David Heath, (formerly an SPAB committee member the post precludes such a connection whilst in office), who recently expressly stated his desire that the cathedral architect should be 'in charge'. He questioned the term used by the Lincoln Architect, Nicholas Rank, when he referred to 'we at Lincoln'. This attitude is diametrically opposed to the recommendations for implementation in this thesis, where the architect might become a team member, and not the exclusive specifier and director of the work.

6.3.4 Implementing Change in Tradition and Skills

During the past two decades, the notion of conservative maintenance has replaced the misguided image of the stonemason being solely responsible for the repair and maintenance of cathedrals. In place of this, action has been taken to reduce man-made causes of decay, such as air-pollution emissions, and greater emphasis has been placed on retaining as much of the ancient fabric as possible. An additional *Care of Cathedrals Measure 1990* has been introduced, together with a comprehensive system of grant funding. In tandem with this, a new discipline has emerged, which partially transfers its methods and ethical thinking from museums and galleries. This discipline of conservation is to be added to the range of methodologies employed at the large physical sites of cathedrals and other historic buildings.

The Situation of the Stonemason

Far from welcoming this event, the stonemasonry fraternity has attempted to ignore it, and training modifications, together with the recently introduced national funding arrangements, have tended to isolate further this most traditional of disciplines, serving to stultify what should be the next stage in its development. In order to redress the balance, three significant steps should be implemented, so that the mason may join with others in the field of conservation. This is in line with other recommendations in this study, relating to funding and the participation of professionals on a collaborative basis. These are as follows:

- To redefine the scope of masonry training
- To review standards of competence (NVQs)
- To introduce an upgraded qualification

This last item will describe a method of meeting the conservator on the same academic and practical status.

Redefining the Scope of Masonry Training

Traditional terms of reference used to describe the craft of stonemasonry, which are still in use today as a model for training, have long been out of date. Rather than accept any process of development the stone trade has concentrated on familiar areas in training, such as basic setting-out and simple tool skills. The modern stonemason, particularly in parts of the commercial sector, has almost become a semi-skilled individual, whose duties hardly resemble those of his forebears. In France, the Compagnons du Devoir, through constant historic comparison and research, has maintained a link with tradition. The question must be asked, however, whether such a model adequately meet contemporary needs? The position of this thesis is that masonry training must re-affirm traditional links, in terms of understanding, at the same time gaining the ability to accommodate and absorb the new methodology of practical conservation. Training institutions need to redefine the circumstances that newly recruited trainees are going to address.

Standards of Competence

In 1993, the responsibility for setting training standards in stonemasonry was shifted from the City and Guilds of London certificates to National Vocational Qualifications (NVQ). Rather than encouraging the development of intuitive craftsmanship, the new standards are tending to stultify potential. The CITB, who carried out a preliminary review (See *5.4 Training Opportunities for Stonemasons and Conservators*), failed to recognise and account for the changes in conservation attitudes which were then underway. In the event, the levels expected of the trainee were simplified in order to create a greater 'paper' success and, as a consequence, what can be described as a process of 'dumbing down' has occurred. If left unchecked, this trend will have calamitous repercussions on the stone industry. Already, there is difficulty in engaging the skills of sensitive and formally trained masons who can demonstrate the competence to analyse and execute effective masonry repairs to cathedral structures.

Standards of competence must be reviewed at the earliest possible time, in order to reverse the decline in understanding which is now evident in newly trained masons. No system has been more effective than the direct transfer of skills and knowledge embodied in the traditional apprenticeship. It must be acknowledged that today's apprentice masons are destined at some stage in their career (and earlier rather than later) for employment on the nation's historic buildings, and the standards required for that work are not represented by those in training schemes. In the first instance, the generic term of conservation needs to be introduced into the descriptive terminology of the craft, so that relevant philosophical and technical emphasis can be implemented at craft level and beyond. The responsibility for revisiting the requirements of the industry must fall to the CITB, with pressure applied by EH and the CFCE.

Upgrading Masonry Training

If stonemasonry is to successfully collaborate with conservation in the practical care of cathedrals the discipline will need to be taught at a higher level, with a similar perspective given to the work. This will require a radical reassessment of the structure of training (see 5.4 *Training Opportunities for Masons and Conservators*). Initially, this might pose the question of the levels to which masonry is currently taught. Two levels are maintained at present; the first being years one and two, which takes the apprentice up to NVQ level 2; the final level, which is generally the third year takes training to NVQ level 3. In view of the significance of the structural nature of the work undertaken by the mason, it is questionable whether these levels are valid. In the same way that experiment as a form of training cannot be tolerated at professional level on historical buildings, this must apply also in the case of apprentices. The 'tick-box' nature of NVQs is calculated to ensure the success of even the slowest learner, a system which is inadequate in the case of the conservation of historic buildings, the cost being too high. Whereas conservation trainees, who are mainly university or college taught, are persuaded of the importance of the many values of the objects and structures they are to work on many, if not most, apprentices who move through the

conventional apprenticeship system maintain little or no theoretical knowledge of the buildings they are destined to work on. It must be remembered that it is a prerequisite of the Burra Charter that knowledge of the cultural significance of the work is necessary (see *4.1 The Evolving Perception of Care*). In the case of cathedrals, where the building performs on many levels, not least of which is on a spiritual level, emphasis on the importance of values cannot be overstated. At the elementary stages of training in masonry, standards are recommended to be significantly broadened and raised.

An Advanced Qualification in Masonry

Standards need to be dramatically raised in relation to elementary stonemasonry practices and introduced into training. At the same time, it is recommended that a new concept of the advanced qualification in stonemasonry is introduced to replace the existing relevant NVQ (which is considered inadequate to the work of stonemasonry). Much concentration is placed on tool skills in current masonry training, which is essential to the craftsman's precision. However, in the case of implementing sensitive repair to an ancient building, precision is not the ultimate criterion, and to doggedly pursue that aim would not necessarily be to produce the finest results. The quality of the mason's work is realised through understanding and feeling. An advanced qualification would set up standards that entailed the trainee to thoroughly research the styles and techniques of the ancient builders, with an attendant study in the materials employed. The training of masons at a higher level would automatically support the raising of standards at elementary level. The following sub-headings outline the aims of a higher qualification in masonry:

- Rediscovering the Language of Masonry
- Ethical Instruction for the Stonemason
- Materials and Materials Science
- Toolskills and the Presentation of a 'Masterpiece'

Rediscovering the Language of Masonry

Masonry practice must correspond to contemporary ethical and technical imperatives, and the appropriate training facilities need to relate to practice. The fundamental language of the mason has long been found in systems of geometry. The natural recourse to geometry in masonry has largely been lost, or dropped, apart from the diluted ability to work out simple mouldings for localised repair. At a recent three day course at York University,[1] one of the speakers, Pascal Mychalysin, spoke of the lack of understanding which accompanied the way modern masons set out individual stones, with no real geometrical knowledge. He described this process as working from the outside into the stone, rather than the medieval way of comprehending the design from

[1]This was a three day module on Stone Conservation held on 23-25 February 1998 as part of the MA in Conservation Studies at the Centre for Conservation Studies, King's Manor, York, to which outside attendance was encouraged. Pascal Mychalysin is currently the foreman mason at Gloucester Cathedral, and is a representative of the *Compagnons du Devoir* of France.

within. By reintroducing the comprehensive study of points, lines, angles, surfaces and solids, the mason will arrive at a position where he can absorb instruction in structural engineering within the understood framework of the Gothic structure (See *1.2 The Medieval Structural System: A Review*). An ability to predict accurately the consequences of intervening in the complex geometry of the masonry construction is the explicit responsibility of the mason. The introduction of a substantial engineering component into the training curriculum, in combination with an intimate understanding of the geometric framework would assure this ability. The foundation of caring for intricate and changeable structural arrangements, in their ideal and corrupted state, would then be established.

Ethical Instruction for the Stonemason

It has been stated in this thesis that the mason employs the capacity for unnecessary destruction within his methodology of repair. Removal of eroded masonry may involve the use of hammer and punch, or pneumatic tools which impact heavily on the building (although such tools as disc-cutters and Kangol hammers, which are used unscrupulously in the commercial sector for speed, are not recommended for this purpose). This factor alone emphasises the need for some ethical guidance during work. Masons often possess a vague notion that replacement of stonework ought to involve less rather than more, but consensual ethics, such as those salient points which have been unanimously agreed upon in the major charters and guidelines are nowhere to be found in formal training courses for masons. The introduction of ethical instruction is essential to the work of conservation of historic buildings and its omission in masonry training should be redressed within an overall review and redefinition of the scope of the stonemason's work, and the appropriate training.

Materials and Materials Science

As part of securing an appropriate understanding of the physical building, knowledge of the primary material, in the form of a study of geology, would be invaluable. This would form part of a larger appreciation of those materials that a) were employed in the original construction, and b) will be used in modern repair and maintenance. A module of materials science for the trainee mason would provide an essential supplementary understanding of the work of repair, providing a broader base to operate from. This study would include lime and lime-based mortars, and grouting techniques, dowelling and stitching methods, and the consequences of using Portland cement, hardly any of which is presently to be found within curricula. An overlap into the materials of associated disciplines would provide a more holistic appreciation of the work of cathedral conservation. Timber, for example, has always been an aid to the mason's work in falsework, moulds, and scaffold arrangements. Knowledge of metals is extremely useful to the mason; lead,

for example, was used extensively in dowelling and fixing, as well as a jointing material in some instances[1].

Toolskills and the Presentation of a 'Masterwork'

Drawing from the model provided by the *Compagnons du Devoir*, the demonstration of competence might be made by presentation of a masterpiece, or masterwork. Whereas the French system concentrates on a complex demonstration of stereotomy, or banker skills (see 5.2 *Masonry Practice*), it would be more representative in the context of cathedral care to show an awareness of the complete array of aims and outlines discussed. In part, this might be a written exercise which dealt with the many theoretical points of history, ethics, and cultural awareness. A practical masterwork would include the full range of physical skills appropriate to the mason, but would also address complex conservation tasks, for example the repair of an ancient vault, or the construction of an arched doorway in an existing structure. An understanding of the engineered structure would need to be demonstrated, together with a sympathetic proposal for treatment, within which an array of specialist approaches could be considered. All of these approaches should be familiar to the mason, even though his own specialism would remain that of structural issues and masonry replacement. An important factor in establishing such a qualification, based on a range of abilities, is that the specific skill of the mason does not become blurred. Raising both standards of ability and contextual awareness is intended to assist the mason to make better judgements by being able to analyse the ailing structure so that the correct treatments are provided. At the same time, a more informed position would encourage a better relationship with the conservator, since they will share a similar platform of knowledge and understanding.

6.4 Suggestions for Further Research

During the conference in 1983: *A Consultation on the Statuary and Sculpture of Lincoln Cathedral (1983),* (See *4.2 New Systems of Critical Dialogue at Lincoln*), the phrase 'no implementation without understanding' was coined, a remark that has long guided the philosophy of care at Lincoln. Current pressures to standardise the conservation of Britain's historic building stock, presumably so that they conform to conditions associated with the processes of approvals, are tending to dilute the power of that driving sentiment. The following ideas for future research urge a reversal of that trend:

Plotting the Work of the Special Repair Programme (1922-1932)

An abundance of written and drawn documentation exists in the Cathedral Works Archive, offering an informed archaeological, architectural historical, or conservation researcher the opportunity to unscramble their relation to the physical impact of the Special Repair on the Cathedral fabric.

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[1] The masonry joints of the great west window of York Minster were found to have been fixed using lead. The stones were placed on lead rolls and the joints sealed prior to molten lead being run into pour-holes, which had been pre-drilled. It was decided during the recent operation to replace the tracery to employ the same technique.

Considerable assistance would be required in order to fully determine the paths of intervention undertaken by Robert Godfrey during that time, although much could be established using non-destructive testing equipment to ascertain where metal reinforcements had been placed. An ideal example would be beneath the clerestory aisles, since the work in these regions is supported by photographs (see Fig 3.8, p121). The composition of a three-dimensional grid plan, at which several serious attempts have already been made, would be essential in plotting this intervention.

Developing the Stonemasonry Craft through Training

The skills of the stonemason have throughout history been undeniable, but the demands of the major source of the mason's work have substantially altered in the last two decades. In order that stonemasonry as a creative and intelligent discipline may step forward into the next stage of its development a radical review of its aims is required. This will require an objective evaluation of the trade within the field of historic building conservation, so that its failings are illuminated as well as its many qualities. A bias should be given in such a study towards an interactive coexistence with the developing discipline of practical conservation, since both disciplines share a common aim of securing the future of the historic structure. A research programme dedicated to the training of masons specifically within the conservation arena would outline the way forward.

The Masonry Structure and the Mortars Employed

Whilst much has been written about the many uses of lime and the value of lime mortars, continuing research is needed relating to lime mortars in the context of the masonry structure. For example, very little is written about lime mortars and renders in relation to sandstone buildings, yet many questions remain to be answered. For example, at the recent seminar, held jointly by the SPAB and the IStrucE, the lime method was openly prescribed by engineers without any mention of the obvious chemical incompatibility in the case of sandstones. The Smeaton report is providing interesting and useful information as far as it goes, but greater emphasis on masonry structural association would provide a more universal context.

A Final Note

At present the business of long-term historic building care is plagued by a multitude of interpretations, creating many points of tension, and making the premise of conservation difficult to pin down. At one end of the spectrum, radical restoration programmes have revamped entire Gothic façades, often appearing to satisfy only the ego of the architect in charge. At the other end, the conservatism of some conservation proposals seem to be based on the desire for a solution to the problem of stone decay. This itself denies the reality that stone naturally erodes, a simple phenomenon that secures the future of mankind by providing soils in which sustenance is nurtured. To militate against this inexorable action in the case of buildings and sculptures is understandable and necessary, though it may ultimately prove impossible. The compromise between the practical demolition of areas of historic structures and the virtual preservation of them in aspic probably lies within the concept of 'sympathetic maintenance', whereby clues to the past

co-exist comfortably with a sense of development. This can result in the experience of a thriving original building which functions in the service of its users.

Sympathetic maintenance of historic buildings requires a thorough understanding of the structure in question, a somewhat open-ended research project in itself, and it should be remembered that some aspects of damage cannot be properly tackled until the conservation of the environment is addressed. It cannot be overstated that the business of caring for a major historic masonry structure is highly complex and, although mainly a practical activity, is fed by front-line research which paves the way forward both ethically and technically. Architectural conservation is an embryonic discipline, a state that has naturally generated a glut of research, much of which is repetitive and some of which is questionable. It is important to stress the need for pertinent and necessary research rather than that which is fanciful or esoteric, because in reality large buildings require their caretakers to observe their true needs; knowledge of the genesis of the building and applied constructional technicalities cannot be over valued. Similarly, research that cannot be transferred to conservation practice offers little meaning to the continuity of historic buildings.

It may at present seem sufficient to safeguard the buildings in our care, and in so doing stave off the influences of decay, but a view needs to be kept on the development of the skills that have been devised initially to construct them, and later developed to care for them. Vigilance is necessary regarding changes that occur in technical understanding across all associated fronts, for example archaeological techniques and findings which may contribute to the constructional understanding, or discoveries in materials science which affect the range of conservation techniques. At any time, both the traditional skills of the stonemason and the emerging discipline of the conservator need to be willing to accommodate change, as this is the sole way that status and compatibility may be maintained during progress. In pursuing the continued care of historic buildings an analogy is apt with what John Harvey wrote in relation to the demise of the French medieval builders. He referred to the perpetual need for development and experimentation in design and technology:

> 'After the middle of the thirteenth century - say, after the death of St Louis in 1270 - this continuous experimentation ceased, quenched by a phase of self-satisfaction. This reflected encyclopaedism in philosophy: the Schoolmen of the time had become satisfied that by now they knew all the answers, and thereafter might sit back happily. Such an attitude spells death, or stagnation, for any culture, and its counterpart among the building masters put an end to the main stream of Gothic impulse.' (20)

Appendices

List of References

Part 6.0 Summary, Conclusions, and Recommendations

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Appendix A

The ASTM Standard Tests For:

Compressive Strength

The American Society for Testing and Materials (ASTM) have devised tests for compressive strength, possibly with their own unique requirements for high style building in mind. The standard test method for compressive strength of natural building stone takes place as follows:

- Scope: The method covers the sampling, preparation of specimens, in order to determine the compressive strength of natural building stone.
- Samples: The samples are chosen to represent the best average of the type and grade of the particular stone being tested.
- Specimen: The specimens may be cubes, square prisms, or cylinders, but possess a lateral dimension of 2" X 2". Three specimens should be used for each conditioning; wet, or dry. The load-bearing faces of the stone to be ground flat, the bedding direction clearly marked.

The compressive strength of each specimen is calculated as: $C = \frac{W}{A}$ where:

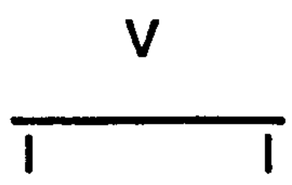
C = compressive strength in psi.

W = total load applied in lbf at point of failure.

A = calculated area of the bearing surface in ins sq.

The Modulus of Rupture

The test conditions are similar to those of the compression tests. The following test example is the modulus of rupture. The specimens are selected and prepared in a similar manner to the compression test. The specimen is then placed upon a pair of supporting knife edges and subjected to the downward force of a loading knife.



The modulus of rupture is calculated as: $R = \frac{3WL}{2bd}$ where:

R = modulus of rupture (psi)

W = breaking load (lbf)

L = length of span (ins)

b = width of specimen (ins)

d = thickness of specimen (ins)

Appendix B

Standard Tests For:

Porosity

The following indirect test is the standard method used to determine porosity. The stone is artificially dried in an oven and weighed (termed WO). It is then saturated in water, using vacuum conditions and weighed twice again, in immersed conditions (termed W1) and in the air (termed W2). Porosity (p) is given as follows:

$$P = \frac{W2 - WO}{W2 - W1} \times 100\%$$

Saturation Coefficient

The saturation coefficient is the measurement of absorption which occurs in a fixed time. It can be defined as being the ratio of the volume of water absorbed to the total volume of voids in the stone. Together with the measurement of porosity, it will give a fuller indication of the stone's absorption behaviour and its potential durability.

The indirect test may continue once the porosity level is established. The stone is dried and allowed to become saturated by immersion over a period of 24 hours. It is then weighed (termed W3). Saturation coefficients are counted in values ranging from 0.40 to 0.95. The higher the value rating, unless the porosity is very low, the more small pores the stone possesses and the poorer the weathering quality. Saturation coefficent (S) is given as follows:

$$S = \frac{W3 - WO}{W2 - WO} \times 100\%$$

Microporosity and Capillarity

The microporosity of a stone is the quantity of the total pores which possess a practical diameter of less than 5 microns. The higher the microporosity of the stone, the greater the percentage of small pores exist within it. Water retained within the micropores is less likely to be drawn out by forces of natural suction. Consequently, the stones possessing high microporosity levels are less likely to be durable.

The tests employed in order to establish microporosity impose a suction pressure equivalent to 6.4m head of water on a sample of stone, following vacuum saturation. The quantity of water which is retained within the micropores is quantified as the microporosity percentage. A 30% value is regarded as durable, whereas a value of 90% is considered unacceptable.

Capillarity is defined as the rate at which water is drawn into the pores of the stone. It is this property which largely controls the movement actions of water within the pore structure, such as evaporation and the migration into adjacent materials. Capillarity is in effect the determining influence of the suction force. Variable pore structures in materials combined in a building can suffer greatly due to capillarity differences.

The controlled test compares the change in weight of uniform samples of stone when placed in a shallow level of water. There is a marked difference in the uptake of water in stones of high and low porosity, dividing the rates of intake into two stages. During the second stage of uptake, a levelling out is reached. The increase in weight is expressed as the content of water, S.

$$S = \frac{Wt - WO}{Ws - WO} \times 100\%$$

Wt = weight in time

Ws = vacuum saturated weight

WO = weight when dry

Appendix C

Case Study: Re-opening the Cathedral Quarry

Background to the Project

In the early 1970s the Cathedral authorities decided that extraction from their Victorian quarry should cease. Reasons given for the decision were obscure and not entirely convincing. One statement maintained that the proximity of the water table had effectively 'water-logged' the stone reserves, and another that military exercises during the war had entirely shattered the remaining stone. It seems more likely, however, that poor business relationships between themselves and the local construction firm contracted to extract the stone were the true reason. If this is so, then question marks relating to the quality of the stone could be discounted.

By the mid 1980s only a small quantity of thinly bedded slabs remained in store to be selected from. The decision was taken to buy stocks of French limestone, Following comparisons with any such stones. *Anstrude Jaune Claire* was chosen and purchased from the agent, Chichester Works Organisation. Three years later, following protestations from the Cathedral masons, a different resource was sought, closer to the local geology, texture, and colour. An opportunity arose to purchase at low cost a consignment of local stone which had been buried under a 19th century railway embankment. This provided an ideal space, both financially and with good stocks of stone in hand, in which to test remaining reserves in the quarry.

Investigating Reserves

A thorough investigation was launched and a Consulting Geologist, Dr David Jefferson, was enlisted. The aims of this search were to establish the history of the quarry and to ascertain suitable reserves of stone with which the Cathedral could be repaired for the foreseeable future. Information proved unreliable on occasion, with at least one paper (Evans 1952) referring to a sequence of around 12m, which did not appear to exist. Early drawings were located within the Cathedral archive, also confusing matters, since they referred to a bed of 'blue clay', not at all apparent. A comprehensive field survey of Lincolnshire limestone was also carried out 'Whether or not the strata exposed continued southward beneath the reserve area was also uncertain, since a number of faults are known in the area and other could certainly exist.' (JEFFERSON, D. Quarrying Stone for Lincoln Cathedral, In: *Stone Industries*, Oct 1992.)

It was necessary to gain firm indications of good quality blocks under the area to be quarried, around one acre of land being the southernmost half of the total site. In order to be meaningful and cost effective, the jointing patterns of the beds of stone, delineating the individual blocks, needed to be regular and showing adequate size, ie. around one metre by two metres. Unlike regular walling stone, often of a relatively small scale, dimensional masonry block should be capable of replacing existing stones on a like-for-like basis. Most stones on the Cathedral were under 300mm in bed height, but could be quite large in area (e.g 1.8m X 1.2m). Originally, stone was taken from

near the ridge, where the beds are shallower. Further north into the escarpment, the beds gained in height, but were found to be blue hearted. Although this is believed to weather out later to a more normal blonde colour, it had been traditionally considered unsuitable for the purpose of conservation work on the Cathedral. Owing to the costs involved, only two bore holes were drilled to establish the existence of reserves, one into the existing quarry floor, the second into the ground to the extreme south of the site. These were intended to provide evidence of consistency in the sequence. A core drill of 92mm was used, providing core samples large enough for carrying out tests.

Reserves of Lincoln Limestone

The available beds of potential dimension limestone were five in number, and were referred to as BS1 - BS5 inclusive. The top bed, BS1, was felt to be of a variable nature and therefore unreliable for use on the Cathedral, as too was the fourth bed, referred to as BS4. The bottom bed, BS5, was also known as the 'Red bed', due to the presence of a red fleck, possibly a soluble iron mineral migrating to the surface where it turns dark due to oxidation. The second and third beds down, however, BS2 and BS3, appeared to be potentially the most usable beds, relating most closely to the original material on the Cathedral fabric. These beds were traditionally known as the 'Silver beds', and sometimes the 'White bed'. The Red bed also can be found on the fabric, but is generally felt to be a slightly inferior material, requiring closer inspection prior to use. Estimations arrived at an approximate total of 9,000m3 usable stone in the ground, not including material that could be used for walling, paving, and other general domestic building purposes. In total the potential quantity of dimension limestone was felt to be around 13,000m3, including blue-hearted stone. Sale of stone unusable on the Cathedral would off-set the cost of quarrying.

Summary and Conclusions

The quarrying operation, now approaching its fifth full season, is felt to be a major bonus for the Lincoln maintenance team, very few cathedrals having access to such reserves of compatible material. The proximity of the quarry to the Cathedral, approximately 1 mile, enables a close link between demand and supply, in terms of quantity and special requirement of individual blocks, for sculpture etc. Extraction of stone has been carried out by Lincoln masons, who realise fully the demands of such material, and is carried out using modern versions of ancient techniques. For instance, plugs and feathers are still employed, but are driven into the ground not by hammers, but by compressed air. The stone is lifted rather than winched from its natural bed by a JCB Loadall with an extending boom, capable of bearing twin forks and lifting three tonnes. Primary and secondary sawing facilities are installed on the site, allowing the stone to be precisely dimensioned prior to delivery to the masons workshop adjacent to the Cathedral. As the face moves southward, the ground is back-filled and the area landscaped. A programme of trees and grass planting is already in place and is complementing those areas of the quarry which were previously designated an area of natural historic interest by the Lincolnshire Trust for Nature Conservation (Figs C1, C2, and C3.).

Fig C1 Quarried stone: large blocks are stacked for selection (centre), with walling stone (right). Beneath, the separate beds of stone are seen, with natural 'joints' between.

Fig C2 Lincoln Cathedral Quarry: The working situation requires flexible lifting arrangements. The JCB Loadall, has 6m extending forks, and the lifting gantry services saw tables.

Fig C3 The sawing facilities include a primary mono-blade frame saw, for slabbing blocks of quarried stone, supported by a Bramley 36" blade circular saw, seen in use above.

Appendix D

A Consultation on the Statuary and Sculpture of Lincoln Cathedral (1983)

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Appendix E

The Lime Method

Introduction

Lime mortars are traditional materials used in historic masonry construction. Soft lime mortars are both chemically and physically the most appropriate materials for use with limestone. The process of making lime can be followed through the lime cycle:

$$Ca\,CO_3 \quad + \quad heat \quad \rightarrow \quad CaO + CO_2$$

Limestone burnt (calcined)in kiln at min. 880°C

(calcium carbonate) (calcium oxide + carbon dioxide driven off)

$$CaO \quad + \quad H_2O \quad \rightarrow \quad Ca(OH)_2$$

Quicklime with water gives slaked lime

(calcium oxide) (calcium hydroxide)

$$Ca(OH)_2 \quad + \quad CO_2 \quad \rightarrow \quad CaCO_3 + H_2O$$

Slaked lime / lime putty carbonates and returns to the original chemical component.

(calcium hydroxide) (calcium carbonate)

Lime is a product of the calcareous material found in natural limestones. These stones may possess a high level of calcium, or they may be associated with silica, alumina, magnesia, oxides of iron, and hydrogen. The relative presence of these substances and others, such as clay and quartz in grains, will determine the nature of the useable lime product, once it is processed. For the purposes of construction and conservation it is important to determine the peculiar qualities of a lime extracted from a particular limestone. Each lime possesses individual properties of weight, colour, and eventual hardness.

Categorisation of limes is made by their performance on immersion in water. The richer the lime, the purer in calcium, and the more constant it remains in such conditions. The more inclined a lime is to set under water the more it is described as hydraulic. Levels of silica, alumina, and magnesia in the stone, and their combination, will effect the hydraulic properties of the lime. Chalk, for example, is extremely high in calcium and its lime is described as non-hydraulic. Stones containing a high proportion of magnesia, alumina, and silica, which will react with inherent clay products, will tend to be more hydraulic.

Grades of lime are many, but in broad terms they can be classified as follows: non-hydraulic, semi-hydraulic, hydraulic, and eminently hydraulic.

Lime Putty

A rich (high calcium) lime-putty may be stored indefinitely in water. It is these types of lime which are the most commonly useful in conservation. Rich limes may be stored in this way without embarking upon the process of carbonation. Separation of the lime-particles through contact with water, and the effective lubrication of each grain, will have enhanced its 'plasticity', making it highly workable with trowel or spatula.

As it begins to dry out and recombine with atmospheric carbon dioxide, the lime-putty begins the process of carbonation, eventually transforming back into a form of limestone. Dangers at this stage are shrinkage and exposure to frost, the process being so slow. A considerable drawback in construction work is the time required for curing. Arch and vault erection may demand the degree of immediacy which can only be provided for by a hydraulic mortar. A disadvantage of hydraulic lime-mortars is the need to use them immediately, with little possibility of storage since it is not the natural process of carbonation which sets the lime, but the chemical reaction of the constituent elements already mentioned. Such limes may not be 'knocked-up' (crushed and re-used) although limes and lime mortars which are non-hydraulic can be recycled in this way, and often were in medieval days.

A lime putty, once dried out, may be ground down and bagged, in which case it is called 'hydrated-lime'. These limes, although more easily handled, transported, and stored, lack the smooth, workable quality of lime-putty, and also have the disadvantage of a short bag-life.

Lime Mortar

The quality of a lime-mortar depends largely upon the care employed in the burning and slaking of the lime. It also relies on the nature of the aggregate which is mixed with the lime, and again upon the degree of effort invested in mixing. In medieval building practice the quality of a mortar was of paramount importance, its performance requiring to be somewhat predictable, not least of which for reasons of safety. It is essential that an aggregate, whether sand or stone dust, is clean so that the faces of the grains may adhere to the lime-coating. The grains should be of a sharp and angular shape, so that an adequate interlocking action will occur. Particle sizes should not vary greatly, so that the risk of creating large spaces is reduced. The optimum mix is a 3:1 aggregate and lime.

The Lime Method

The lime method was developed by Professor Robert Baker after he had seen some lime processes used in Italy. The lime method utilises products from stages in the lime cycle to provide a complete, chemically compatible treatment for decayed limestone:

- Cleaning using a lime poultice

- Consolidation by the application of lime water
- Repair with lime mortars
- Protection by a lime shelter coat

Cleaning Using a Lime Poultice: The application of a lime poultice is principally to soften the layer of dirt on the surface of the stone, although it is expected at the same time that a degree of revitalisation will be given to the friable stone. The wet poultice applied to the stone for a period of time should encourage the salts within the stone to re-organise, allowing the lime water to become absorbed into the matrix of the stone. Consolidation is established as contact with the air eventually converts the lime to calcium carbonate, a process known as 'carbonation'.

Freshly slaked lime, still very hot, is applied to the pre-wetted stone, by trowel, spatula, or a gloved hand. The lime putty is pressed firmly into the contours of the carved stone, until it is an approximate uniform 75mm thick coating. Wet sacking, or plasterer's scrim, is placed over it and secured with string. The whole is then covered with heavy grade polyethylene sheeting and loosely tied. Over the next two or three weeks the polyethylene sheeting is periodically lifted and the poultice dampened with hand-sprays. This ensures that the lime is kept soft and remains active, preventing it from binding to the stone on being later removed.

When the prescribed period of dampening is over the lime poultice is carefully removed. This is carried out piece by piece, using spatulas, small brushes, and with water hand-sprays being used to help soften the lime, at the same time loosening the surface dirt. The process is finalised by careful and painstaking cleaning, using small brushes, tooth-picks, scalpels and if necessary the micro air-abrasive.

In wrongly applied circumstances, the lime poultice can present a number of problems. The conservator Roger Harris, who worked with the conservation team on the Wells Cathedral west front programme writes: 'Freshly slaked lime is difficult and hazardous to apply, and the damage done to the stone by applying a 3" thick layer of boiling lime to painted medieval sculpture may be considerable.' (HARRIS, R.A. *Informal Notes on the Conservation of a Cathedral Facade*. Letter to M.0'Connor, Oct 1988.) He goes on to point out that a possible argument against its use could be illustrated by the obvious problems of hanging a hundredweight of wet lime putty on a weakened and decaying piece of stone. Objections raised by health and safety considerations present a strong case against the use of the method.

Stonework to be cleaned by poulticing must be first inspected and recorded. Ferrous metal dowels and cramps must be removed as sustained exposure to moisture will cause corrosion and subsequent expansion, leading to fracturing of the masonry. It is prudent to remove unsympathetic mortar repair as these can create a build-up of moisture and often conceal iron fixings. Patches of

polychromy should be identified and recorded. If these are found to be adhering badly, or if any friable areas of stone become apparent, preliminary consolidation should also be considered. Where crumbling stonework is of questionable strength, an alternative cleaning method should be considered.

Consolidation by the Application of Lime Water

The application of lime water, followed by the meticulous execution of lime mortar repair, and the provision of a protective lime based shelter coat, constitute the basis of this consolidation technique. The central aim of the lime water method of stone consolidation is to introduce calcium hydroxide into the pores of friable limestone, and then let it convert into calcium carbonate in situ.

Preparation of Lime Water

The lime water is prepared several weeks in advance of the intended work in a sealed bin, advisably in close proximity to the area to be consolidated. Lime water can consist of either by being siphoned directly from a slaking tank, or can be prepared by fresh lime being stirred into a plastic bin of water and allowed to settle thoroughly until the water is clear. Conditions of storage should be cool, calcium hydroxide being held in greater suspension at lower temperatures (0.14g in 100ml of water at 15°C). Other than the careful siphoning action required to take the top lime water away, the bin should not be disturbed, so that the lime settles to the bottom. On the top of the water a skin of calcium carbonate will develop. This is formed by reaction between the lime water, calcium hydroxide ($Ca(OH)_2$) and the atmospheric Carbon dioxide. Cloudy lime water should be siphoned away, or allowed to settle. Contact between the water and air should be avoided as this will neutralise the lime water by carbonation. A float of polystyrene sheet, penetrated by the siphon tube will assist in this. The bin is finally wrapped with wet sacking and polyethylene sheeting, which serve to keep the water cool by evaporation.

The Application of Lime Water

Thoroughly cleaned, with all previous repairs where possible removed and left open, the stonework is completely coated in lime water. Application is made carefully, without allowing more than a minimum contact between air and lime water. For this purpose conservators working on Wells Cathedral developed a method of utilising hand-pumps with nozzles removed for quick dressing thereby delaying the process of carbonation. An initial coating serves to prime the stone, with better absorption being achieved in subsequent applications. Between thirty and fifty separate coatings of lime water are made over a period of days, two applications at a time and with a period of a few hours between each. Clean sponges are used to gently wipe off the excess fluid on the surface of the stonework, with care being taken to remove any white residue, or lime 'bloom', which may begin to accumulate on the surface.

Evidence of Effective Consolidation

Obtaining proof that decaying limestone benefits from consolidation by lime water has proved elusive, although it is widely felt that there is a positive contribution. Many friable plaster surfaces have received added strength by this treatment (PETERSON, S. Lime Water Consolidation . In: *Mortars, Cements and Grouts*, Rome, ICCROM. 1981). The west front conservation programmes of both Exeter and Wells Cathedrals were based on the lime method. Significant reports claim that, following the application of lime water, previously friable stonework assumed a more solid physical state.

Scientific examination, carried out under laboratory conditions, has been undertaken by Dr Clifford Price. This study, however, failed to prove that a significant deposition of calcium-hydroxide had occurred within the pore system of the stone. Study carried out at the same time also failed to determine, as a result of lime water impregnation, an increase in the resistance of the stone to abrasion. Although it was felt that a beneficial change did occur, this could not be scientifically confirmed. Dr Price was forced to conclude: 'on the basis of the laboratory experiments described, there is no conclusive evidence that multiple applications of lime water serve to consolidate friable limestone.' (PRICE, C.A., and ROSS, K.D. The cleaning and treatment of limestone by the 'lime method', Part 11. A technical appraisal of stone conservation techniques employed at Wells Cathedral, London, Monumentum, 1984 pp301-312).

Repair with Lime Mortars

The stonework, cleaned by lime poultice and further treated with lime water, is now ready for the painstaking process of lime mortar repair. This stage of the lime method is the most demanding of the conservator and is the final statement of the treatment. Each repair, on being approached, has to be regarded as an individual set of problems, with critical attention kept on the objective totality of the work. The lime mortar repair will act sacrificially.

Preparing the Mortar

The quality of a lime mortar depends largely on the particle size of the lime and the completeness of the coating of lime around each particle of aggregate. Lime putty, is continually going into suspension, improving in consistency the longer it undergoes the slaking process. A finely slaked lime is essential for successful lime mortar fills and repairs. Two particular aspects are of importance: a) the ingredients of the mortar are thoroughly integrated, and a scrupulous pounding and pummeling is required in order to break-down any recalcitrant lumps into fine grains, and b) water should be introduced into the mix in small quantities. Water occupies space in the mix, which will later be vacated as the water evaporates. The greater the amount of water to evaporate the greater the spaces that are left and, consequently, the weaker the mortar.

The lime to aggregate ratio depends upon the type of stone being repaired, and the nature of the fill. A basis upon which to begin, however, is 1:3. No manufactured hardening or activating agent, such as Portland Cement, should ever be added to the mix. The limes employed in such repairs are high calcium limes, and possess no hydraulic, or self-setting, qualities. In circumstances requiring a 'weak hydraulic mortar' (ASHURST, J and N. Practical Building Conservation Vol 1 *Stone Masonry*, Aldershot, Gower Press 1988), a judicious addition of natural additives can assist in substituting the carbonation process. Carbonation requires contact with air and a deep fill may largely deny this. Pozzolanic agents will aid the process, while at the same time limiting shrinkage to some extent. Pozzolanas were originally discovered by the Romans in volcanic ash and employed in the manufacture of cements and concretes. A suitable available additive of this type is HTI (High Temperature Insulation), a finely ground refractory brick-dust. Other materials which will react with lime to create hydraulic compounds are powdered clay products, iron slag, and pulverised fuel ash.

Applying the Fill

In executing repairs of this nature, a fine line naturally develops between securing adequate protection of the historic stonework and the preservation of archaeological integrity. The key-word is protection, with only a minor emphasis placed on sculptural interpretation. It should be borne in mind that water is the paramount destructive agent, Ledges and lips require only a subtle reduction in inclination to retain water. Very friable areas may demand a judicious protective repair in order to divert the natural run of rain-water. Protective aspects of hood mouldings and canopies may deserve particular attention during this stage, as with those features of mouldings and carvings which have been specifically designed to dispel moisture.

All cavities and interstices must be free from dust or other detritus, and a final flushing out with distilled or de-ionised water will assist in this and also dampen the inner walls of the cavity to be filled. A thin solution of mortar paste should be painted onto the cavity and left for a time to acquire 'key' to the stone. If the cavity is excessively deep, small fragments of the same stone-type can be pressed into a mortar bed. The introduction of such fragments of stone, wedged into the gap, helps build up the cavity, reducing the likelihood of the damp mortar cracking under its own weight. The pieces of stone will also retain moisture longer than the binding mortar, delaying the drying process and reducing the danger of shrinkage. This advantage continues long after the repairs are finished, levelling out dramatic temperature changes exacted by the weather.

The mortar, moistened to a state where it can be squeezed and still retain its shape, is pressed into the cavity, assisting excess moisture to ooze away. This action should be undertaken decisively so that the carefully prepared lime mix does not separate, as the ingredients will be inclined to do when over worked. Ensuring that the mortar is well compacted will reduce the threat of shrinkage and the appearance of micro-cracks. Such fissures would readily accept the ingress of moisture, allowing the lime-mortar to be attacked by frost and freezing moisture.

It is of obvious importance that the mortar repair should not detract from the quality of the worked stone. Therefore some effort is required in order to ensure that fills are not overtly bland and even, in colour or texture. Skill is required in this aspect of the work, particularly when addressing large areas of repair. It is a good idea to play down the repair so that it neither distracts the eye nor misleads it by invention of form. Mouldings, or carved features, it should be remembered, are 'read' from the ground, the lower horizontal edge or line usually defining the form.

Colour Matching

Natural stone possesses the quality of seemingly varying its colour tones as the natural light changes. In matching such qualities a range of trials around the base colour should be prepared. These will act like the colours of a painter's palette and when used with skill will prevent the fill being conspicuous. As a rule it is advisable to aim for a slightly paler shade than the base colour, as migrating soluble iron may darken the mortar after a short time. A stock of stone dusts varying from light to dark and ranging from coarse granular textures to finely ground, will make up the aggregate of the mortar and produce different coloured finishes

Drying Procedure

Lime mortar repairs benefits from slow drying, with less danger of shrinkage and resulting hair-line cracks. Should such cracking occur, it is essential to thoroughly remove the fill and start again. Once a repair is considered to be complete (and left slightly full to be 'cut-back' later), it should be covered in damp cotton wool under a layer of cling-film, or fine-grade polyethylene sheeting. Frequent return visits to spray the cotton wool with a water hand-spray will help to restrain the drying process and further limit the risk of cracking.

Protection by Lime Shelter Coat

A shelter coat is a layer of protective lime mortar applied to the surface of the stonework, the function of which is to receive the impact of the weather and prevent the inherent impurities within it causing damage to the valuable historic fabric beneath. It may be applied over the total surface, or locally, depending on the condition of the stonework. It is described as being 'sacrificial', and can be replaced periodically.

The composition of the shelter coat is more or less the same as the repair mortar, although the stone dust is more finely ground and the ratio of the mix is slightly more aggregate with less lime. An additional ingredient of casein, or formalin, may be added as a binder, increasing adhesive power and durability. The coating is applied with bristle brushes and rubbed into the pre-wetted stone surface with the aid of wads of clean hessian. The colour of the mortar coating is controlled in the same manner as the mortar repair, but since in essence the coating is designed to cover a larger area, greater skill and care is required in order to modulate, or blend the colouring. As with the mortar fills, the shelter coat must be persuaded to dry slowly in order to avoid cracking.

Polyethylene covering over dampened cotton wool, which is frequently sprayed with water, is ideal for this purpose.

Denying wear to precious historic sculpture and carving by the introduction of a sacrificial layer, thereby shielding the masonry from the constant attrition of wind-born abrasion, must be regarded as a positive step. Such a coating may also serve to reduce levels of moisture penetration to the stonework. In turn this lowers the incidence of salt crystallisation, the destructive cycle of degradation caused by dramatic wetting and drying.

It is essential that the consistency of the shelter-coat is coarser than the base stone, using aggregates of a larger grain-size. The real danger of this application lies in blocking the pores of the stone, either partially or wholly, and preventing the natural expulsion of moisture. In those regions of a building where there is a consistently high level of damp there is a threat that high-calcium limes may not have the opportunity to dry-out and carbonate.

Appendix F

Silane Consolidants

Consolidation is a means of imparting structural strength to stone that has become friable. Silane based consolidants use low viscosity compounds of silica to penetrate deep into the porous structure. These then react in situ to form polymer networks. Effectively, a silica lattice is created within the stone which shrinks back onto the pore walls and gives structural cohesion.

The most common silanes used in conservation are ethyl silicates and alkoxysilanes. Respective examples are the products Wacker Stone Strengthener OH, and Brethane (developed by the BRE).

Ethyl Silicates

Hydrated silicon oxides, or silica mixed with water, forms a mild silicic acid. This can be introduced into the stone where, as the water begins to evaporate and the acid contacts with CO_2 in the air, it forms into a colloidal mass within the pores of the stone. As de-hydration and contraction occur, a chemical bond is formed between the stone and the gel and an improvement is actuated to the cohesion of the friable stone.

Silicate esters are the product of a reaction between silicic acid and alcohol, forming a consolidating gel-like substance as contraction occurs during evaporation of the alcohol. Sodium and potassium silicates have in the past been in common use as consolidants for porous building materials. These substances are dissolved in water and on becoming exposed to the air also form a gelatinous mass. Alkali salts are often produced as a by-product, appearing on surfaces as efflorescence, and desalination of these areas will then be necessary.

Alkoxysilanes

Amongst the most commonly selected inorganic consolidants are the products known collectively as alkoxysilanes, Employing a solvent-based carrier, deep penetration takes place before consolidation occurs. The basis of the consolidation action is known as polymerisation, the chemical union of the small molecules, or monomers, forming larger ones of the same compound. The presence of water in the stone or atmosphere aids polymerisation by acting as a catalyst.

Acrylic Silane Combinations

Acrylics can be dissolved into silanes. The combination of the two will provide, from the silane, a hydrophobic action and deep consolidation. At the same time, as the solvent of the acrylic solution evaporates and gravitates to the surface, security is offered to loose and flaky surfaces by the resin which remains. Most importantly, a bond will be established between the two levels of consolidated stone, with the stronger outer consolidants effectively protecting the more fragile and vulnerable areas and the deeper, safer areas being bonded to the surface by the weaker

consolidant. An example of this is Racanello E55050, a mixture of acrylic resins and a silicone polymer, but the solvent carriers are so harmful to the user that it is no longer available in this country. Another example is the use of Paraloid B72 (a methyl methacrylate co-polymer) with Brethane.

Conclusions

The chemical state of silane consolidants permits deep impregnation into the stone, enabling it to be employed generally rather than solely locally. Since water is the principal agent in the decay of stone the hydrophobic nature of silanes will effectively prevent the growth of mould, which will in turn prevent the accumulation of dirt. Such a build-up of soot and dust would be hygroscopic and therefore its absence will help prevent decay. However, the water repellent nature of silanes is not compatible with the porous nature of limestone, and harmful interfaces may be set up. Inevitably, some salts will reside within the stone, but the introduction of a silane consolidant will in theory entrap them and render them inactive. Silanes offer good resistance UV light and react well on exposure to oxygen, but they are brittle and present low resistance to mechanical shock.

The relative effectiveness of solvents to retard the setting of the consolidant tends to mark the individuality of the particular brand. Brethane, for example, (a methyl-trimethoxy-silane), is mixed with a catalyst immediately prior to treatment. This means that once the process is underway it must be seen through to completion. Other brands may be controlled by precipitation, allowing the conservator more time for manoeuvre. The question of health and safety should always be addressed in association with their use. Silanes are highly volatile and the solvent carriers can be extremely harmful to the human system. A major disadvantage, which must remain a paramount consideration, is their irreversibility. In this respect their use is a last resort to preserve the object, since their employment transgresses the first rule of conservation, ie: the principle of reversibility wherever possible. Such a radical introduction of a substance into the matrix of a material dramatically transforms its make-up, therefore the question of the test of time must arise, since silanes have only been in use since the early 1960s.

Appendix G

The Lincoln Frieze Colloquium: October 1995

(Published O'CONNOR, M. The Secrets of the Frieze, In: *Church Building*, Melhuish, N. ed. Spring 1996)

Contradictions in Style and Construction

Introduction

Work has been in progress on the conservation of the Romanesque frieze at Lincoln Cathedral since 1988, following an international symposium convened to discuss its deteriorating condition. On Friday 6 October of this year, a group of scholars, including art historians and archaeologists, was invited to Lincoln to debate recently acquired knowledge of the frieze, gained during the work. Six panels have so far been removed from the façade and only one, a circa 18th century replacement copy, has been put back. The remaining five were considered too fragile to withstand the elements and to perform structurally.

The Received View

Since the final quarter of the 18th century, during the time of the architect, James Essex, the scheme of relief sculptures which spans the entire 11th century façade, constructed by Remigius, has been the subject of academic discussion. However, Zarnecki's views of the frieze have commanded general support since his early writings of 1963, including its attribution to Bishop Alexander, known as the 'Magnificent'. The scheme was felt to have been perhaps the jewel in the crown of his rebuild of the 1140s, when according to Henry of Huntingdon 'Alexander restored with subtle workmanship the building damaged by fire, so that it was more beautiful than before and second to none in England.' Elaborating upon Remigius's somewhat ascetic west front, which is apparently all that survived the conflagration, Alexander set about enriching the three doorways and extending the height of the gable and the towers. Within this campaign of work, the view is held that the frieze panels had been inserted into the ashlar, immediately beneath Remigius's existing string course.

An Archaeological Unveiling

As the core behind the panels becomes exposed, during recorded conservation work, an archaeological inspection and report is commissioned. The City of Lincoln Archaeological Unit (CLAU) have been asked to provide this service, with Dr Lawrence Butler of York University carrying out supervision and analysis. Recently, certain anomalies have arisen to question the theory of insertion, with practical indications tending to deny the relatively straight forward exercise of chopping out the ashlar and letting-in the face-bedded slabs. In three cases, the surrounding original ashlar has been utilised as an integral part of the design of a panel. Two of the panels making up the *Elect in Heaven* theme possess ashlar stops, additional uncarved sections left for fixing purposes. These have been further reduced to form nibs into the adjacent masonry and curiously resemble carpentry joints rather than those found in traditional masonry. All but one of

the panels, *Avarice*, have been worked in a limestone most similar to Ancaster, quarried 25 miles south of Lincoln, whereas almost the entire Cathedral, including *Avarice*, is worked in the local Lincoln limestone. There are some interesting exceptions, such as sections of Norman arcading, which are also in Ancaster. Most of these are thought to be later repairs, but some, following archaeological analysis, were felt to be original.

Examination has now been made of the cores behind six panels from the northern run of the frieze. Panels 2 and 3, the *Sodomy* and *Avarice* panels, the *circa* 18th century replacement panel, plus the corework partly exposed behind the adjacent panel 4, the *Harrowing of Hell* and lastly, panels 7 and 8, the *Feast of Dives* and *the Death of Lazarus and Dives in Hell*. Dr Butler examined the theory of insertion based on three criteria. First of all, the condition of the mortar core would show clear signs of secondary intervention. An individual panel, inserted into the space where the ashlar walling had been removed, would betray evidence of 'squeezing of mortar against the back of the panel or against the joints of the panel.' Secondly, an inspection of the composition of the mortars, both from the cavity behind the panels and from areas of less contention, would either suggest a comparative disparity or not, depending on the date the panels were actually installed. In the event, Dr Butler deduced that all the evidence based on mortar could not support the theory of later insertion. In his report, he states that 'the panels, the core, and the surrounding stones are all of one building operation.' Finally, the question of building technique was considered, testing the theory of insertion some sixty years later. In the case of panels 6 and 7, stones at the bottom right and left hand, respectively, are deeply bonded into the original ashlar, and part of the carving of panel 8 extends into the surrounding stonework, which is unquestionably of the original build. The argument in favour of insertion, in the view of Dr Butler, was found to be 'ambiguous'. In conclusion, he proposed that the insertion of the panels, previously argued on the basis of style, could only be maintained if larger areas of stonework surrounding the panels had been removed, or if a concentrated effort had been made to blend the mortars, so that 'no joins were visible and few air spaces were left behind the panels.'

The Colloquium

Members of the colloquium were welcomed by the Subdean, who emphasised the intention and need to share information of such work as it was uncovered. Once formal introductions and morning coffee in the Chapter House were out of the way the gathering was split into two groups, to visit three sites. One group would visit the scaffold to examine the panels and exposed core, where Dr Butler would present the outcome of the recorded findings. The second group would visit the Cathedral conservation workshop, where two further panels, *Abraham's Bosom* and *Sodomy*, plus a section of *The Harrowing of Hell*, were on the work bench. An explanatory exhibition in the Angel Choir, showing the first three panels to be removed for conservation, was to be the change-over point. Animated discussions arose spontaneously at each of the sites, theories for and against insertion and original installation were freely given. These views were later distilled and

presented during a formal discussion, under the chair-team, comprising of Canon Rex Davis, Sub-dean, Dr John Baily, Cathedral Architect, and headed by Dr Richard Gem. This was held in the Chapter House, following lunch.

A short opening address was given by Dr Richard Gem, in which he intimated three main stages that the discussion might best take. It was important, he felt, that the facts were clearly presented and what they implied. After this, a chronology of the build would help to provide a context, and finally, it would be necessary to call on the art historians to consider such implications that the recently acquired information presented.

New Information

The first stage commenced with a description from Dr Butler of the general system of operations at Lincoln, with regard to the frieze and archaeology. All recording and analysis embodied an integrated attempt to understand the west front of Lincoln Cathedral, he stated, and consistent working methods and standards were adopted at all levels. This was realised in three phases during the work. Firstly, initial recorded examination is carried out on the stonework, looking at masonry and mortar patterns, with pigment traces and later repairs and alien materials, included. As material is removed from the fabric, the exposed core is recorded using similar methods, and in the case of the panels, the process is used following removal. Dr Baily declared that it was the intention of the Dean and Chapter to publish this accumulation of data in a comprehensive form, which would be capable of assessment, following what was currently an acute learning experience.

Comments were invited, via the Chair, with a condition imposed that dates at this stage should not be considered. It was affirmed following Dr Philip Dixon's enquiry, that the mortar cores had not been investigated in-depth, with Richard Gem stating unequivocally that the archaeological evidence would never be conclusive until such exploration was done. Tim Tatton-Brown required no such confirmation, however, declaring that it was 'clear as a bell' that the panels were part of an original build, sufficient evidence being given by the thin slabs and wedge-shaped core of the *Sodomy* panel. Stating that he had never encountered such 'maladroit' shaping in the section of a frieze scheme, Neil Stratford felt that such logic could not be applied. Thomas Cocke indicated the abnormal thinness of the panels, used as ashlar, in an 11th century building. If further recording was required, a non-destructive method would be preferable to Lawrence Butler, but it was suggested by Richard Halsey that the core was already partially disturbed, and it ought to be acceptable to extend this. Richard Gem then raised the matter of mortar analysis, to which Dr Butler replied that this had been done only visually. Philip Dixon questioned the significance of analysis, stating that it was similarities that mattered; differences normally did not, and technical mortar analyses usually only showed marked disparities. Sandy Heslop drew attention to the fact that the panels possessed an exactitude across the whole breadth of the façade, which he felt was quite convincing in its pre-planning. At this, John Baily asked Professor Zarnecki whether he felt the sculptures were adapted rather than measured in an 'orchestrated' manner. Professor Zarnecki

replied that some slight trimming may have been necessary on the scaffold, but the panels were clearly designed for their specific destination. As the new evidence was presented and defended, it became almost unanimously held that the key to the dating of the Lincoln frieze was to be found in the core, and a feeling of consensus moved towards the notion that the new information must present a revised view of the Lincoln west front and the Romanesque frieze.

Context and Interpretation

Entering into his own suggested second stage, Richard Gem presented an extended and informative sequence of the construction of the Lincoln west front, as it was understood. In doing so he appended the following material point. Looking at the architecture, its style belonged to the late eleventh century, but could the sculpture be consigned to that period? How, for example, would such new information affect our understanding, firstly of architecture and then of style and dating of sculpture? A variety of signs suggested the mid-twelfth century. There was after all, he emphasised, no great evidence for the date of 1092, other than the availability of the Cathedral for liturgical purposes. A coherent dating could not be reliably supported by historical documentation. In view of this, he ventured, steering the enquiry towards a discourse on the chronology of pattern, were answers perhaps to be found in trends of jointing ? Style might in fact provide more of a key, both of sculpture and of architecture. How would the sculpture historians respond to such dating?

Style and Understanding

Through this confusion, the historians attempted to explain how style could offer guidance. Professor Zarnecki referred to a carved corbel at Lincoln, which provided a stylistic link with similar heads at Old Sarum and on the Lincoln central doorway. Changing his mind over the years, Sandy Heslop had moved from the belief that the frieze may have been earlier to being possibly even later. There were strong clues to dating, he stated, in hairstyles, drapery and costume, as well as the carving of limbs, ribs and muscle definition. Such examples in the frieze were happier in the mid to late twelfth century. Adding to this, Philip Dixon pointed to the depth of carving, movement, and dynamic, which he felt were moving towards Gothic. Similarities between Lincoln and Malmesbury should be considered here, Neil Stratford offered, an idea that was at once rejected by Jeffrey West, on the basis that the group was too small a model upon which to make such an assessment. Professor Zarnecki, effectively terminating all speculation, stated that the Lincoln frieze was fully developed Romanesque sculpture.

Conclusions

In attempting to draw conclusions from the days considerations, Richard Gem was forced to confess that things did not add up. The stones were there. It was safe to accept the new archaeological findings, but the sculpture dating was also sound. Was the conclusion to be drawn that the slabs were fixed in place around 1090, only to be carved some eighty years later? David Stocker intensified an earlier point, that 1157 was an important historical date, with Lincoln chosen by Henry II to celebrate great victories. Could it be that the west front was then 'titivated' for that

prestigious occasion? It was suggested in an attempt at compromise that the blank panels may even have been painted until they were eventually carved. But is it practically feasible that such sculptures could be carved, *in-situ*, sometimes to within half an inch of the back of the stone? What would further archaeological explorations tell us? Would it explain why Remigius used plain ashlars that extended sometimes two feet into the wall, but in his most precious efforts allowed the stones to be only wafer thin? And do the 'locked in' stones testify to being planned as part of the frieze, or was it merely easier to fix around them during insertion? Ultimately, Richard Gem concluded, the dating of the frieze would rely upon a complete three dimensional understanding of the west front, which should be accompanied by a comprehensive publication, with those panels left off the façade due to structural decisions, being adequately displayed

List of Participants

Richard Gem

Richard Halsey

Tim Tatton Brown

Lawrence Butler

George Zarnecki

T.A. Heslop

Paul Williamson

Philip Dixon

Neil Stratford

Thomas Cocke

Keith Murray

Peter Hammond

Michael O'Connor

Kay Beadman

Jane Scarrow

Susan Friend

Richard Crookes

Gerald Burbidge

John Baily

The Dean Brandon Jackson

The Subdean Rex Davis

Appendix H

The Romanesque Frieze in its Architectural Setting: A Symposium (1988)

List of Participants

Maylis Bayle (Paris)
Alan Borg (London)
Peter Burman (London)
Marie Therese Camus (Poitiers)
Thomas Cocke (Cambridge)
Caroline Elam (London)
Richard Gem (London)
Seamus Hanna (London)
T.A. Heslop (Norwich)
Deborah Kahn (New York)
Michael Kaufmann (London)
Peter Kurmann (Geneva)
Raffaella Rossi Manaresi (Bologna)
Nigel Melhuish (London)
Michael O'Connor (Lincoln)
Adriano Peroni (Florence)
Willibald Sauerlander (Munich)
Roger Stalley (Dublin)
Simon Tait (London)
Eliane Vergnolle (Paris)
Jeffrey West (London)
George Zarnecki (London)

Jeremy Benson (London)
Christine v. Bornstein (Ohio)
Walter Cahn (Yale)
Martin Caroe (London)
Karl Ludwig Dasser (Munich)
Eric Fernie (Edinburgh)
Rosalie Green (Princeton)
Jaques Henriet (Paris)
Erla Hohler (Oslo)
Lech Kalinowski (Krakow)
Terry L. Kindu
Peter Lasko (London)
Wm Martin
Serafin Moralejo (Santiago)
David Park (London)
Anne Prache (Paris)
Rolf Snethlage (Munich)
Neil Stratford (London)
Melinda Toth (Budapest)
Katherine Watson (London)
Paul Williamson (London)

Fabric Council and Consultants

The Dean Oliver Fiennes
Kate Foley
Antonia Gransden
Peter B. Hill
John Larson
Nigel Malim
Clifford Price
Lady Wedgwood

The Subdean Rex Davis
John Baily
Peter Hammond
Peter R. Hill
Robert Maguire
Keith Murray
David Stocker

LINCOLN CATHEDRAL

THE RECORDING, REPAIR AND CONSERVATION OF THE ROMANESQUE FRIEZE PANELS

REVISION 6/94

1 AIM

The intention of this Policy and Method Statement is to:-

1.1 Support the continued life of each panel by the application of appropriate conservation techniques.

1.2 Inform this process by the observation and recording of constructional and archaeological evidence of the panels and the surrounding masonry.

1.3 To seek an aesthetic balance between the conserved panels and the frieze and its context.

2 CONTROL OF THE WORKS

2.1 The programme of works and the techniques to be used are determined by the Architect and Surveyor to the Dean and Chapter, with advice from conservation, archaeological and other specialists where appropriate.

2.2 The programme of archaeological investigation and recording is under the supervision of the Consultant Archaeologist to the Dean and Chapter.

2.3 The methods of recording, cleaning, conservation and repair of the Frieze panels are to be agreed with the Consultant Conservator to the Dean and Chapter. Additional consultants in conservation, structural engineering and other specialisations shall be appointed from time to time as advised by the Cathedral Architect.

2.4 The work is to be undertaken by the conservation staff of the Cathedral Works Department and specialist sub-contractors where relevant, under the technical supervision of the Consultant Conservator and the general supervision of the Clerk of Works and his deputy, and under the direction of the Cathedral Architect advised by the Archaeological Consultant.

2.5 The work is to be carried out within the terms of this document which establishes the policy and methods of conservation as agreed by the Cathedrals Fabric Commission for England. Any proposed variation in policy or methods must be agreed in advance of works being undertaken by the CFCE.

2.6 Each proposed phase of work within the overall programme will be submitted by the Cathedral Architect to the Fabric Council for discussion and endorsement on an annual basis. Any particular problems or questions arising from the work will also be submitted to the Fabric Council for discussion and advice. Written progress reports will be assembled by the Cathedral Architect and submitted to the Fabric Council at each meeting during the course of the programme of work, copies of documents submitted to the Fabric Council will be sent to the Cathedrals Fabric Commission for England for information and possible comment.

3 RECORDING THE EXISTING CONDITION

Before any work to the fabric is permitted, the existing condition of the frieze panel and its context to the surrounding structure must be examined and recorded. This will require the involvement of the Cathedral Architect, Consultant Archaeologist, Conservator and Structural Engineer. Specialist advice may also be required with regard to surface encrustation, pollution attack, residual paint or other surface treatments etc.

3.1 Photography

3.1.1 Black and white stereo photography will be taken by the Photogrammetric Division of English Heritage or an agreed alternative. This will consist of general coverage of the whole area, and individual cover of each panel.

3.1.2 35mm or medium format colour transparencies and prints and black and white prints will be taken of each panel, the surrounding stonework and general details thereof by conservation staff. Particular attention to be given to the method of insertion, the tool marks on the panel and surrounding masonry that has been carved or cut to fit, etc.

3.1.3 Conservation specialists will take mono or stereo 35mm transparencies to record cracks, blisters, pollutant crust, pigment traces etc where this is deemed necessary.

3.2 Drawings and Written Observations

3.2.1 Using outline drawings based on photogrammetric plots, marked up with a reference grid linked to the Cathedral grid, the conservators will make a record of the pattern of pollution encrustation on the surface of each panel using areas of different colour to note the average thickness in a specific area.

3.2.2 Using large scale (or where necessary full scale) drawings the conservation staff will also record traces of pigment, cracks, fissures, repairs, loose and hollow areas, mortars, surface coatings, gesso, stains and similar observations, as advised by the consultant conservator and archaeologist.

3.2.3 Using large scale (or where necessary full scale) drawings the archaeological staff will record evidence not only of the panel but of the surrounding masonry and when panels are removed of the sides and rear of the panel, the exposed reveals and the backing material. Records will be made of:

3.2.3.1 Type of stone (in conjunction with the Consultant Geologist) type of original mortar (with bagged samples), the tooling characteristics, masons marks, relevant profiles.

3.2.3.2 Evidence of repair, alteration, repositioning and replacement of complete panels or individual pieces of the panel, and the surrounding masonry blocks. Later mortars and Roman cement (with bagged samples).

3.2.3.3 The nature, surface, stratification and composition of the wall core behind removed panels. Evidence of disturbance and the introduction of later materials.

3.2.4 All drawings will use the grid reference system established on the photogrammetrical drawings.

3.3 Sampling and Analysis

Specialist consultants shall be appointed as necessary:-

3.3.1 To determine the geological identification, composition and bedding plane of each stone and its mechanical performance.

3.3.2 To identify the pollutant crust, the depth of soluble pollutants in the stone, and any surface treatments given to the stone in the past.

3.3.3 To identify different mortars and their performance.

3.4 Structural Integrity

3.4.1 In conjunction with the Consultant Structural Engineer a detailed examination shall be made of the panel and the surrounding masonry. This is to record any fracture, movement and signs of settlement and to obtain an understanding of the structural condition and relationships, especially any transference of loading from the surrounding masonry onto the panels. These to be recorded where relevant upon the record drawings related to the reference grid and by report.

4 WORKING PROCEDURES

4.1 Cleaning

4.1.1 The surface is to be cleaned with fine air-abrasive methods, with 17 micron aluminium oxide abrasive sparingly used so as to avoid damage to any painted fragments or friable surfaces.

4.1.2 Areas that are friable or blistered may require some lime reinforcement to strengthen the surface before cleaning.

4.1.3 The possibility of laser, or other, cleaning techniques are to be kept under review. If such use is considered suitable a proposal will be made to the Fabric Council and the Cathedrals Fabric Commission for England for inclusion as a permitted method.

4.2 Repair in-situ or following removal

4.2.1 After cleaning and further examination those panels not showing signs of structural distress will be conserved in-situ.

4.2.2 After cleaning, those panels, or parts of panels, showing clear signs of structural distress will be supported with eltoline tissue and removed for repair work. The criteria for removal are:

4.2.2.1 That examination of the back of the panel from above and the side (where possible) indicates that the panel can be removed without fragmentation caused for example by previous pressure grouting adhering to the back.

4.2.2.2 That examination of the face and edge shows the presence of delamination or shear cracks or both, giving rise to the real possibility of actual loss of fragments or parts of the panel if no action is taken.

4.2.2.3 That in the judgement of the Dean and Chapter's consultants the panel can be removed without incurring significant material loss.

4.2.3 Repair work to panels that are not to be removed permanently will be by lime mortars. Deep impregnation with consolidants such as silane is not permitted.

4.2.4 Repair work to panels that might be removed permanently from the building may have local treatment using acrylic or polyester resin mortars and stainless steel dowels and cramps where greater strength is needed, as determined by the Consultants.

4.3 Decision on reinstatement or otherwise of removed panels

4.3.1 Whilst conserved panels should, where possible, be retained in their original position, it is recognised that in specific circumstances they should be removed permanently from the facade to secure their survival. The criteria for deciding whether or not a panel can be returned to the facade are:

4.3.1.1 Whether the structural strength of the stone is capable of withstanding the action of wind, rain and frost without loss of fragments or parts of the carved work for a period of 30 years.

4.3.1.2 Whether the surface condition of the stone, especially exfoliated areas, blisters and fissures can be sufficiently held by appropriate conservation techniques to withstand the action of wind, rain and frost without surface loss recurring for a period of 30 years.

4.3.2 There are four panels (5, 6, 7, 8) where the carved work extends onto adjacent ashlar walling. Should these panels be considered for permanent removal, an additional assessment will be submitted to the Fabric Council to consider whether:

4.3.2.1 The carved ashlar walling should be removed to retain the integrity of the carved work.

4.3.2.2 It is structurally prudent to remove the carved ashlar walling.

4.3.3 During the process of evaluating the possible removal of sculptures there shall be a presumption in favour of maintaining the artistic integrity of the original design. This is to be considered in respect of individual panels and in the composition of groups of panels.

4.4 Installation of new or conserved original panels

4.4.1 If a panel cannot be returned to the facade it will generally be replaced by a free copy, hand carved in limestone to match the original. 'Free copy' shall mean an exact copy but with missing elements being replaced as near as possible to the manner and style of the original. The proposal for each replacement panel will be submitted to the Fabric Council as a full size drawing or, where the replacement of missing elements is involved, as a clay model for approval prior to work on such a replacement panel being started.

If methods other than a hand cut 'free copy' are considered suitable, these should be submitted to the Fabric Council and Cathedrals Fabric Commission for England for discussion and evaluation.

4.4.2 Each replacement panel is to be of a thickness to allow it to act as structural masonry. Where this is not possible the Consultant Structural Engineer is to be consulted with regard to the possible use of a stainless steel supporting frame behind the panel.

4.4.3 Where an original panel is to be re-inserted into the facade it may be necessary, on the advice of the Consultant Structural Engineer, to insert a stainless steel supporting frame behind the panel. This procedure can also be adopted behind panels which are thought likely to be removed in the future so as not to disturb the load distribution in the masonry wall.

4.4.4 As far as is practicable within the limits posed by the need for structural stability and integrity, significant archaeological evidence will be retained in-situ behind replaced panels.

4.5 Evaluation on Completion of the Work

4.5.1 At completion of the work the series of panels will be re-evaluated in consultation with the Fabric Council and Cathedrals Fabric Commission for England to consider whether:-

4.5.1.1 Any original panels should be taken out to retain the aesthetic continuity of that part of the frieze, where the mix of originals with copies is seen as visually inappropriate.

4.5.1.2 Any copy panels need to be replaced because of the quality or style of the workmanship.

4.6 Continuing Evaluation

After completion of the work the original panels will be inspected at least on a quinquennial basis to evaluate whether any panels are showing signs of distress which may lead to unacceptable surface damage or structural failure. This Report to be made to the Fabric Council for consideration.

5 RECORDING THE WORK IN PROGRESS

5.1 Photography

5.1.1 Detailed 35mm or medium format transparencies, colour and black and white prints will be taken at each progress stage, in particular to record evidence of building sequences and material that may be subsequently lost or covered up.

5.1.2 At the completion of work large format photographs will be taken (and possibly at major intermediate stages) as part of the series started at 3.1.

5.2 Drawings and Written Observations

5.2.1 Each conservator will keep a personal site notebook or day book in which shall be entered a daily record of the work carried out. Observations, discoveries and any other relevant notes shall also be entered in the day book, referenced where relevant to the location grid. At the end of each specific task (cleaning, dismantling, etc) a typed summary of the operation will be prepared from notes in the day book. This will be bound together with photographs and the relevant coloured-up line drawings to form one section of the final report.

5.2.2 Records will be kept by the appointed archaeologist (under the supervision of the Consultant Archaeologist) of all evidence of building and alteration sequences exposed as work proceeds and especially when panels are removed.

5.3 Sampling and Analysis

5.3.1 To undertake further work on the identification of mortars from 3.3.3.

5.3.2 To undertake surface pigment and medium analysis where possible.

5.4 Structural Integrity

5.4.1 To undertake further analysis of the structural condition of each panel and to inspect and record evidence of the wall core exposed by the removal of such panels as are to be removed.

6 THE HOLDING OF RECORDS

6.1 All records, be they photographic, drawn or written to be duplicated, the originals being held by the Cathedral Archive and the duplicates elsewhere, at the National Monuments Records or other similar establishment. Original documents which have not been deposited in the archive together with master copies of deposited documents, will be kept in the Cathedral Works Department Archive where working copies will be made from them.

6.2 Records will be made on the most suitable archive materials - acid free paper etc - in accordance with current archival practice.

6.3 The identification and numbering system will be that agreed with the Cathedral Librarian and Archivist, so that it forms an integral part of the index system used for the Cathedral records.

7 STORAGE AND DISPLAY OF REMOVED PANELS

7.1 Secure interim storage for panels permanently removed from the facade will be provided within the Cathedral.

7.2 The declared commitment is to provide a permanent location where the panels can be displayed to the public in an appropriate manner, to coincide with the estimated completion of the West Front Conservation Programme in 1998. The intention is that the display space will:-

7.2.1 Be as close as possible to the Cathedral.

7.2.2 Provide a secure and suitably controlled environment in which the long-term future of the panels can best be guaranteed.

7.2.3 Ensure a context suitable for Romanesque sculptures of pre-eminent importance, with appropriate presentation and interpretation standards.

7.2.4 Provide for public access including for disabled people.

8 REVISIONS

8.1 It is recognised that this document may require revision from time to time as views are moderated and adjusted in the light of experience and in response to new evidence.

8.2 If such revision is necessary, a proposal will be prepared by the Cathedral Architect advised by the relevant specialists and by the Fabric Council; it will then be submitted by the Administrative Body to the Cathedrals Fabric Commission of Enland for approval before adoption.

John Baily: Architect & Surveyor
20 June 1994

JLB/CP

12 August 1994
Revision B

LINCOLN CATHEDRAL & ENGLISH HERITAGE

PROTOCOL

This protocol relates to the application and approval procedures for grant aid from English Heritage (EH) to the Dean and Chapter of Lincoln (DCL).

1. Applications are made in the first instance at the invitation of EH to their timescales and in their format. This makes brief reference to the scope of work and its cost.

2. On receipt of an initial grant offer DCL submit, via Fabric Council and CFCE approvals, a detailed proposal for each project as a package that acts out by drawn, written and photographic means:-

   2.1 The scope of the work.

   2.2 Reports on existing condition by the conservators, architect, archaeologist, engineer and other specialists as appropriate.

   2.3 The methods of approach and techniques to be used on the repair/conservation by:-

   The Architect's specification and drawings.
   The Consultant Archaeologist, Conservator, Engineer and other specialists' reports as appropriate.
   The Clerk of Works and Quantity Surveyor's cost estimates and timetable.
   The Works Department's conservation, archive and trade staff reports as appropriate.
   This information to be collated and sent to EH by the Architect.

3. Providing the proposal is clear, complete and represents generally acceptable practice, EH confirm the grant size and any conditions upon it, and give approval to start.

4. In order to maintain a flow of approved work, the approval mechanism is related to two timescales.

   4.1 Initial applications to EH by August (clause 1) for detail approval by the year end, for commencement at the start of the next financial year. This means all proposed applications must be agreed by the Fabric Council in their June meeting and by the Dean and Chapter at their May meeting.

   4.2 For detail approvals within an overall approval three dates per annum are available for submission to EH which relate to Fabric Council meetings as follows.

   Late January for March F.C. meeting.
   Mid-April for June F.C. meeting.
   Late August for October F.C. meeting.

EH will provide approval/rejection prior to FC meetings so that clearance to proceed can be given at the F.C. meeting.

5. EH are available for general discussion and advice when so asked.

6. DCL will inform EH of any proposed omissions or additions to the work prior to the work being carried out. EH may visit to inspect the work and discuss variations and agree grant adjustments. Such dialogue is between EH and the Architect on works and with the Clerk of Works on valuations and variations to the grant offer.

7. On completion of the works or parts of the works EH visit to inspect the works as complying with the proposal together with any amendments and to measure and agree the costs upon which the grant is made. When the records of the works are complete and in the Works Department archive EH may visit to inspect.

8. On completion of a project the Architect, with others as appropriate will submit a brief report on the work with 'as built' drawings.

9. Works undertaken DCL which comply with Fabric Council and CFCE agreements but are deemed by EH to be outside their terms of reference are excluded from this Protocol.

10. It is understood that EH respond to proposals put to them and are not involved with the internal administration or structure of DCL or in the internal development of policies or specifications other than through the existing channel or representation on the Fabric Council and the Glass Advisory Committee and as an advisor to CFCE under the provisions of The Care of Cathedrals Measure.

Appendix K

Laser Cleaning the Romanesque Frieze: An Investigation

Introduction

Eight original Romanesque Frieze panels and one copy panel have been cleaned since 1987 using conventional methods. This has largely consisted of the micro air-abrasive technique which works very well and has for many years been widely used as the best available tool for cleaning fine sculpture. The introduction of the laser into the repertoire of tools increases the cleaning options available to the conservator. Trials to date show that the laser technique improves on micro air-abrasive in several ways, eg in sensitivity to the substrate, improved operator visibility and control, and mechanical reliability, but brings with it new and different questions, calling for further research.

Over the last five years Lincoln Cathedral Works Department has collaborated with both Loughborough University Physics Department and the National Museums and Galleries on Merseyside (NMGM). Until recently, Lincoln's involvement was largely in providing stone samples for laboratory work with only small scale trials and demonstrations taking place at the Cathedral. However, since December 1995 the Cathedral has taken a more active role in bringing laser technology and stone conservation together. Lincoln's conservation team and a Loughborough University physicist joined forces for an intensive training course at NMGM, and this culminated in a three week period of on-site laser cleaning of the Cathedral fabric in January 1996. This exercise brought the laser out of the laboratory and into a real working situation. An awareness of the practical hazards of laser use in the context of an active site were made apparent during time spent by M O'Connor with Groux S.A.R.L at Notre Dame Le Grande, Poitiers, and Tours Cathedral. Although all the practical problems of health and safety, and manoeuvring on scaffold etc, were overcome at Lincoln, it was clear that significant tuning could be achieved over a longer period of time.

Background to the Project

During the last twenty years lasers have found application in several aspects of conservation and restoration of historical artefacts. Work at Loughborough has been concerned with the cleaning of surfaces. In particular several different kinds of lasers have been used to investigate the removal of surface layers from old stone. Most of this work was led by the intrinsic self-limiting aspects of the laser radiation, stone surface interaction and the potential for increasing cleaning rates.

The underlying principle in all laser cleaning interactions is the fact that the material to be removed, be it organic or inorganic layers, or paint, must exhibit different absorption properties to that of the underlying substrate. In the case of Lincoln Cathedral the underlying limestone is strongly reflective to laser light around the visible and near infra red region of the spectrum, but

the commonly found contamination which it is required to remove during conservation is strongly absorbing and therefore easily removed by laser. Further more, there is growing evidence that laser cleaning self terminates at a so called patina layer which is the preferred level of cleaning where a calcium sulphate layer is left to possibly protect the underlying stone. Although the efficacy of laser cleaning does not appear to be in question, the state of the cleaned surface needs more detailed study to be assured that absolutely no damage is done to the underlying stone.

Project Description

The project will address a series of questions raised by earlier work both at Lincoln and elsewhere, while providing a measured approach to cleaning the most valuable parts of the Cathedral. The following four areas of study may be identified:

1. Investigation into the effect of laser cleaning on the substrate. Laser cleaning involves a number of physical processes including heating, ablation, vaporisation and plasma formation above the surface. All of these may damage the underlying stone by melting, shock loading or even radiation damage. A range of surface analysis and examination techniques will be used to study changes in the surface of the stone during and after cleaning.

2. Polychromy: Little is known about the effects of laser radiation on Polychromy. Where traces of paint and pigment are present they will be lit at the interface between the stone and any surface encrustation. By their very nature the absorption properties of these materials will be different and this may provide a route to protect and preserve these important features. The known pigments binding media and grounds found on the frieze will be simulated on appropriate substrate for analysis.

3. Health & Safety: Laser cleaning is frequently mentioned as having environmental advantages in not requiring irritant dusts or water and being generally very quiet in operation. However, the interaction of laser pulses of high power with materials is a complex process. It is therefore proposed that the material removed from the surface in the form of dust and particulate debris should be investigated to assess any possible health hazard to the worker. The University already has projects involving collaboration between the Chemistry and Mechanical Engineering plastic Departments investigating the chemical hazards produced by laser cutting of plastics and metals. On line monitoring is being looked at and plans will be made to carry out similar measurements on stone. The question of optical radiation hazard also needs to be considered.

4. On-site use. The health and safety aspects above are tied in with the day to day use of lasers as practical tools. We will evaluate the different laser delivery systems which have been proposed or manufactured with the aim of making the laser a simple to use tool. The optical question in terms of the transfer of the laser technology from the laboratory will also need to be looked at. This aspect will cover areas such as practicability of laser cleaning of the Cathedral as well as weather exposure questions.

Project Implementation

Loughborough has one of the most powerful Nd-YAG laser systems available which has been demonstrated to be effective in removing dirt from Lincoln stone. Ms Vivi Pouli, of Loughborough University, has spent nearly one year in the Department of Physics learning about lasers and associated techniques. During this time she has had the opportunity to work at Lincoln with the Cathedral conservation team, assimilating a range of technical approaches. In turn, this has benefited the conservators, who have received detailed understanding of the physical effects of some treatments, such as cleaning, on stone sculpture.

The laser application section of the Department of Physics at Loughborough is headed by Professor David Emmony, who has supervised study in laser cleaning of sculpture for many years. He is aware of the circumstances of the Lincoln Frieze and has an intimate knowledge of Lincoln stone, and the project will be headed by him. Ms Pouli will be given free access to the Nd-YAG laser system as well as other diagnostic and analysis equipment at Loughborough. She will be able to spend extended periods of time at Lincoln working with the laser and the conservation team there. Therefore, the work will take place both at Lincoln and at the Loughborough laboratories, the relevant periods being determined by Michael O'Connor of Lincoln Cathedral Works Department and Dr Emmony.

It is proposed that the fragment of the frieze immediately next to the Dives and Lazarus panel is cleaned by laser. Work will only be carried out by those conservators trained in the use of lasers, namely Kay Beadman and Jane Scarrow, as well as Ms Pouli. This will be scrupulously monitored and documented for presentation to the FAC, and the EH Cathedral's Architect, David Heath. It is expected that positive results will lead to the cleaning of further panels, following approval, depending on the outcome of the research. The area surrounding each panel to be cleaned will be isolated, with appropriate safety precautions taken whilst the laser is active. These systems have been successfully established during an earlier operation.

This proposal, to be carried out over 2 years, has been discussed by the Lincoln Cathedral Fabric Council (FAC) and is supported by them, as well as Mr Keith Taylor, the Consultant Conservator. At the same time, laser cleaning conforms with the policy document : The Recording, Repair and Conservation of the Romanesque Frieze Panels 6/94.

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23 July 1996.

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