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Research Notes

MEDIEVAL MASONS' TOOLS. II. COMPASS AND SQUARE

L. R. SHELBY

This second paper in a series of studies on medieval masons' tools is concerned with the compass and square.[1] That these tools were of particular significance in the work of medieval masons is indicated by their frequent use as symbols of the craft, as in the seal of the stone-cutters of Strasbourg, the masons' windows at Chartres, and the sepulchral monuments of several master masons.[2] The choice of the compass and square by the masons themselves suggests that a study of the form and use of these tools might produce some valuable insights into the work techniques of these men. Indeed, the underlying assumption of this paper is that, until the history of their tools is adequately described, the achievements of medieval masons cannot be properly evaluated from a technological point of view.

One of the more striking features of medieval masons' tools is their simplicity. This simplicity contrasts even with the tools available to builders in early modern times and, in some cases, in antiquity as well.

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[1] See L. R. Shelby, "Medieval Masons' Tools: The Level and the Plumb Rule," *Technology and Culture*, II (1961), 127–30. Recently my attention was drawn to a medieval text that corroborates the conclusion in this article regarding the use of the level. See the description of the level by the medieval mathematician, Leonardo of Pisa, in *Scritti di Leonardo Pisano, matematico del secolo decimoterzo*, II, *La Practica geometriae*, ed. B. Boncompagni (Rome, 1862), 108.

[2] See Pierre du Colombier, *Les chantiers des cathédrales* (Paris, 1953), Figs. 1, 7, 8, 12, 13, and 16, and Pl. XXVII. As late as 1545 the portrait of the master mason from Münster, Herman tom Ring, was painted with the left hand grasping a compass. See F. M. Feldhaus, *Geschichte des technischen Zeichnens* (2d ed.; Wilhelmshaven, 1959), Abb. 61. But the compass also symbolized other occupations. Albrecht Dürer used it in his engraving "Melencolia I" to represent the work of the mathematician (i.e., geometer: cf. E. Panofsky and F. Saxl, *Dürers "Melencolia I"* [Leipzig, 1923], pp. 66–67), while Agostino Romelli placed it in the frontispiece of his *Le diverse et artificuose machine* (Paris, 1588) to symbolize the engineer.

In order, therefore, to provide a basis for comparison and contrast, we shall glance briefly at the periods preceding and following the Middle Ages in this study of the medieval compass and square.[3]

Perhaps the earliest device used by the ancients to draw an accurate circle was the simple one made by attaching a string to a peg and rotating the radius formed by the loose end of the string.[4] This technique may have been used by the Egyptians, who do not seem to have possessed the compass.[5] However, the compass was known to the Greeks; indeed, according to ancient legend it was invented by Perdix, nephew of Daedalus, the famous craftsman of archaic Greece.[6] Three different words were applied by the Greeks to the instrument for drawing circles: *tornos*, *karkinos*, and *diabētēs*. Since these words were used but not defined by classical Greek authors, the precise character of the object referred to cannot easily be determined. *Tornos* is a word associated with turning, or making round, and may refer only to the device of peg and cord for describing circles.[7] On the other hand, both *karkinos*—which also means "crab" and "pincers"—and *diabētēs*, associated with the idea of walking or stepping across, call up images of the compass with legs for marking off circles.[8] However, there is no need to elaborate here a philological discussion of these Greek words, for we

[3] For developments in the construction and use of the compass and the square in more recent times, see W. F. Stanley, *A Descriptive Treatise on Mathematical Drawing Instruments* (5th ed.; London, 1878), pp. 21–58; W. G. Stephan, *Drawing Instruments* (New York, 1908), pp. 23–25, 51–66; and F. E. Giesecke, A. Mitchell, and H. C. Spencer, *Technical Drawing* (4th ed.; New York, 1958), pp. 34–42; as well as the pamphlet, *Historical Note on Drawing Instruments* (Pasadena, Calif., 1950), pp. 8–14.

[4] Alois Nedoluha, *Kulturgeschichte des technischen Zeichnens* (Vienna, 1960), p. 12.

[5] Somers Clarke and Reginald Engelbach (*Ancient Egyptian Masonry* [London, 1930], p. 224), do not mention the compass with other Egyptian tools, nor does the illustrative material in this book indicate that the compass was available to Egyptian masons.

[6] Diodorus Siculus IV, 76, ed. C. H. Oldfather (London, 1939), III, 58; *Hygini Fabulae*, CCLXXIV, 14, ed. H. I. Rose (Leiden, 1934), 167.

[7] This is probably the meaning in the early use of the term in Theognis 805, *Elegy and Iambus*, ed. J. M. Edmonds (London, 1944), I, 324.

[8] From the allusion to the geometer's techniques of drawing in Aristophanes' *Clouds*, 176, one can even extract the image of a metal instrument:

> Sprinkling fine ashes upon the table,
> Bending a small skewer, then holding this "compass" [*diabētēs*]—
> He snatched a mantle from the palaestra.

may turn more profitably to evidence from Roman times that reveals the precise forms of the compass.

Fortunately, there are extant not only illustrations from tombstones of Roman masons but actual bronze tools from a mason's shop at Pompeii.[9] The British Museum also has a set of Roman masons' tools which includes two bronze compasses.[10] From this evidence we learn that there were at least three kinds of compasses available to Roman masons. There was what is known in English as a pair of dividers—constructed simply of two pointed legs connected at one end by a rivet. No handle was provided above the joint for manipulating the dividers. There were also calipers—"dividers" with curved or bent points used to measure either external dimensions or interior openings of relatively small objects. Finally, there was in the possession of the mason at Pompeii a pair of proportional dividers for enlarging or reducing the dimensions of a drawing or other object.[11] Presumably it was to these various types of compasses that Vitruvius was referring when he wrote that the architect must be skilful in using the compass (*circinus*) and other instruments in making drawings and in setting out the work on building sites.[12]

Were these same compasses available to medieval masons? Did they develop other types not used by Roman masons? Turning first to literary sources, we may note Isidore of Seville's definition of a compass simply as "that which makes a circle. By this instrument can be duplicated a line that extends in a single, straight direction."[13] Clearly Isidore has reference here to a pair of dividers, perhaps not unlike those already noted in Roman times. Theophilus, twelfth-century author of the *Schedula diversarum artium*, mentions the use of a compass in making a small silver cup, but the character of the tool cannot be clearly deter-

[9] See Hugo Blümner, *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern* (Leipzig, 1884), Vol. III, Fig. 2, for the tombstones; and J. A. Overbeck, *Pompeji in seinen Gebäuden, Alterthümern und Kunstwerken für Kunst- und Alterthumsfreunde* (2d ed., Leipzig, 1866), Vol. II, Fig. 277, for the Pompeian tools.

[10] Nos. 2671 and 2677 in the Greek and Roman collection.

[11] The Greeks perhaps also possessed proportional dividers. Philo of Byzantium, a mechanician living *ca.* 200 B.C., mentions the use of the *karkinos* for enlarging or reducing models of engines of war. See *Philons Belopoika* (*Viertes Buch der Mechanik*), 55. 24–27, ed. H. Diels and E. Schramm (Berlin, 1919), p. 18.

[12] Vitruvius *De architectura* I, i, 4, ed. F. Granger (London, 1956), I, 8.

[13] "Circinus dictus quod vergendo efficiat circulum. Huius modus duplicata linea fit, quae simplex per latitudinem extensa fuerat" (*Isidori Hispalensis Episcopi etymologiarum sive originum libri XX,* XIX, 19, 10, ed. W. M. Lindsay [Oxford, 1911]).

mined.[14] Another passage is somewhat more revealing, where Theophilus mentions "iron compasses composed of two parts; some are larger, some are smaller; some are straight, some are curved."[15] Theophilus may be referring here both to dividers and to calipers, although the meaning of the passage has been debated.[16] One other important point in the passage may be noted—that the compasses are said to be made of iron instead of the bronze used in Roman times. Professor Lynn White has recently emphasized the fact that iron was more plentiful for making tools in northern Europe during the Middle Ages than it had been in Roman Italy, where the evidence from Pompeii suggests that, in a sense, the Romans still lived "more in a Bronze than in an Iron Age."[17] This point is demonstrated by the large number of iron tools described by Theophilus in Book III of the *Schedula.*

An interesting reference to mathematical instruments occurs in the correspondence of two eleventh-century scholars. Ragimbold of Cologne writes to Radolf of Liége: "I have an instrument with three feet for measuring geometrical figures, whether they be long and straight, square and broad, or thick and solid."[18] Perhaps Ragimbold is referring here to a three-legged compass; if so, this constitutes a very early reference in European history to such an instrument.

Even if the three-legged compass was to be found in the studies of some medieval scholars, pictorial and monumental evidence does not indicate that this kind of compass was used by medieval masons. In the

[14] *Technik des Kunsthandwerks im zehnten Jahrhundert. Des Theophilus Presbyter Diversarum Artium Schedula,* III, 26, ed. Wilhelm Theobald (Berlin, 1933), p. 75.

[15] A free translation of "Sunt et circini ferrei duabus partibus compositi, majores et minores, recti et curvi" (*ibid.*, III, 16, p. 70).

[16] Cf. the remarks of Theobald (*ibid.*, p. 285) with the translations in Theophilus, *De diversis artibus,* ed. and trans. C. R. Dodwell (London, 1961), p. 72, and F. M. Feldhaus, *Die Technik der Vorzeit, der geschichtlichen Zeit und der Naturvölker* (Leipzig, 1914), col. 1370.

[17] Lynn White, Jr., *Medieval Technology and Social Change* (Oxford, 1962), p. 40.

[18] "Geometricas figuras ad mensurandum tres pedes habemus ad instrumentum, longum quem et rectum, quadratum quem et latum, crassum quem decimus et solidum" (quoted in Paul Tannery and Abbé Clerval, "Une correspondance d'écolâtres du XI^e^ siècle," *Notices et extraits des manuscrits de la Bibliothèque Nationale et autres bibliothèques,* XXXVI, pt. 2 [1901], 530). For an excellent discussion of terms and usages of mathematical instruments by medieval geometers, see V. Mortet, "Note historique sur l'emploie de procédés materiels et d'instruments usités dans la géométrie pratique au moyen âge (X^e^–XIII^e^ siècles)" (*Congrès international de philosophie,* 2d sess. [1904], pp. 925–42).

Church of Saint-Ouen at Rouen, statues of Alexander and Colin de Berneval portray these two master masons holding in their right hands pairs of dividers that point to architectural sketches held in their left hands.[19] The dividers are quite simple, consisting merely of two pointed legs held together by a tongue-and-groove joint. Dividers portrayed on the tombs of Hugh Libergier at Reims and of Matthew d'Arras at Prague are more peculiar in that the curving legs cross each other. Some have thought that these represent proportional dividers, but this view has recently been rejected.[20] A drawing in the *Sketchbook* of the thirteenth-century architect, Villard de Honnecourt, shows a pair of dividers with legs that end in needle points.[21] The dividers have no handle, and there is a curved bar to maintain tension when the legs are open. From other illustrations it appears that this was a common construction of the medieval masons' compass. The best such illustration is to be found in a miniature from around 1250 (Fig. 1), which portrays God the Father designing the world with the aid of a pair of dividers.[22] However, the unusual feature should be noted that there is a handle above the joint of the dividers by which the instrument can be rotated. Another pair of dividers is shown in an English miniature from the middle of the thirteenth century (Fig. 2). The peculiarity of this instrument is its size, for this "great compass" stands nearly waist-high to the master mason who is holding it.[23]

These illustrations and the lack of evidence for other kinds of compasses lead to the conclusion that medieval masons and master masons had at their disposal only the simple divider-compass. On the other hand, there were available to early modern architects and masons several different kinds of compasses. Merely a listing of those described and illustrated in the early eighteenth-century *Traité de la construction*

19 Colombiers, *Chantiers des cathédrales*, Fig. 12.

20 *Ibid.*, p. 67.

21 H. R. Hahnloser (ed.), *Villard de Honnecourt* (Vienna, 1935), Pl. 39a.

22 This was not an uncommon theme in the work of medieval miniaturists and glaziers. See G. M. Rushforth, *Medieval Christian Imagery as Illustrated by the Painted Windows of Great Malvern Priory Church Worcestershire* (Oxford, 1936), frontispiece and pp. 150–51; Anthony Blunt, "Blake's 'Ancient of Days': The Symbolism of the Compasses," *Journal of the Warburg Institute*, II (1938–39), Pl. 9b and p. 53, n. 4; and Panofsky and Saxl, *Dürers "Melencolia I,"* Abb. 29 and p. 67, n. 3, for further reproductions and numerous references to other examples.

23 Yet another such "great compass" is illustrated in a fourteenth-century miniature, with the difference that two bars are provided for stabilizing the legs. See Colombier, *op. cit.*, Fig. 15.

Fig. 1.—Thirteenth-century miniature. Vienna, Nationalbibliothek, Cod. 2554, f. lv. (Reproduced from F. M. Feldhaus, *Geschichte des technischen Zeichnens* [Wilhelmshaven: Franz Kuhlmann, 1959], Abb. 47, with permission of the Nationalbibliothek and Franz Kuhlmann KG.)

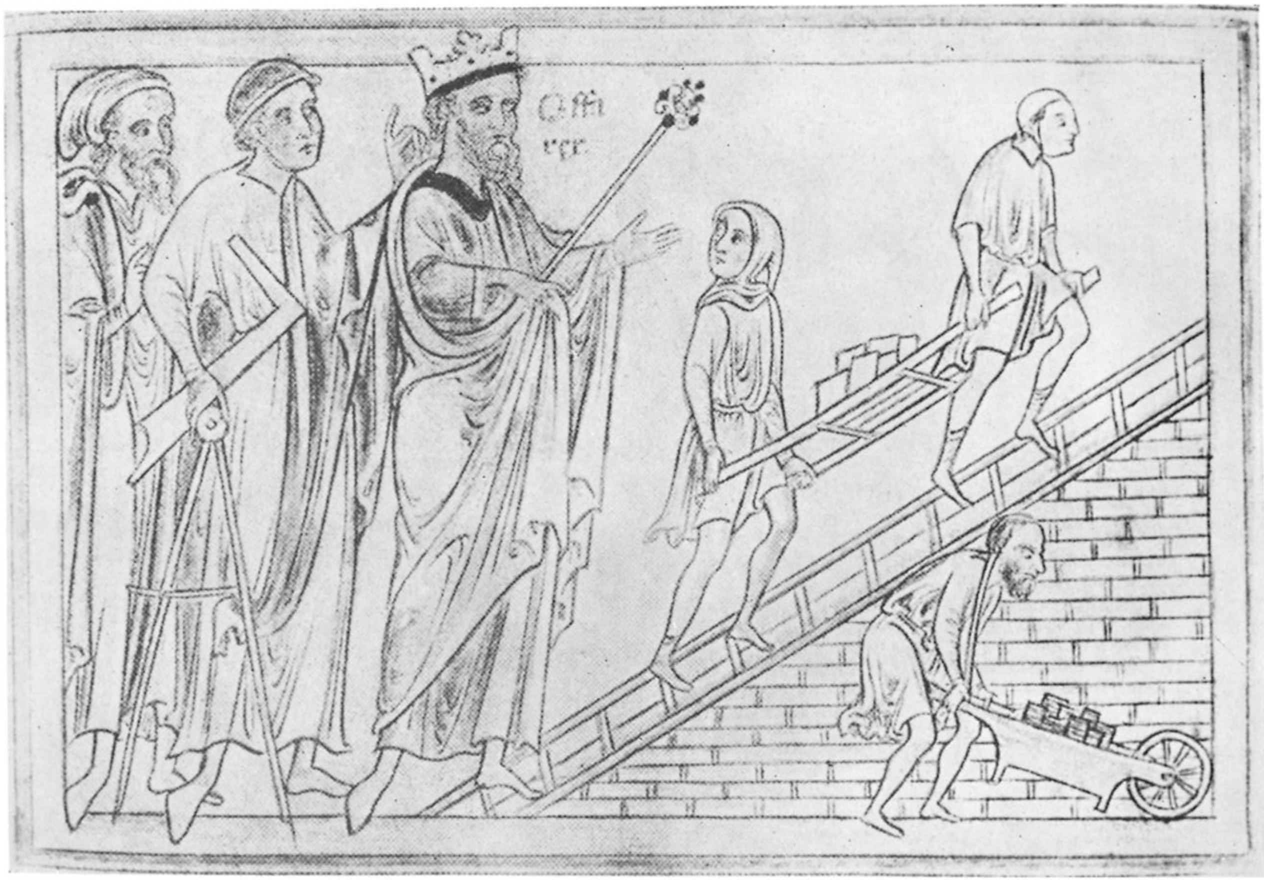

FIG. 2.–Thirteenth-century miniature. Dublin, Trinity College Lib., MS. E. 1. 40. (Reproduced from L. F. Salzman, *Building in England* [Oxford, 1952], Pl. 4, with permission of the Board of Trinity College, Dublin, and of the Clarendon Press.)

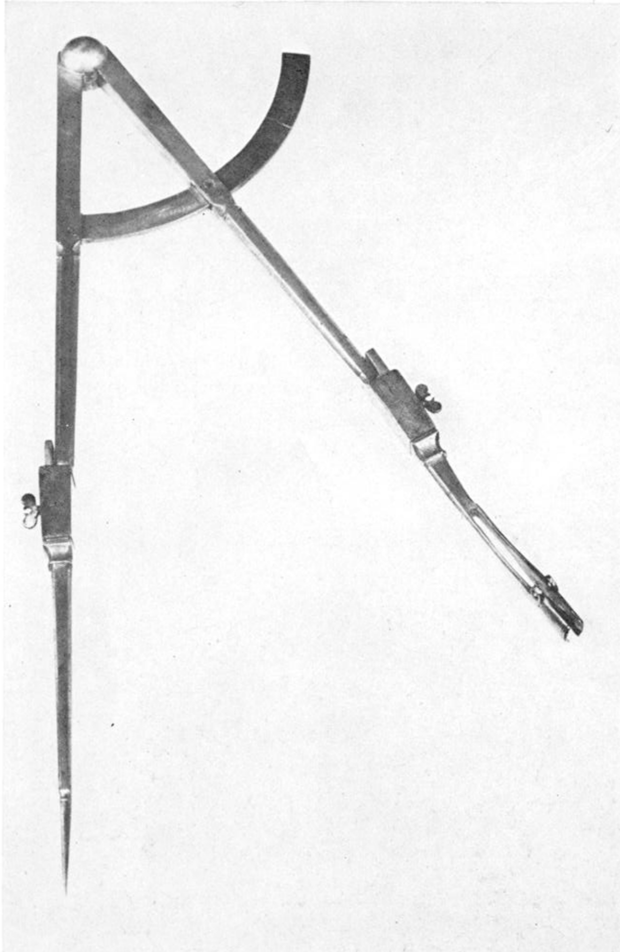

Fig. 3.—Sixteenth-century compass. (Photograph courtesy of the Mathematisch-Physikalischen Salon, Dresden.)

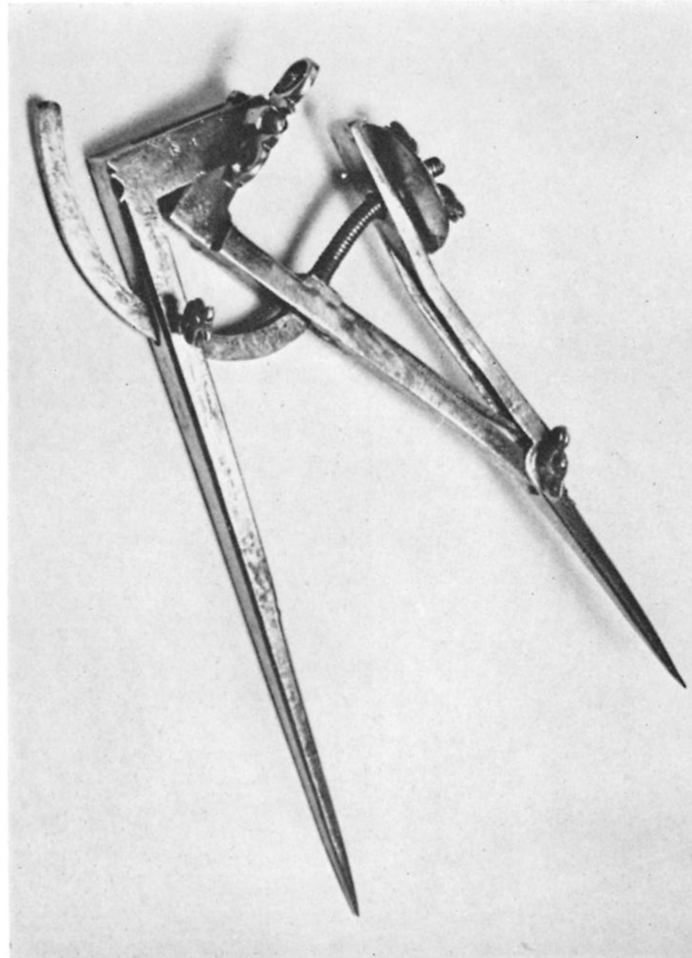

Fig. 4.—Sixteenth-century compass. (Photograph courtesy of the Mathematisch-Physikalischen Salon, Dresden.)

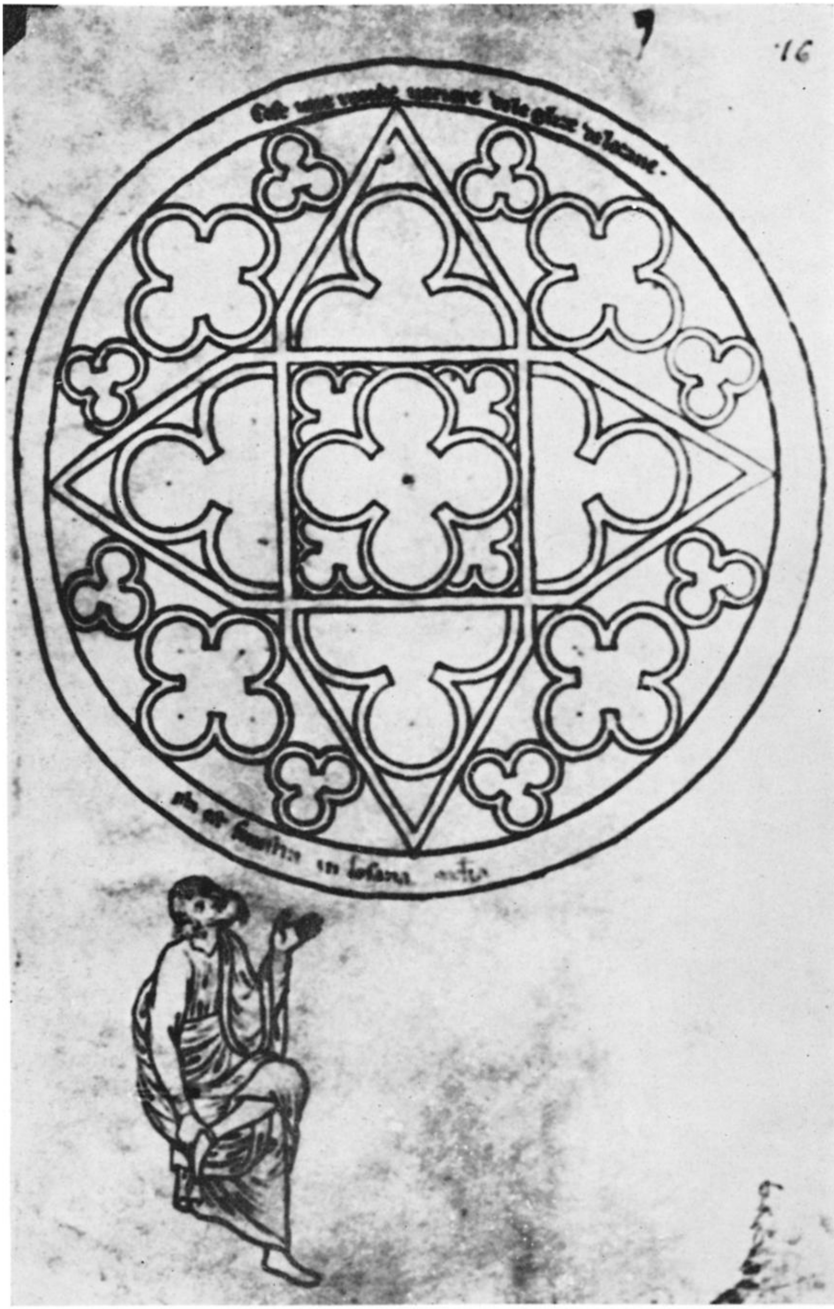

FIG. 5.—Thirteenth-century architectural drawing. Paris, Bib. Nat., MS. Fr. 19093. (Reproduced from *The Sketchbook of Villard de Honnecourt,* ed. T. Bowie [Bloomington, Ind., 1959], p. 50, with permission of the Bibliothèque Nationale and Theodore Bowie.)

FIG. 6.—Fifteenth-century miniature. London, Brit. Mus., Add. MSS. 18850, f. 17v. (Reproduced from Pierre du Colombier, *Les Chantiers des cathédrales* [Paris, 1953], Pl. XI, with permission of the Trustees of the British Museum and A. et J. Picard Cie.)

FIG. 7.–Twelfth-century miniature. Herrad von Landsberg, *Hortus Deliciarum.* (Reproduced with permission from L. F. Salzman, *Building in England to 1540* [Oxford, 1952], Pl. 5.)

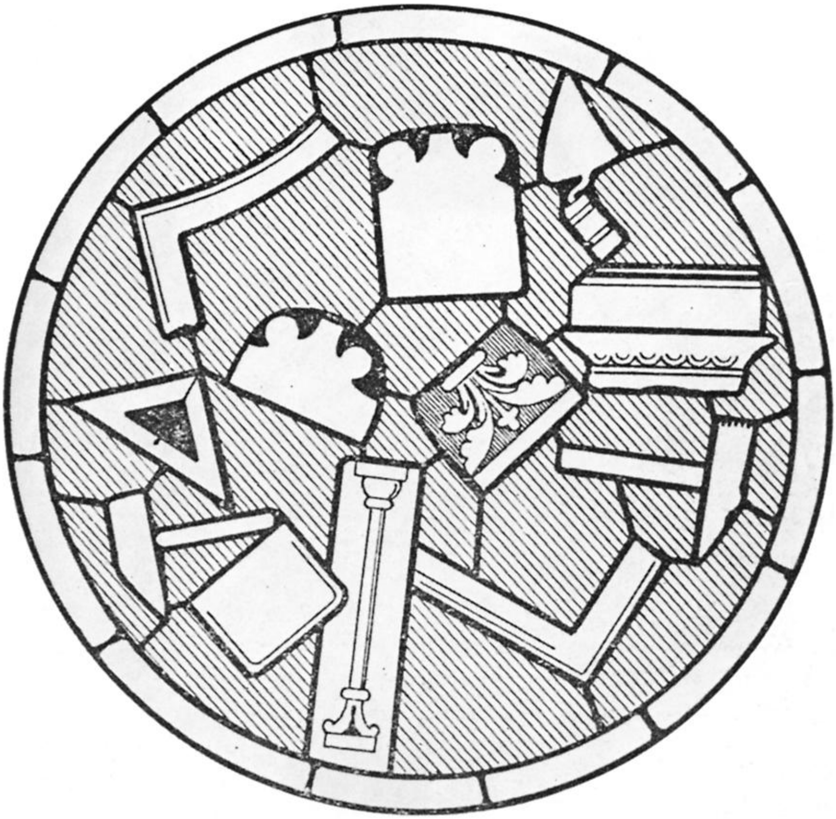

FIG. 8.—Thirteenth-century window. Chartres Cathedral. (Reproduced with permission from Pierre du Colombier, *Les Chantiers des cathédrales* [Paris, 1953], Fig. 3.)

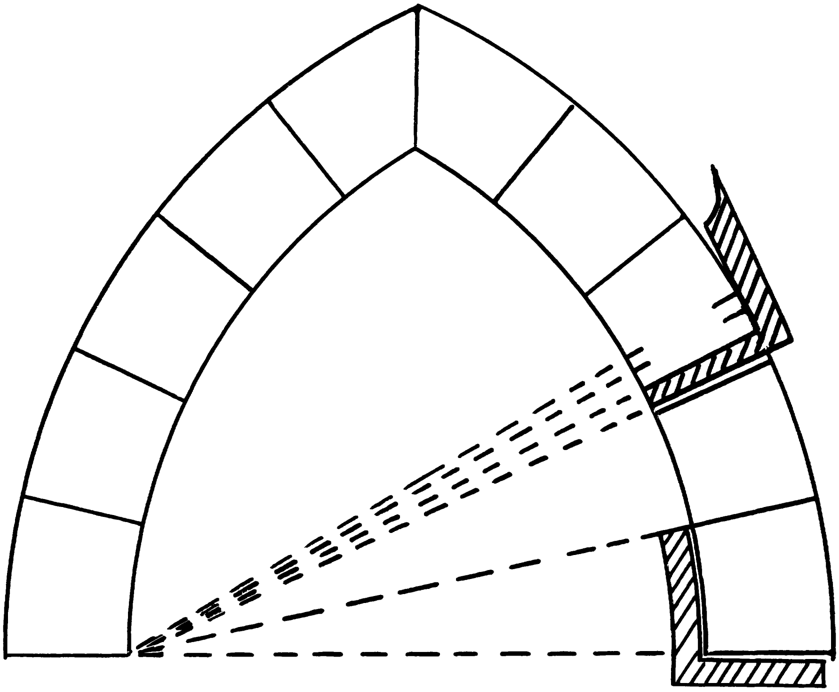

FIG. 9.—Use of special squares in setting out the voussoirs of an arch

et des principaux usages des instrumens de mathematique of Nicholas Bion indicates the advances that were made from the later Middle Ages to Bion's own day. Bion mentions first the *compas ordinaire*, of which there were two kinds: the *compas simple* (in English circumlocution, "a pair of dividers"), and the *compas qui change de pointes à l'encre, au craion, ou l'à une Roulete.*[24] This latter, with its pen, lead, or wheel attachment, has been of inestimable service to modern draftsmen, but was apparently unavailable to masons and architects of the high Middle Ages. However, it seems to have been developed in the later Middle Ages, for there was a fine example of a brass compass dating from around 1550 that was until 1945 preserved in the Mathematisch-Physikalischen Salon, Dresden, Germany[25] (Fig. 3). It has the characteristic curved-arm support that passes through one leg. As can clearly be seen from the photograph, the ends of both legs are detachable, one end consisting of the point, the other of an attachment for holding a piece of graphite or a rotating wheel.[26] A similar compass is preserved in the Ashmolean Museum, Oxford, dating from *ca.* 1540.[27]

Very modern in its appearance is Bion's illustration of the *compas à ressort* (bow compass), with its set screw controlling the tension in the bow legs and making possible fine adjustments for close work. The simplicity and efficiency of this instrument contrast strongly with the sixteenth-century "bow compass" shown in Figure 4. This latter compass, which is interesting but awkward in appearance, has two (or four?) set screws for controlling tension and thus required several adjustments in using it. However, its peculiar construction allowed greater expansion of the legs than is possible with the normal bow compass.

Other compasses illustrated in Bion were also developed in late medieval or early modern times. The *compas à coulisse* (beam compass), the *compas de reduction simple* (proportional dividers with fixed joint), and the *compas de reduction à tête mobile* (proportional dividers with movable joint) were illustrated by Leonardo da Vinci in two manu-

[24] *Traité de la construction* (2d ed.; Paris, 1716), p. 9. The first edition of 1709 was inaccessible to me.

[25] Direktor Grötzsch of the Salon informs me that the compass was destroyed in the bombing of Dresden in February 1945.

[26] On the other hand, the first known illustration of a compass capable of using ink is to be found in Joseph Furttenbach, *Mechanischer Reissladen* (Leipzig, 1644), Fig. 39. See the reproduction in Nedoluha, *Technischen Zeichnens*, Bild 2.

[27] H. W. Dickinson, "A Brief History of Draughtsmen's Instruments," *Transactions of the Newcomen Society*, XXVII (1949–51), 76, and Pl. XVII, Fig. 4.

scripts dating from *ca.* 1495.[28] Another instrument described and illustrated by Bion, the *compas de proportion* (sector, or sometimes, proportional compass), owes its origin to an equally famous personage, Galileo Galilei, who in 1606 described the instrument in a pamphlet, *Le Operazioni del compasso geometrico, et militare.*[29] On the other hand, several of the compasses mentioned by Bion either would have been of little use to masons or else represent only variations on the basic principle of dividers.

By comparison with the instruments of ancient or early modern times, we see that the medieval compass was a simple tool. It fell into the class of compasses known as dividers and varied only in the size of the instrument, the shape of the legs, the kind of joint, and the means of holding the instrument in the hand. Nevertheless, this type of compass was an adaptable tool and could be used for a number of different purposes by the master mason and the other masons working under his direction.

The importance of the compass can easily be recognized in the work of the master mason as architect. In medieval building practice, plans and elevations did not possess the supreme importance they do in modern times, but during the later Middle Ages drawings came to be more and more widely used.[30] This is not the place for an examination of all the technical aspects involved in medieval draftsmanship; we are interested here only in the role of the compass in that practice. In this connection, perhaps the best examples come from the *Sketchbook* of Villard de Honnecourt, whose use of the compass can be seen both in the precepts contained in the book and in the actual process of making the drawings that illustrate those precepts. The drawings are in ink, but in certain places markings are still visible from a previous sketch made with lead. This long ago led William Burges, after an examination of the original manuscript in the Bibliothèque Nationale, to conclude that

[28] Paris, L'Institut de France, MS. B, f. 59, and Milan, Biblioteca Ambrosiana, Codice Atlantico, f. 394r; reproduced in Feldhaus, *Technischen Zeichnens,* Abb. 50, 56, and 57.

[29] Reprinted in *Le Opere di Galileo Galilei,* Edizione Nazionale (Florence, 1890), II, 365–424. For Galileo's role in the invention of the proportional compass, see the comments by the editors (*ibid.,* II, 337). On the use of this instrument in early modern times, see Derek J. Price, "The Manufacture of Scientific Instruments from c. 1500 to c. 1700," *A History of Technology,* ed. Charles Singer *et al.* (Oxford, 1957), III, 627–28.

[30] Besides the several late medieval plans and elevations that are still extant at Vienna, Prague, Strasbourg, Cologne, and elsewhere, a number of English building contracts attest to the growing importance of drawings. See examples in the appendix of contracts in L. F. Salzman, *Building in England down to 1540* (Oxford, 1952), pp. 423, 462–63, 472.

Villard "was the possessor of a bow pencil, but not of a bow pen, for all these circles, as well as all the straight lines (with very few exceptions) were inked in by hand."[31] However, our investigation has shown that thirteenth-century master masons most likely did not have the type of compass known as the bow pen. That some kind of compass was used cannot be doubted, for the punctures in the parchment in the middle of the circles are still clearly visible (Fig. 5). H. R. Hahnloser, editor and commentator on the *Sketchbook*, has recognized that the circles were drawn first with a compass and inked in by hand, but he has not stated clearly what kind of compass was used.[32] Until the manuscript can again be investigated with this particular question in mind, a categorical answer should not be attempted. It seems highly probable, however, that circles were marked or pressed on the parchment by means of simple dividers that did not have pen or pencil attachment; these construction lines then guided the draftsman who inked in the drawings by hand.[33]

The master mason found other uses for the compass in his role as technical supervisor of masonry construction. In his task of setting out the building site he may have used the "great compass" for marking circles directly upon the ground or floor of the building, which marks were then used as guidelines for the masons who set the stones.[34] This directness of method was characteristic of medieval building. For instance, in 1448 Henry V was anxious to see where his sepulchral monument would be placed in Westminster Abbey. At the king's request the master mason, "with an instrument of iron whiche he browght with hym, markyd out the lengthe and brede of the said sepulture."[35] Construction then proceeded upon those lines marked out.

[31] W. Burges, "An Architect's Sketchbook of the Thirteenth Century," *The Builder,* XVI (1858), 758.

[32] Hahnloser, *op. cit.*, p. 184.

[33] By the early fifteenth century in Italy these construction lines were drawn in silverpoint. For a contemporary description of the silverpoint technique, see Cennino d'Andrea Cennini, *Il Libro dell'arte,* chaps. v–x, ed. D. V. Thompson, Jr. (New Haven, Conn., 1932). An early fifteenth-century example of this technique used in making an architectural drawing is reproduced and discussed by Howard Saalman, "Giovanni di Gherardo da Prato's Designs concerning the Cupola of Santa Maria del Fiore in Florence," *Journal of the Society of Architectural Historians,* XVIII (1959), 12, and Fig. 1.

[34] For the great compass in use, see the imaginative drawing on the title page of each volume in Viollet-le-Duc, *Dictionnaire raisonné de l'architecture française du XI^e^ au XVI^e^ siècle* (Paris, 1867–68).

[35] Account quoted in W. H. St. John Hope, "The Funeral, Monument, and Chantry Chapel of King Henry the Fifth," *Archaeologia,* LXV (1914), 177.

The compass also played an important part in setting out marks for guiding the stonecutters in their work. Stones from medieval buildings have been recovered which still bear these setting-out marks,[36] and the smooth lines indicate that dividers were used to incise curves and circles onto the stones. This conclusion is further supported by a medieval miniature (Fig. 6) that shows a mason marking a stone with the aid of a compass.

* * *

Tracing the development of the masons' square through ancient and medieval times is not as complicated as tracing that of the compass, because of the simpler form of the square. An Egyptian square recovered from a royal tomb of the Old Kingdom illustrates this point; the tool consists merely of two narrow boards joined at right angles to each other.[37] Greek references to the square (*gōnia* or *gnōmōn*), even more so than to the compass, do not provide satisfactory technical details about the construction of the tool. It is not until Roman times that these details become available, when once again evidence from masons' tombstones indicates the forms of the square used by classical builders. There were at least two kinds in use: one similar to the Egyptian square, the other made from a flat board with a right angle cut from it.[38] It might be noted in passing that this latter type could have been used only for checking external angles and thus could not have been the kind of square (*norma*) suggested by Vitruvius for squaring the inside corners of a room.[39]

The same limitation would apply as well to the square described by Isidore of Seville: "It is constructed out of three rules, of which two are two feet long, and the third is two feet and ten inches long. They are of equal thickness, polished, and joined together at the ends of each

[36] See examples reproduced in Robert Willis, "On the Construction of Vaults of the Middle Ages," *Transactions of the Royal Institute of British Architects*, Vol. I, pt. 2 (1842), Figs. 6 and 7; and Robert Branner, "Villard de Honnecourt, Archimedes, and Chartres," *Journal of the Society of Architectural Historians*, Vol. XIX (1960), Figs. 5 and 6.

[37] See Clarke and Engelbach, *Ancient Egyptian Masonry*, Fig. 264; reproduced in Shelby, "Medieval Masons' Tools," Fig. 3. In an appendix on building tools, Norman Davey (*A History of Building Materials* [London, 1961], p. 223) points out that the Egyptian masons' A-shaped level could also be used as a set square, since the A was set at 90°.

[38] Anthony Rich, *A Dictionary of Roman and Greek Antiquities* (4th ed.; London, 1874), p. 447, with illustrations. See Blümner, *Technologie*, Vol. III, Fig. 2, for other examples from tombstones.

[39] Vitruvius, *op. cit.*, VII, iii, 5.

to form a triangle. This is a square."[40] This type of set square may have been used in Isidore's day, or the good bishop may have been merely copying classical sources as he was wont to do.[41] However, I have not found in later medieval illustrations any examples of squares with cross-pieces as described by Isidore. The only variations to be found in these illustrations are in the width, length, and shape of the two "arms" of the square. At first glance these variations seem insignificant, but closer study of them indicates important differences in the nature and use of the tool. For instance, a twelfth-century miniature depicts a square with one long and one very short arm (Fig. 7). This may have been merely exaggeration by the artist, although it should be noted that the other tools in this miniature are drawn realistically; besides, squares are shown in other medieval illustrations with one arm considerably shorter than the other (see Fig. 2). If we accept these proportions as relatively accurate, the following might be surmised about the construction of the tool. Let us suppose that the square was carved from a single piece of wood; the short arm would then correspond to the necessarily narrow width of the board, while the longer arm, running with the grain of the wood, could be cut at any convenient length.

But was the masons' square always made of wood during the Middle Ages? L. F. Salzman has found a couple of instances in later medieval English building accounts where squares were made of iron, but other examples from these accounts indicate that they were normally made of wood.[42] Metal squares seem to have replaced wooden ones only gradually. In 1576 the French architect Philibert de L'Orme still thought of the square as a wooden instrument; in 1709 Nicholas Bion described and illustrated the square as made of brass, but in 1755 the article on the masons' square in Diderot's *Encyclopédie* noted that the instrument could be made of wood or metal.[43] Finally, a wooden square which I recently saw in England in the masons' shop of the Bath and Portland Stone Company is said to have been in use less than sixty years ago.

40 "Conponitur autem ex tribus regulis, ita ut duae sint binum pedum, tertia habeat pedes duos, uncias decem, quas aequali crassitudine politas extremis cacuminibus sibi iungit ut schemam trigoni faciant. Id erit norma" (Isidore, *Etym.*, XIX, 18, 1).

41 Certain phrases of the passage appear to be derived from Pliny *Naturalis Historia*, XXXVI, 22, 51, #172, ed. L. Janus (Leipzig, 1878), V, 136.

42 Salzman, *op. cit.*, p. 339.

43 Philibert de L'Orme, *L'œuvre de Philibert de L'Orme comprenant le premier tome de l'architecture* . . . , II, 2. Facsimile of 1567 edition, ed. C. Nizet (Paris, 1894), p. 36; Bion, *Traité de la construction,* p. 24 and Pl. IIId; *Encyclopédie, ou dic-*

The number of medieval miniatures that show the master mason holding a square in his hands indicate the constant use of this tool in his work. Before the introduction of the transit into construction work the task of setting out the building had to be accomplished "mechanically" with lines, plumb bob, rule, and square, as stated by Vitruvius in Roman times.[44] In using such means in the Middle Ages to set out large buildings, the mason had to take great care to prevent mistakes, for a small mistake at one end of a church three hundred feet long would be greatly magnified by the time it reached the other end.[45] This can readily be seen in the nave of Beverley Minster, Yorkshire, where the pillars on either side of the nave become more and more out of line with each other as they extend westward, until there is a difference of eighteen inches in the widths of the two sides of the westernmost bay.

The square was a basic tool for stonecutters and stonesetters as well as for master masons. Its importance is obvious in the matters of squaring stones and of preparing flat surfaces for the markings that directed the cutting of fancier stones. But the masons' square was also used as a kind of T-square for marking these surfaces with the compass, as shown in the fifteenth-century miniature in Figure 6. Furthermore, once the stones had been cut, their placement in the wall was effected with the aid of the square (Fig. 7).

These normal, everyday uses by the masons are obvious and need little comment; but there were special applications of the square that are not as familiar. In the first place, one fact about medieval masonry that has not received sufficient attention is that angles were measured in gradients, not in degrees.[46] Gradients were expressed as the ratio of the sides of a right triangle. This ratio determined the angle that the hypotenuse made with the base of the triangle, and this was the angle under consideration. If the arms of the square were graduated, angles could thus easily be marked off with this tool. To be sure, I have seen no medieval illustrations where such gradations are shown on the square,

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tionnaire raisonné des sciences, des arts et des métiers, ed. Denis Diderot (Paris, 1755), V, 871.

44 Vitruvius, *op. cit.*, I, i, 4.

45 As late as 1567 Philibert de L'Orme (*Premier tome de l'architecture*, II, 1, ed. Nizet, p. 33v) chided his fellow architects for inaccurate use of the square in setting out their work.

46 Robert Willis (ed.), *Facsimile of the Sketch-book of Wilars de Honecort* (London, 1859, pp. 144–45), pointed this out in commenting on Villard's formula for determining the angle of the stones in a church steeple (Pl. XXXIX in Willis' edition; Pl. 40h in Hahnloser's edition).

but this may be merely a result of the small size of the square in the miniatures.[47]

Another interesting use of the square occurred to me after puzzling over the fact that a number of illustrations show squares which are "out of square." Some of these even depict one arm with a definite curve (Fig. 8). Was this illustration a misrepresentation, or a figment of the artist's imagination, or does it accurately depict a kind of tool used by medieval masons? Assuming the latter, one might surmise that such a tool could have been very handy in the construction of arches. If the curved arm of the square were constructed on the same radius as the curve of the arch, then the tool could have been used in setting out and cutting the voussoirs for the arch, as shown in Figure 9.

Yet another puzzling feature about some medieval representations is that the edges of the two arms of the square are not parallel (see Fig. 2). In an interesting hypothesis recently stated, Professor Robert Branner suggests that the angle of difference between the two edges was used to obtain the joint faces of the voussoirs of an arch.[48] If the two edges of the arm corresponded to radial lines of the arch, then the radial joints of the voussoirs could be obtained simply by marking successive radial lines on the stone with the square (see Fig. 9).

In a recent book B. G. Morgan has developed an even more elaborate explanation for these squares with tapering arms.[49] He suggests that the arms of the square represent the sides of right triangles that were used by some medieval English master masons in determining the proportions of buildings they were designing. Since the acute angles of a right triangle are determined by the length of the legs of the triangle, Morgan concludes that the masons' square with tapering arms represents two different triangles—the "general" (with angles of 90°, 60°, and 30°) and the "canonic" (with angles of 90°, 58° 37′, and 31° 23′).[50] The choice by the master mason of one or the other of these triangles as the basic geometrical figure of his design would thereby affect the entire proportions of his building. Morgan proceeds to analyze geometrically

[47] R. G. H. Thomson ("The Medieval Artisan," *History of Technology*, II, 386) positively states that the gradations were there, but the miniatures he cites do not show them.

[48] Robert Branner, "Three Problems from the Villard de Honnecourt Manuscript," *Art Bulletin*, XXXIX (1957), 65–66. Branner bases his hypothesis on diagram 40g of Villard's *Sketchbook* (Hahnloser's edition, *op. cit.*)

[49] B. G. Morgan, *Canonic Design in English Mediaeval Architecture: The Origins and Nature of Systematic Architectural Design in England, 1215–1515* (Liverpool, 1961), pp. 55–69.

[50] *Ibid.*, pp. 52, 55.

several later medieval English buildings, showing which triangle was used for certain cathedrals (or parts of cathedrals, as the case might be).

This is an intriguing theory, and Morgan is to be commended for supporting it with some documentary evidence and with an example of an old (eighteenth-century?) masons' square, as well as for keeping his discussion on a more practical level than many advocates of *Baugeometrie*. Unfortunately, he has not gone quite far enough in this direction. Even if one assumes that his choice of the "general" and "canonic" triangles for the canons of late medieval English architects is correct (and special advocates of other geometrical figures might be loath to assume this), and if one accepts his conclusion that the masons' square contained these triangles, one is still faced with a crucial practical question. How was such a square actually used in setting out the larger dimensions of the church (over-all length, breadth, height, and various diagonals)? Yet Morgan has made little attempt to answer this question.[51] As usual in such studies, he has provided plans and elevations of various cathedrals, with red lines drawn all over them to show the "geometrical proportions" of the buildings. But he has not shown how a square (such as that carved on the tomb of the French master, Hugh Libergiers) with arms approximately twelve and twenty inches in length, and with a taper of 1° 30′ 10″, could have been used in setting out these construction lines, some of which would have been hundreds of feet in length and would have passed through piers and walls already in existence when the new part of the building was being designed and constructed. Had Morgan given more careful attention to this problem of actual building technique, his explanation of the tapered-arm squares, as well as his arguments for canonic design in English medieval architecture, would have been more convincing.

Nevertheless, the implications of Morgan's study do correspond with the conclusion that arises from other considerations in this paper. We have seen that the basic feature of the masons' compass and square was that of simplicity. The conclusion presses upon us that it was not the sophistication of the tools themselves, but rather the skill and ingenuity displayed in the use of those tools that made possible the great achievements of the medieval masons.[52]

[51] His discussion of the "Use of the Mason's Square" (*ibid.*, pp. 68–69) is brief and inadequate for the complexity of the subject.

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