# GEOMETRY AND GOTHIC DESIGN

*by John H. Harvey*

For nearly a century-and-a-half students of Gothic architecture have discussed the evidence for the use of systems of proportion in mediaeval design. In 1845 C. R. Cockerell posed the question in his account of Cesare Cesariano's discussion of the rival methods employed at the building of Milan Cathedral between 1385 and 1400.[1] Exactly one hundred years later, and apparently oblivious of Cockerell's study, the late Paul Frankl published his essay on 'The Secret of the Mediaeval Masons',[2] and the last forty years have seen much relevant activity, notably by American and British scholars including Ivor Bulmer-Thomas in his reconsideration of the relevant rediscovery of Euclid about AD 1120.[3] It is not my present purpose to traverse the whole field of recent studies, but rather to attempt a return to first principles and to the main facts for which there is positive historical evidence.

At the start it is clear that there has been a great deal of fundamental misunderstanding as to 'the Secret'. The real problem relates to the specific character and quality of Gothic design, and cannot be dissolved into a series of purely technical propositions in practical geometry and stereometry learned by rote. It is indeed certain that mediaeval stonemasons did so learn a greater or lesser number of routine processes by the application of square and compasses, but the sum total of these fragmentary secrets regarding construction did not and could not constitute 'The Secret' of *design*. The nature of that major secret was obviously different in kind, as can be deduced from the essential difference between the Gothic canon and the antecedent and succeeding reliance upon the modular schemes prescribed by Vitruvius and followed by the architects of the classical world and of the Western Renaissance.

It was Camille Enlart who, at the beginning of this century, clearly specified the fundamental distinction as consisting in the constant Gothic reference to human scale. Whereas in classical buildings the same multiplier related to overall dimensions and to every modular part, the Gothic masters in their designs seemed as if guided by the observation of a natural fact: that both a large tree and a small tree of the same species have leaves of the same size.[4] There was a necessary multiplication of mouldings and details for the greater supports of a cathedral, as compared with those of a parish church; but the relation to the human norm was always there. We are still ignorant as to the precise procedures by which the building masters in their designs were able to give practical application to this vital principle, and to that extent their methods are even now a major secret.

Beyond this general principle of aesthetic design there were

closely related technical secrets. One of these concerned the scale and depth of foundations required for buildings of different sizes. Secondly, it was essential (without methods of mathematical calculation then unknown) to provide buttressing adequate to restrain not only the thrusts of the fabric itself, but also those of external forces, notably wind-pressure. It may well be that the source of these technical solutions lay in trial-and-error, possibly verified by experiments with scale models.[5] This was apparently the case, at least to some extent, as regards later refinements in construction, but there seems no evidence of such usage in the opening phase of Gothic in Western Europe. One possibility is that such experimentation had taken place elsewhere and that its solutions were borrowed ready-made at some date in the twelfth century.

Initially it is necessary to review some of the evidence which has emerged since Cockerell opened the debate 140 years ago. There has been major progress in three related fields. First in importance is the matter of professional secrecy and its maintenance by the Gothic masters.[6] Secondly there is the use of geometrical draughtsmanship as a preliminary to the erection of Gothic structures.[7] Finally, there has been exposition of some particular systems applied to the proportions of plan and elevation, together with the solutions to practical problems of the setting-out of parts.[8]

Concerning modern speculative Freemasonry it has been remarked that the Secret of the Masons 'consists of the fact that they possess no secret',[9] and it may be this sceptical view that has been transferred backwards to the operative stonemasons of the Middle Ages. We have already seen, however, that one profound secret—that of modulation of the proportionate relationship *to human scale* of Gothic buildings and their details—still remains mysterious. By reading Vitruvius or his commentators, and by taking thought, it is possible for anybody of even rudimentary education to design a classical building according to Greek or Roman canons; no parallel re-creation of Gothic proceeding from its first principles has yet been achieved. Better or worse copies of Gothic architecture, based on careful observation of forms and geometrical relationships found in its composition, are certainly possible; but the relative failure of the Gothic Revival as against the Renaissance is the measure of ignorance of the underlying principle or of its practical expression by means of some 'gimmick'.[10]

Whether or no this major principle of proportion, or a collection of other craft secrets of design, constitutes 'The Secret' of Gothic, the acknowledgment that there were, in the period c.1100-1500, secrets maintained by the master builders is vital to

our understanding of mediaeval buildings and their authorship. The often repeated theories of monastic and clerical responsibility *for Gothic design* in architecture are necessarily fallacious in that there is no scrap of evidence that the vital secrets ever escaped into manuscript or, later, into print. There is, on the contrary, positive evidence that the masons were responsible for the murder of a patron, Bishop Conrad of Utrecht in 1099, because a major technical secret regarding foundations had been betrayed to him.[11]

In the face of the extensive evidence that mediaeval building masters did possess *some* secret, it is surprising that attempts should even now be made to deny the existence of such a secret altogether, by claiming that it could never have been maintained.[12] This flies in the face of all that is known of secrecy as a factor in human activities, from the religious to the industrial. Even where legal codes do not admit the sanctity of the confessional, courts have very rarely challenged the absolute right of the priest to remain silent. The conduct of the law itself depends to a great extent upon the inviolability of confidences between client and lawyer; and breaches of medical confidentiality are rare in the extreme. In other professions too it is of the essence that a high degree of secrecy must be maintained. The very idea of a breach of secrecy, in all these cases, is so remote that there is in general no formal legal sanction, but simply universal expectation that privacy will be maintained. The fundamental source of all these forms of secrecy lies not in sanctions imposed organisationally, but in a sense of honour.

It is true that industrial secrecy is often breached, whether by deliberate corruption or by espionage, and that in such circumstances recourse is had to the enforcement of sanctions by the corporations concerned or by law, notably the laws of patents and copyright. There is, however, a major difference between the maintenance of such technical secrets of composition and process in manufacture, and of those of principles of design used by mediaeval masters: the masters were self-consciously aware of being free men of good birth and *therefore* bound by the code of honour; and, secondly, they regarded their occupation as the Art of Geometry, not as a mechanistic process such as the building construction of modern times.[13]

It has been objected that there is abundant evidence that, during the Middle Ages, there was extensive social contact between building patrons and their architects. The lack of written records of the principles of Gothic design might, therefore, simply mean that they were communicated orally to an ever widening circle of interested amateurs. That much information of a non-secret kind did in fact pass, from theologians among the patrons to the master

craftsmen responsible for design, is indeed obvious. Yet there is no evidence at all for any leakage of the principles of design in the opposite direction. Human intercourse, in former times as now, is carried on without breach of confidentiality in regard to matters regarded as secret. There is, moreover, explicit evidence of the maintenance of secrets on the one hand, and on the other of the way in which technical information may pass between those of the same craft in cases where it would not be imparted to an outsider. For a thousand years, from the seventeenth to the seventh century B.C., the secret of a remarkable glaze for earthenware was preserved in an elaborate cryptogram in cuneiform script.[14] In the mediaeval period it has been noted that the precise recipes for making green, blue and red glass are missing from the treatise on *The Various Arts* by Theophilus (c. 1110-1140).[15] Within modern times the vital secret of silk-throwing, maintained as a trade monopoly for centuries, was stolen by John Lombe of Derby (c.1693-1722), whose brother Sir Thomas Lombe (1685-1739) was thus enabled to set up the first throwing machines in Britain. John Lombe had disguised himself as a common workman to obtain entrance to an Italian throwing-mill in 1718, but is said to have been poisoned by Italian workmen four years later. The principle of death as the penalty for betrayal of craft secrets is no melodramatic fiction.[16]

Research into the second main problem, that of draughtsmanship, has been impeded by undue scepticism as to the use of drawings. The fact that comparatively few working drawings have survived has been used, illogically, as if it proved that none were made. Even before the epoch of serious modern research the original drawings for Cologne Cathedral had been rediscovered; many of those for Strassburg were never lost.[17] The album of Villard de Honnecourt by itself goes far to refute the negative outlook of much of the literature, but it has even been suggested—last ditch of incredulity—that Villard might have been a clerk rather than a building master! Numerous discoveries have continued to be made, notably in the Germanic region of Europe, but are buttressed by individual drawings elsewhere, from those of the mid-thirteenth-century Rheims palimpsest onwards.[18] Besides drawings on parchment and paper, plaster tracing-floors have survived, as at Wells Cathedral and York Minster;[19] and other examples of setting-out exist on walls and roofing-slabs, and have been discovered on the beds of stones withdrawn from buildings ruined or in course of restoration.[20] It cannot any longer be denied that, at any rate as far back as the second quarter of the thirteenth century, architectural draughtsmanship played an essential part both in the formulation of each design, and in the diffusion of ideas by means of copies of drawings.

Notwithstanding the immense weight and expanding volume of this decisive evidence in regard to the last three of the four centuries of Gothic, it has been argued that the same methods were not necessarily used from the beginning.[21] Yet, logical as this distinction may be, it must remain unconvincing in the absence of positive evidence, or even any suggestion of an earlier system suddenly superseded (c.1225) by the one familiar to us. Moreover, we know from the chronicle of Gervase that the French master William of Sens, employed to direct rebuilding at Canterbury Cathedral after the fire of 1174, produced moulds or templates from which the working masons were to cut the stone.[22] The production of such templates inevitably presupposes skill in geometrical drawing and implies derivation from general designs, in whatsoever manner drawn to scale. Master William, whether on the works of Sens Cathedral or elsewhere, had either learned these methods from some earlier master or had invented them; but independent personal invention is ruled out by the recognizably individual styles of different masters who produced the pre-Gothic and proto-Gothic of the mid-12th century. The only conclusion possible is that, regardless of the method of design used for the immense buildings of the later Romanesque, the new pointed-arch style depended upon skilled draughtsmanship involving the use of square, compasses, and graphic methods of enlargement and reduction. The existence of a continuous technique of drawing to scale, from the sixteenth century B.C. in Ancient Egypt down to the Middle Ages, is certain.

The third main field of modern research on the subject has been explored by means of precise surveys and archaeological investigation, showing that planning and design were—long before the coming of Gothic style—already geometrical. Yet the geometry employed was much simpler, based upon classical Roman methods and often relatively inaccurate. The basis of plans was additive, consisting mostly of squares in simple relationships and measured in Roman feet or later in regional units.[23] So far as there was derived proportion in detail it was largely secured by decimal subdivision, as if sketched on graph-paper. This had certainly been the basis of much antique art, notably that of the mosaicist, working from pattern-books which could be carried throughout the Empire, and using tesserae cut to standard sizes. Derived through late-Roman traditions of building, these usages of the Romanesque had progressively lost more and more of the precision of their classical prototypes. In the arts outside architecture, this went hand-in-hand with the secular process of copying and re-copying, with a consequent loss of capacity for the direct observation of nature. In the West, ever since the fifth century A.D., the knowledge of geometry had been running down, and it is striking that the

recovery of scientific geometry through Arabic versions of Euclid should have coincided with the first appearance of an architectural style incorporating the pointed arch—and a great deal else—derived from Saracenic models.[24]

It is not necessary to assume any direct connection between a formal knowledge of Euclidean geometry and ability to design in the new Gothic idiom. We do not have to imagine master masons in France or England as academic students of the Quadrivium (arithmetic, geometry, astronomy, music) at Paris or Oxford. On the other hand, the marked improvement in the setting-out of plans, with true right-angles, and in the dressing of individual stones, proves beyond doubt the arrival in the West of a much better understanding of applied geometry amounting to a substantial part of the major technological revolution observed at the time. It is in fact probable that this revolution had been in progress before the arrival of Euclid at a date around 1120 or, at latest, within the next ten years. The new standards of masoncraft and of planning go back some ten to twenty years before that, and cannot be assigned to Adelard of Bath (certainly still in the Near East in 1114), nor to any subsequent students of geometrical texts founded on the recovery of Euclid. Whatever influence the detailed knowledge of Euclid's text may have had upon the later transformation of architecture and building (after say 1130), the new wave of technology was a parallel but rather earlier line of development. It cannot, however, have been a totally unrelated phenomenon, for the more precise methods displayed existed in the same geographical area as the Arabic versions of Euclid and almost certainly owed their quality to the fact that, in the East, pure and applied knowledge went hand in hand in a way unknown to the West before the nineteenth century.

The new type of accurate high-quality construction was based upon a *practical* knowledge of geometry applied to the setting-out of buildings and of the individual members of which they were composed. This new technique had arrived in the West shortly before 1100, and in England soon after. It affected construction almost at once, as has long been observed by architectural historians, notably in regard to the rebuilding of the central parts of Winchester Cathedral after the fall of the tower in 1107.[25] Fine-jointed masonry of the same kind is found in the works of Roger, bishop of Salisbury (consecrated 11 August 1107) at Sherborne Castle about 1110-20 and at his cathedral of Old Sarum by 1113. Increased sophistication in mouldings, enrichment and carving is evident by c.1120-25.[26]

The sudden and rapidly generalized appearance of a new technique in masonry cannot be explained as the outcome of internal

development and invention in the West, but must be an introduction from elsewhere. For it is beyond mere coincidence that fine-jointed masonry of comparable type, associated with detail resembling Western Romanesque, is found in the city gates of Cairo built in 1087-92, by Armenian masters who were refugees from Urfa (Edessa) on the northern borders of Syria. Within that region are other dated works displaying the same characteristics: accurate setting-out, fine joints, refined mouldings. Examples include the two western arches of the Tigris Bridge near Diyarbakir (A.D. 1065), parts of the Great Mosque of Diyarbakir rebuilt after a fire of 1116 (dated inscriptions of 1117-18 and 1124-25); and the Armenian Royal Chapel in the fortress of Anarvarza, built for Thoros I between 1111 and 1129.[27] These surviving buildings are sufficient to prove the existence in the generations on each side of 1100 of a highly developed school of masoncraft precisely upon the route of the so-called First Crusade of 1197, and largely within the Crusader county of Edessa, which remained under Frankish control from 1098 to 1144. For well over a generation, at the crucial time, close contact was thus established between the Frankish West and the frontier area between northern Syria and what is now south-eastern Turkey. Furthermore, this was associated with the great campaign of Crusader building further South in Syria and Palestine.

Transfer of skills from East to West could have taken place in three ways. Western masons, whether as members of the Crusader forces or as pilgrims, may have observed the better methods employed and taken them home in the form of notes or simply memorized. Secondly, it is likely that Saracen prisoners of war were brought back to Europe, and that they were often skilled artists or craftmen rather than mere servants. In third place, though perhaps the most important means, we have to consider the possibility of personal contact including direct pupilage. An actual instance of such pupilage is recorded by Usamah Ibn-Munkidh (1095-1188), whose father (1068-1137) captured a Frankish woman. Her son, Raoul, accepted Islam and 'learned the art of working marble from a stonecutter who had paved the home of my father; married a Muslim woman who bore him two sons; and then when the boys were five or six years old, took his whole family and joined the Franks at Afamiyah (Apamea, Qal'ah al-Mudiq, between Antioch and Hama), the father and sons reverting to Christianity.[28] Had these apostates from Islam been recaptured by the Saracens, their punishment would have been certain death, so that there must in such a case have been extreme pressure to return to Europe. We can hardly suppose that this instance was unique, nor that religious conversion was inevitably involved. Not only Armenian, but Greek, Coptic and other local Christian artists and craftsmen could well have taken likely pupils from among the Frankish settlers.

Given these basic facts, it is fruitless to seek in the West for evidence of a direct transfer of knowledge of book-geometry from literate academics to the masters of practical geometry who designed buildings of worked stone. That transfer, from theory to practice, had already taken place in the Near East, where no intellectual snobbery existed to produce an artificial barrier between clerks and craftsmen. Nor is this an isolated phenomenon linked only to the historical accident of the 'First' Crusade and the Crusader Kingdom and principalities in the East. Long before 1095, when Pope Urban II opened the great era of crusading, there had been close contacts between East and West. The era of the crusades had in fact begun early in the eleventh century, when the fanatical Fatimid caliph al-Hakim destroyed much of the Holy Sepulchre and other churches. Later, from 1027 to 1048, there was a period of peaceful intercourse when the Byzantine emperors were allowed to rebuild the sanctuaries, and it is highly significant that a new wave of building churches of great size then opened in the West: Speyer Cathedral, begun about 1030; the abbey church of Hersfeld (1037); and St. Rémi at Rheims (1041), were planned on a scale unknown since classical times.[29] The ability to roof wide spans was, in particular, the mark of a new epoch and was to lead to the gigantic Norman churches of a generation later. Fresh impetus was given to the movement by the largely Norman expedition against the Moors of Spain under Duke William VIII of Aquitaine, who captured Barbastro in 1064. Thousands of prisoners were taken, including singers, poets and other artists: ransom was refused and the captives were sent to France, Rome and even to Constantinople.[30] To such sources must be due the revolution in mechanical knowledge which suddenly provided hoisting tackle able to deal with large blocks of stone. The new masonry of improved quality was first seen in northern Europe in the third church of Cluny abbey, built in 1085-1121. The Norman cathedral at Winchester, begun in 1079, and the abbey church of Bury St. Edmunds (c.1081) were as large or even larger than Cluny, but they and Durham Cathedral (1093-1104) were the greatest achievements of an older technology.

At this point we must consider briefly what numbers of individuals were involved in bringing about such major changes. On the one hand there is abundant evidence that some epoch-making changes in human development have been brought about by a single man. The musician Ziryab (A.D. 789-857), driven from Bagdad by the jealousy of his master, reached the Umayyad Court of Cordova in 822 and for the next 35 years played a principal part in dictating fashion—not merely in music but as a Beau Brummel of the age—setting style in clothes, inventing recipes in cookery, and laying down the order of courses served from soup to dessert,

as well as the use of toothpaste.[31] Europe owes virtually the whole of modern arithmetic, including the general use of Arabic numerals and double-entry book-keeping, to Leonardo Fibonacci of Pisa, an Italian educated in North Africa in Muslim surroundings and bringing back their learning between 1201 and 1228.[32] We have already seen that the jealously guarded secret of silk-throwing was deliberately stolen by John Lombe in 1718 and brought to England.

It is not, therefore, necessarily a matter of any large number of skilled persons, and initially at least the essential secrets might be in the hands of very few. We are not dealing with many thousands of craftsmen, spread over Western Europe and four or five centuries, but with a relatively small number of specialized designers, the architects of major buildings. Although no approach to actual numbers can be worked out, it is possible to obtain some vague idea from the records of certain works, where from ten to twenty working masons might be employed, up to 100, 150 (or even 400 at Beaumaris Castle in 1295).[33] Allowing that undermasters and wardens, as well as chief masters, had knowledge of design, it is unlikely that the proportion of men of architectural status rose above 10% of the total of masons, at the very outside. Even among craftsmen of standing, such as those masons who took up the freedom of York, only a minority (about 30 at the most out of 150 between 1294 and 1501) appear to have had supervisory status in this sense; and they must have been greatly outnumbered by employed journeymen who never even rose to be freemen of the city as independent masters.[34]

The masons' trade in fact differed greatly from most of the mediaeval crafts in that it provided slight scope for 'the little master' with his own shop. From Norman times major building had been on a scale requiring outstanding organizational skill, dealing in large quantities of materials which had to be ordered in advance and transported to the site, and in a substantial work-force. Little of the output could be shopwork, and the rank-and-file had to be mobile and were often forced to travel far from their homes by the system of impressment. This gave rise to the system which has been described as that of the Lodge Masons—based on the lodge of some major building such as a cathedral or castle, and wholly unconnected with such static guilds or companies of masons as were formed in a few cities. In England only the London Company was to become of any importance among the latter. The Lodge masons, however, were independent and subject to their own Master who had a free jurisdiction comparable to that of the lord of a manor. This system arose in England—though it may well have owed its origin to Eastern craft fraternities—and was deliberately imitated at Strassburg by 1275, when the cathedral lodge was granted by the

Emperor Rudolf I pre-eminence over the lodges of Germany (all the German-speaking lands of Europe), with free jurisdiction 'according to the English fashion'.[35]

What the system was is known in considerable detail from the Constitutions of Masonry, a code already written down by the fourteenth century and detailing rules for masters and for subordinate masons. It provided also for the holding of assemblies or general congregations where the Master, if need were, was to have the support of the Sheriff of the county, Mayor of the city, or Alderman of a town. In practice the system was regional, as it was in Germany, where the evidence for the holding of periodical national and regional conferences is extensive.[36] In England the sharply marked divisions of local style, shown notably in the design of church towers, indicate that there was close conformity to the boundaries of counties or dioceses.[37] Although occasional instances of out-county distribution are found, the general adherence to the historic bounds is markedly precise.[38]

That geometrical propositions of the kind involved in Gothic design should remain secret is extremely tantalizing, but this is no reason for supposing that they did not exist. They would have been imparted at an advanced level of instruction to a few senior pupils only, and were probably never set down in writing. This is the less surprising in that the courts of the masons were not courts of record, so that even their sanctions against transgressors of the 'code of practice', though not secret in character, have not come down to us.[39] Eventually, when fashion had moved away from Gothic style and the easy-to-read system of Vitruvius had won the day among patrons, there came a time when the essential secrets were no longer imparted. Only the lesser technical propositions were handed down and are in part still preserved by master masons.

It is improbable that even the most highly skilled masters of modern times preserve any direct clue to the Gothic canon: over four centuries have gone by since the last generation of mediaeval architects passed away. Yet it has not proved beyond the inductive powers of modern scholars to rediscover some of the technical 'secrets'—methods of manipulation of square and compasses—which were integral to the stereotomy employed by Villard in the middle of the thirteenth century. There can be little doubt that the Secret was derived from some outstanding geometrician of the Saracenic world of a thousand years ago. Some modern follower may well reveal its nature to us.

## ABBREVIATIONS

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|---|---|
| *AMST* | *Transactions of the Ancient Monuments Society* |
| Atkinson 1947 | T.D. Atkinson, *Local Style in English Architecture: an Enquiry into its Origin and Development* |
| Branner 1957 | R. Branner, 'Three Problems from the Villard de Honnecourt Manuscript', *Art Bulletin,* XXXIX, 61-6 |
| Branner 1960 | . . . 'Villard de Honnecourt, Archimedes, and Chartres', *JSAH,* XIX, 91-6 |
| Branner 1973 | . . . 'Gothic Architecture', *JSAH,* XXXII, 327-33 |
| Briggs 1927 | M.S. Briggs, *The Architect in History* (Oxford: Clarendon Press) |
| Bucher 1968 | F. Bucher, 'Design in Gothic Architecture: a Preliminary Assessment', *JSAH,* XXVII, 49-71 |
| Bulmer-Thomas 1979 | I. Bulmer-Thomas, 'Euclid and Medieval Architecture', *Archaeological Journal,* CXXXVI, 136-50 |
| Cockerell 1846 | C.R. Cockerell, 'William of Wykeham', *Proceedings of the Archaeological Institute at Winchester in 1845* |
| Colchester & Harvey 1975 | L.S. Colchester & J.H. Harvey, 'Wells Cathedral', *Archaeological Journal,* CXXXI, 200-14 |
| Conant 1968 | K.J. Conant, 'The After-Life of Vitruvius in the Middle Ages', *JSAH,* XXVII, 33-8 |
| DNB | *Dictionary of National Biography* |
| DB 1910 | *Encyclopaedia Britannica,* 11th edition |
| Enlart 1902 | C. Enlart, *Manuel d'Archéologie francaise* (I, Paris) |
| Frankl 1945 | P. Frankl, 'The Secret of the Mediaeval Masons', *Art Bulletin,* XXVII, 46-60 |
| Grimschitz 1947 | B. Grimschitz, *Hanns Puchspaum* (Wien: Kunstverlag Wolfrum) |
| Hahnloser 1972 | H.R. Hahnloser, *Villard de Honnecourt* (2nd enlarged edition, Graz: Akademische Druck u. Verlagsanstalt) |

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| Harvey 1950 | J.H. Harvey, *The Gothic World* |
| Harvey 1958 | . . . 'Mediaeval Design', *AMST,* VI, 55-72 |
| Harvey 1968 | . . . 'The Origins of Gothic Architecture: Some Further Thoughts', *Antiquaries Journal,* XLVIII, 87-99 |
| Harvey 1969 | . . . 'The Tracing Floor in York Minster', *Report of the Friends of York Minster,* XL for 1968, 9-13 |
| Harvey 1972 | . . . *The Mediaeval Architect* (London: Wayland Publishers) |
| Harvey 1974 | . . . *Cathedrals of England and Wales* |
| Harvey 1975 | . . . *Mediaeval Craftsmen* |
| Harvey 1984 | . . . *Somerset Perpendicular: The Church Towers and the Dating Evidence* (London: Ancient Monuments Society) |
| *JSAH* | *Journal of the Society of Architectural Historians* (Philadelphia, Pa., U.S.A.) |
| Kletzl 1939 | O. Kletzl, *Plan-Fragmente aus der deutschen Dombauhütte von Prag* (Stuttgart: Veröffentlichungen des Archivs der Stadt Stuttgart, Heft 3) |
| Knoop & Jones 1933 | D. Knoop & G.P. Jones, *The Mediaeval Mason* (Manchester: University Press; 3rd revised edition, 1967) |
| Morgan 1961 | B.G. Morgan, *Canonic Design in English Mediaeval Architecture: The Origins and Nature of Systematic Architectural Design in England, 1215-1515* (Liverpool: University Press) |
| Shelby 1969 | L.R. Shelby, 'Setting out the Keystones of Pointed Arches: a Note on Medieval *Baugeometrie', Technology and Culture,* X, 537-48 |
| Shelby 1971 | . . . 'Mediaeval Masons' Templates', *JSAH,* XXX, 140-54 |
| Shelby 1972 | . . . 'The Geometrical Knowledge of Mediaeval Master Masons', *Speculum,* XLVII, 395-421 |

Shelby 1976 . . . 'The "Secret" of the Medieval Masons', in B.S. Hall & D.C. West, *On Pre-Modern Technology and Science: Studies in Honor of Lynn White, Jr.* (Vol. I; Malibu, Calif.: Undena Publications), 201-19

Shelby 1977 *Gothic Design Techniques: The Fifteenth-century Design Booklets of Mathes Roriczer and Hanns Schmuttermayer* (Carbondale, Ill.: Southern Illinois University Press)

Webb 1956 G. Webb, *Architecture in Britain: The Middle Ages* (Harmondsworth: Penguin Books)

Willis 1846 R. Willis, 'The Architectural History of Winchester Cathedral', *Proceedings of the Archaeological Institute at Winchester in 1845*

**NOTES**

1. Cockerell 1846
2. Frankl 1945
3. Bulmer-Thomas 1979
4. Enlart 1902, 56-7
5. Doubt has been expressed as to the feasibility of using scale models to simulate reactions under stress, but Dr. A.W. Skempton has kindly provided me with the mathematical demonstration that the method of trial-and-error, employing scale models of structures, is valid.
6. Shelby 1976, a detailed analysis which regrettably throws the baby out with the bath-water by refusing to accept that there ever was any secret, on the singular ground that secrets cannot be kept.
7. Kletzl 1939; Grimschitz 1947; Bucher 1968; cf. Harvey 1950; Harvey 1958; Harvey 1972.
8. Branner 1957; Branner 1960; Morgan 1961; Conant 1968; Shelby 1969; cf. Harvey 1969.
9. *'Das Geheimnis der Freimaurer darin besteht, dass sie kein Geheimnis haben'*, which I recollect having read some fifty years ago in a work by Lanz von Liebenfels, but possibly a quotation or proverbial.
10. Harvey 1972, 29-30.
11. Ibid., 103, 283; cf. DNB, s.v. Lombe, John (c. 1693-1722). The Utrecht story as we have it specifies that the secret consisted of the knowledge of how to keep water out of the foundations; but this is probably a rationalization or deliberate simplification. It is likely that the real secret was that of 'calculating' the necessary foundations for a major building.
12. Shelby 1976.
13. Harvey 1972, 76, 148; and, for the text of The Constitutions of Masonry, 191-207; cf. Shelby 1972.
14. Harvey 1972, 102-3; Harvey 1975, 50-1.
15. Harvey 1975, 50.
16. DNB, s.vv. Lombe, John; Lombe, Sir Thomas.
17. Briggs 1927, 86-101.
18. For general surveys of the evidence see Harvey 1950, 29-36; Harvey 1972, 101-19; cf. Bucher 1968.
19. Harvey 1969; Harvey 1972, 114-15; Colchester & Harvey 1975, 214 and Fig. 2.
20. Branner 1960.
21. Branner 1973; cf. Hahnloser 1972, 341-403.

22. For a translation of the whole of the architectural account by Gervase see Harvey 1972, 210-15; on templates cf. Shelby 1971.
23. Conant 1968; Harvey 1974, 59-60, 94-5.
24. Harvey 1968, 91-2 and Fig. 1.
25. Willis 1846, 18-20, 28-31. The fall of the first central tower at Winchester was on 7 October 1107; whereas the first road bridge of stone arches in England, across the River Lea at Old Ford, had been erected before the death of Queen Matilda in 1118. The arrival of the new wave of fine masonry can therefore be placed within the ten years 1108-1118.
26. Webb 1956, 46.
27. Harvey 1968; for Anavarza see M. Gough in *Anatolian Studies,* II (1952), 125-7.
28. Harvey 1972, 95-7.
29. Harvey 1974, 46-7, 85.
30. Harvey 1972, 74, 282.
31. Ibid., 152, 286.
32. EB 1910, vol. 16, 454-5.
33. Knoop & Jones 1933, 90 (3rd ed., 1967, 81).
34. F. Collins, ed., *Register of the Freemen of the City of York, 1272-1558* (Surtees Society, XCVI for 1896), 1897.
35. Harvey 1972, 138.
36. Shelby 1977; for a general summary see Harvey 1950, 21-2 and Fig. 9.
37. Harvey 1984.
38. For the general subject of local style, see Atkinson 1947.
39. For a thousand years the Tribunal de las Aguas has met in Valencia every Thursday at noon, under both Muslim and Christian rulers of Spain, to settle all disputes regarding irrigation of the plain; it has never been a court of record, but its decisions are final and have not at any time been disputed.