Marie-Thérèse Zenner

Villard de Honnecourt and Euclidean Geometry

Marie-Thérèse Zenner presents a brief overview of the survival of Latin Euclid within the practical geometry tradition of builders, taking examples from an eleventh-century French Romanesque church, Saint-Etienne in Nevers, and a thirteenth-century Picard manuscript of drawings (Paris, Bibliothèque nationale, MS fr. 19093), known as the portfolio of Villard de Honnecourt.

Introduction

In Antiquity, within the Mediterranean basin, and in the West during the Middle Ages, scholars considered mechanics as one of the more noble of human activities, placing it at the confluent of ideal mathematics and the three-dimensional physics of the terrestrial world. From these periods, we have inherited two monumental works of an encyclopedic character that each unite knowledge of built structures, of machines and of nature: namely, the text by the Roman architect, Vitruvius (written c. 33/22 BC), and a manuscript by Villard de Honnecourt, a Picard (a region now situated in northern France), written some 1250 years later.

Whereas the mathematical content in Vitruvius's work is relatively easy to discern—because it is explicit in the text—the collection of Villard is much more difficult to understand, consisting essentially of drawings which remain obscure except to those initiated in the same oral tradition prevalent during the thirteenth century. And yet these drawings can be cracked when studied within the larger context of applied mathematics — the practical geometry — from between the first and seventeenth centuries. One perceives, not surprisingly, that the basic geometric knowledge of the medieval architect derives ultimately from the Elements of Euclid.

The Portfolio Of Villard De Honnecourt

But to understand the "travel sketchbook" of Villard de Honnecourt is an arduous task requiring not just inter- but trans-disciplinary knowledge. Besides questions of paleography, language (the thirteenth-century Picard dialect), and technical vocabulary, the analysis of Villard's drawings also requires advanced knowledge in mechanics (civil and military), in architecture (materials and techniques), in "gromatics" (that is, the land-surveying, the discipline of measuring the earth as well as the measurement of solids and of objects at a distance, as for example in Figure 3 below), in stereotomy (the science of calculating, drawing and cutting complex solids, such as stone or wood for building, commonly known in French as the *art du trait*, or art of tracing), the selective use of a base-twelve (duodecimal) system of counting,[1] just to cite some of the aspects in Villard's portfolio treating of mathematics other than the 'pure' mathematics of Euclid of Alexandria (c. 325-c. 265 BC).

In the abundant and longstanding bibliography on the portfolio,[2] while there has been occasionally question of practical building geometry, in terms of an art, there has rarely been question of the mathematical bases for this geometry, in terms of a science. Indeed, the geometer Pappus, also of Alexandria (c. 290-c. 350 AD), had long ago advised that it was impossible to achieve competence in both domains and, if one were required to work with geometry, the best road was learning through experience rather than theory.[3] According to Pappus and later, Vitruvius, one of the only exceptions to this rule was Archimedes of Syracuse.[4] In this context, Villard was with little doubt a 'working geometer' (as per the French term *opératif*) rather than a theoretician.

But if Villard knew geometry, of what geometry are we speaking? Historians have long privileged the Greco-Arabic tradition of translation, established in the eighth century, and the increasingly important transmission of these ancient texts to Europe, beginning especially in the second quarter of the twelfth century. In recent years, research by Wesley M. Stevens and Menso Folkerts has shown, however, that the corpus of Euclidean plane geometry (books 1-4) survived largely intact in Latin translations, appearing as early as the sixth century, principally in works of Boethius and Cassiodorus Senator (*Institutiones*).[5] These texts were combined with works from the Roman land surveyors (*agrimensores*) beginning in the late eighth century. This renewed interest in geometry appears to have been both theoretical and practical, and the center of production for this new grouping of geometric-gromatic material has been identified as the Abbey of Corbie (about 15 kilometers east of Amiens, in northern France).

The geographic location is perhaps relevant, as will be shown, to architectural history as well. There is no graphic documentation for ideas in design and construction during the Romanesque period (eleventh- to early twelfth centuries). The extant corpus of Romanesque monuments is perhaps the most significant group from the pre-modern period missing this type of external evidence. Not surprisingly, therefore, medieval architectural historians have come to rely on comparisons with the only two remaining documents on architectural design, albeit spanning a period of four hundred years, but encompassing the Romanesque period: we have the Plan of St.-Gall (c. 817/19) and the portfolio of Villard (c. 1220/35). Like Corbie, the Abbey of St.-Gall (now in the Germanic-speaking part of Switzerland) was of early Irish foundation, which, according to one school of thought, would suggest a long-standing respect for antique learning. Moreover, the Plan of St.-Gall is contemporaneous with the revival of geometric-gromatic texts at Corbie. Based on the spread of these manuscripts, later additions and commentaries, we may be justified, therefore, in considering an area between northern France and eastern Switzerland, with parts of Belgium and Germany, as a principal zone influenced by this revival.

Four hundred years later, Villard too was associated in some capacity with the Abbey of Corbie. His presumed birthplace, Honnecourt-sur-Escaut, is situated relatively near Corbie in Picardy (roughly 60 kilometers east, and 15 kilometers south of Cambrai). A Latin note added to the manuscript by the so-called Magister II (c. 1250/60) states that

Villard worked on a ground plan (fol. 15r) with a certain Pierre de Corbie. Other commentaries in the manuscript suggest a link between Villard's portfolio and the early geometric-gromatic texts. For example, on folio 18v of the portfolio (Figure 2, at right), Villard (or his scribe) wrote: *Ci comence li force des trais de portraiture si con li ars de iometrie les ensaigne…* ("[h]ere begins the force of lines for drafting, as the art of geometry teaches…"). Elsewhere, Magister II added a commentary (fol. 20r) on a leaf of "technical drawings" he added to the portfolio: *Totes ces figures sont estraites de geometrie* ("[a]ll these figures are taken from geometry"). A phrase referring to "the art of geometry" appears as well on folios 1v and 19r.[6] In the theoretical treatises, one finds very similar terminology. For example, the heading of a Latin text from the eleventh century specifies: *Incipiunt figurae excerptae ex geometria* ("[h]ere begins the figures excerpted from geometry").[7] In the eighth to eleventh-century texts, in particular, the Elements of Euclid were not known as such—-they were known rather as the Geometria of Boethius, so references to "excerpting" material from *geometria* very likely refer to such a source.

It is probable, therefore, that Villard (and Magister II) had access to written texts, having perhaps even studied them at Corbie itself. This hypothesis would necessarily modify the accepted notion that the builder's practical geometry was handed down by means of a strictly oral tradition, and that the oral aspect was propagated because they were all illiterate. It is much more likely that the oral tradition was privileged due to concepts of trade secret and the importance of having information ready-at-hand (that is, memorized) when working in rough conditions on-site. Fortunately for us, Villard's portfolio breached the tradition of corporate secrecy.

The Euclidean Heritage

Given the claim that drawings in Villard's portfolio were made according to "the art of geometry," can we identify in them any purely Euclidean construction? In folio 18v (Figure 1), we see a drawing of two flamingos, just left of the text stating that the force of geometry begins here. The curves of their long necks and bodies suggest a simple case of the intersection of two circles for determining a perfect right angle with a compass and straightedge. A Villard expert, Bechmann, has previously identified the figure as an *aide-mémoire* for drawing a perfect right angle but does not speak of Euclid in this context.[8] We suggest that the drawing has another level of interpretation, as an example of Euclid proposition 1.1—to construct an equilateral triangle on a given finite straight line (Figure 2). If we draw two circles separated by their common radius (i.e., the base line as in Figure 1), we have created the third point required for constructing an equilateral triangle, both above and below the given line.

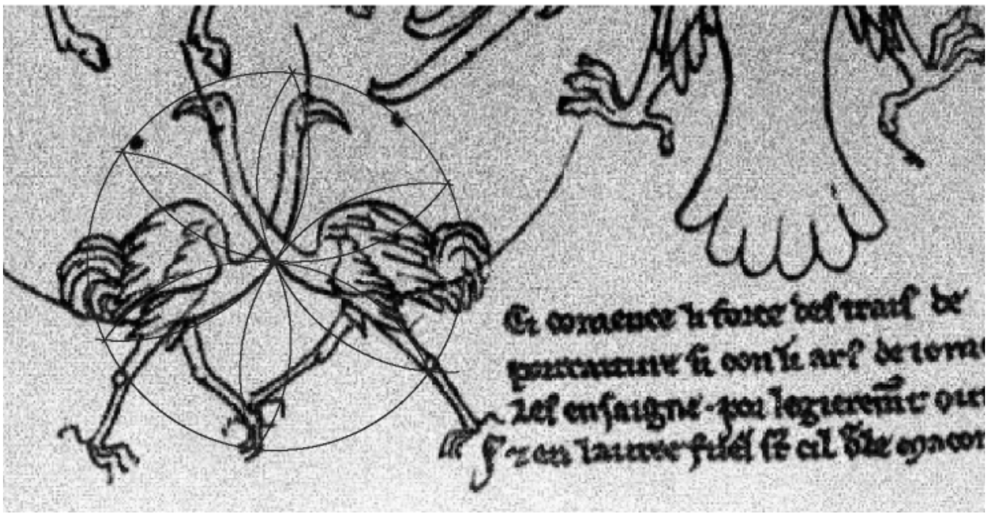

Fig. 1. Paris, Bibliothèque nationale, MS fr. 19093, fol. 18v, (c. 1220/35), detail of two flamingoes with inscription, reproduced with permission from Lassus, Album de Villard, 1858, reprint, Paris, Éditions Léonce Laget, 1976, (drawing of hexagonal overlay: Center for the Study of Architecture)

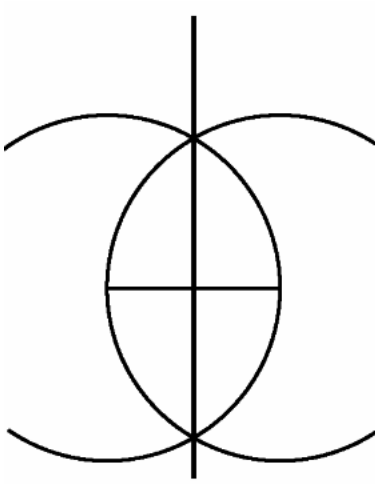

Fig. 2. Demonstration of a specific case of Euclid proposition 1.1, using two circles separated by their common radius, to determine a perpendicular to the base line determined by the two centers (drawing: Center for the Study of Architecture)

In our Figure 1, we illustrate the consequence of Euclid 1.1 when the base line is a given radius but without a specific orientation.[9] The radiating aspect of the two necks and four legs gives a hint. The bottom point of intersection between the necks and the far right-hand knee of the one flamingo, for instance, determine a radius of a circle, which can be sub-divided using the compass into points for six equilateral triangles (in other words, a hexagon inscribed within the circle). There is iconographic justification for the use of junctures at the neck, a knee, and the two claws (feet). Within the oral builder's tradition of apprenticeship (known as *compagnonnage*), the typically bearded older master physically embraces the younger apprentice in a certain ritual, heads closely joined, arms and legs interlaced, with overlapping junctures at ear, knee and feet. Very similar poses are given in the portfolio itself on the facing leaf (fol. 19r, two drawings on third row) to illustrate devices for constructing, as well as in the pose of the so-called wrestlers (fol. 14v). But the best example may be found in a previously misidentified bas-relief on the richly sculpted, early twelfth-century façade of the church, Notre-Dame-la-Grande in Poitiers (France), which appears to have been added within the theologically based iconographic program as a signature of sorts.[10] This sculpture, other monumental signatures on the same church and *compagnonnage*, in general, will be the subject of a forthcoming study.

We suggest, therefore, that it is not at all by coincidence that Villard inscribed the text "here begin the force of lines for drafting" next to the drawing of the two flamingos. From the two circles with a given finite straight line between their centers as radius, one can construct an equilateral triangle (or hexagon), a square, then a golden-section rectangle and most every other elementary geometric form, moving from point to point with a deductive logic of form, using only compass and straightedge.[11]

There is yet another level of interpretation. On the walls of medieval buildings one very often finds a contemporary graffiti in the shape of a six-petalled flower (as seen in the overlay, Figure 1). We suggest that this compass construction is a mnemonic device for recalling the two flamingos, in other words Euclid's proposition 1.1: firstly, the flower construction is easier to engrave than the forms of two birds; and secondly, whereas the straight lines of an approximately shaped hexagon would be theoretically easier to carve, the flower more directly and precisely recalls the almond-shape created by the overlap of two circles (see Figure 2).

The almond-shape is often referred to as the *vesica piscis* (the bladder of the fish) and it has a rich iconographic and mythological tradition of its own. Of potential interest here is the connotation of the flamingo with the fish. The species most likely represented on Villard's folio 18v is the pink "Greater flamingo" originating in the Mediterranean, notably, the Sinai in Egypt. Their larger beak permits them to feed on fish. It would not be impossible to consider that the flamingo was chosen as an animal totem because of this association, in addition to the obvious advantage of its long neck as a means to indicate the intersection of two circles. Indeed the fish association is another means of suggesting that the key figure is an overlap equal to the radius of the two circles, for only this case produces the *vesica piscis*, only this case illustrates Euclid 1.1. The six-petalled flower design may, therefore, be a kind of signature, left behind during the passage of an initiated geometer, that is, "one who knows the road to Egypt."

Systematic analysis of those drawings in the Villard portfolio using principles of 'constructive geometry' will permit us to identify additional aspects of Euclidean geometry, which were handed down in the building trade largely through an oral tradition, and subsequently to identify, where possible, their use in architecture and mechanical engineering in the medieval period.

The so-called technical leafs (fols. 20r, v) in the portfolio were added as a palimpsest (i.e., after scraping off the drawings on the original parchment leaf) by the later hand, Magister II (c. 1250/60). The subjects of these two folios belong to the gromatic corpus, a textual and practical tradition of 'measuring problems' handed down as such at least since the texts by Heron of Alexandria (c. 10-c. 75 AD). The Euclidean principles at the basis of these drawings are also identifiable. In a detail at the bottom of one leaf (fol. 20v, Figure 3), we see a crouching man actively sighting the height of a tower, using an isosceles right triangle (45°-90°-45°). The principal behind the method consists of moving back and forth until the triangle's hypotenuse aligns with the tower's summit; the distance measured along the earth will then be equal to the tower's height. This device uses a specific case of similar triangle theory as put forth in Euclid's proposition 6.32.[12]

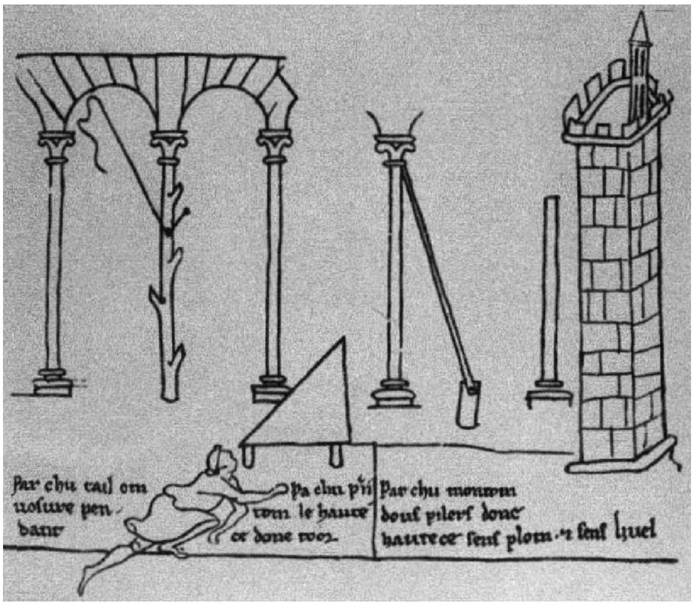

Fig. 3. Paris, Bibliothèque nationale, MS fr. 19093, fol. 20v, (c. 1220/35), detail of man sighting height of tower using an instrument — an isosceles right triangle mounted on feet (built of wood?), reproduced with permission from Lassus, Album de Villard, 1858, reprint, Paris, Éditions Léonce Laget, 1976

An Architectural Example of Euclidean Geometry?

A long-term study of the French Romanesque church, Saint-Etienne in Nevers, suggests the use of Euclidean principles in the design of the plan and elevation. This former priory church (c. 1063/74-c. 1090) situated in the Upper Loire Valley (now part of the Burgundy region), belonged to the monastic order of Cluny and was patronized by several highly important people in Europe at the time of its re-founding,[13] but what distinguishes it most is that it possesses the first known example of a triple elevation (that is, nave arcade, gallery and clerestory) beneath a high vault.[14] Surprisingly, this innovative structure is supported by minimal external buttressing (refer to the plan, Figure 4). One can partly explain this by the fact that the structure works by laterally distributing forces through a tiered system of blind arcading in the interior and exterior faces of the nave and aisle walls; one can partly explain it by the fact that, as we were able to demonstrate by means of a standard structural analysis, the stilted quadrant arches in the galleries are the first known example of functional 'interior' flying buttresses, resulting in an efficient distribution of remaining transverse forces to the ground (i.e., along the line of a parabolic arc).[15]

We have posited that the architect chose dimensions in such a way as to 'guarantee' in advance the successful distribution of load, in other words, a stable three-dimensional solid. There was no particular experimentation in view of the fact that the archaeological evidence suggests one design, quickly and coherently built, using the finest materials and craftsmanship available at the time. During an analysis of the plan derived from our measured survey, it became clear that three dimensions (or several simple fractions thereof: ½, 1/3, ¼…1/12) were used to determine both the plan and the elevation.[16] Briefly, we propose that the design layout on the ground began by setting out two points of a given finite straight line (Figure 4). This line determines the length of dimension A, and using these two centers draw two circles of dimension C. The former represents the minimum vault height (in the sanctuary and transept arms); the latter the maximum vault height (intrados of the octagonal dome in the crossing). This is not a case of Euclid's proposition 1.1, but our instinctive understanding is that additional overlap of the two initial circles would reinforce the structural stability in a large-scale three-dimensional construction.

The rest of the plan design follows on the same principle (for example, Figure 5, with reference to dimension B, the height of the nave vault and the reinforced exterior width of the west façade, which once supported two towers). Plan dimensions were then rotated 90° to the vertical and verification of the height of vaults could be done using the isosceles right triangle instrument (shown in Figure 3) or an astrolabe with its sighting angle (i.e., using the alidade) set at 45°.[17]

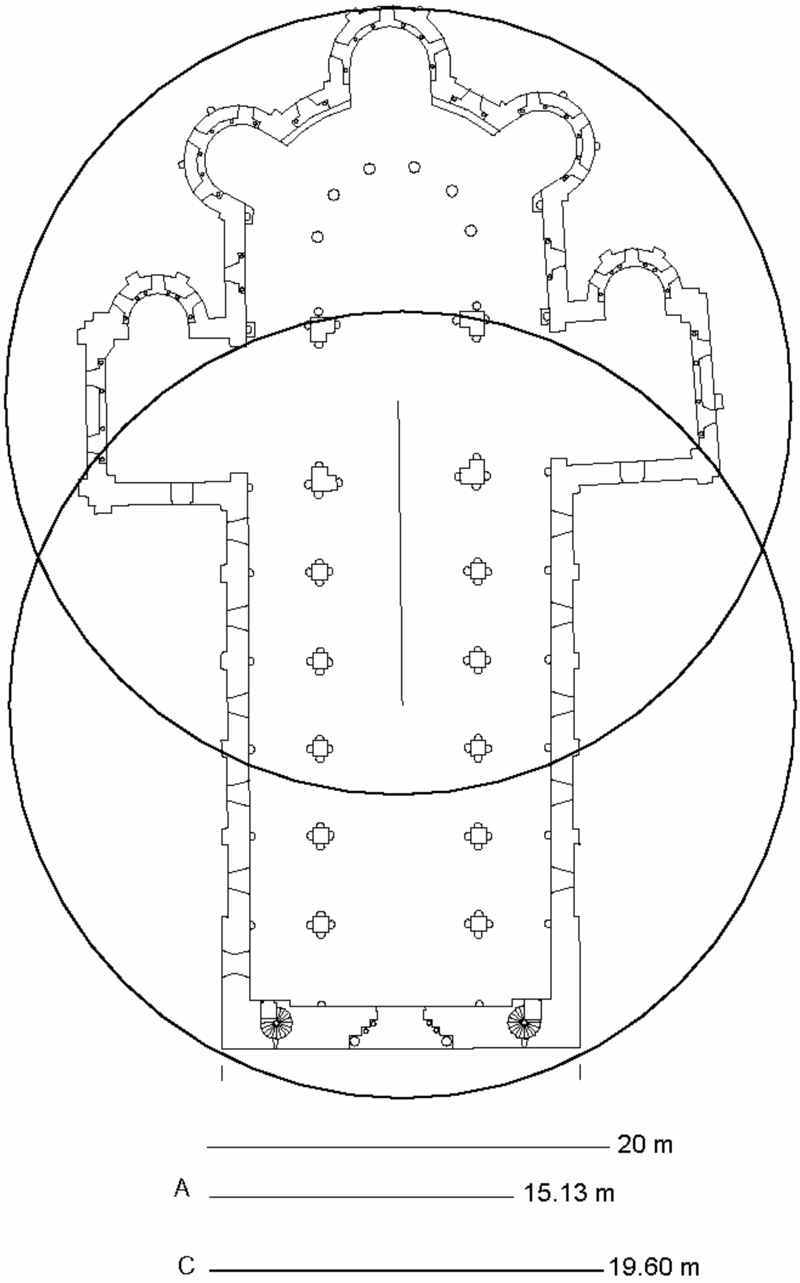

Fig. 4. Saint-Étienne of Nevers, France (c. 1063/74-c. 1090), plan after Addiss (based on joint measured survey), overlaid with two circles of dimension C, with their two centers separated by dimension A (drawing: author)

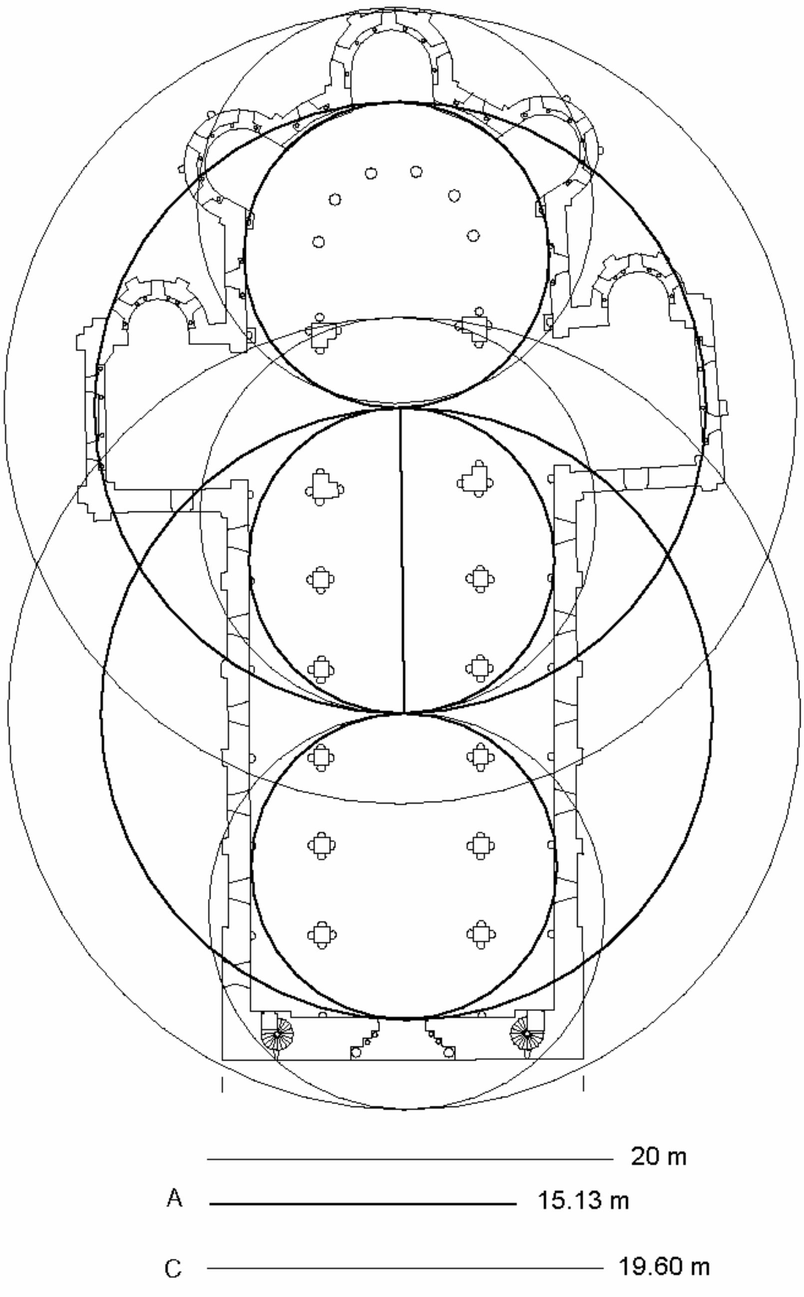

Fig. 5. Saint-Étienne of Nevers, France (c. 1063/74-c. 1090), plan after Addiss (based on joint measured survey), overlaid with circles of dimension C and A to illustrate basic plan geometry (drawing: author)

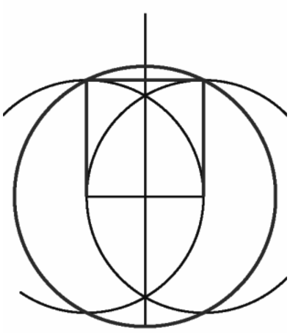

Fig. 6. Construction of a square on the base line in Figure 1 using compass and straightedge: (a) mark off distance of base line along upper extension of the perpendicular; (b) measure from either end of base line to same point on perpendicular to obtain proportion of diagonal of the half square; (c) draw circle of same radius from intersection of base line and perpendicular; (d) use points of intersection on two original circles to complete square with straightedge (drawing: Center for the Study of Architecture)

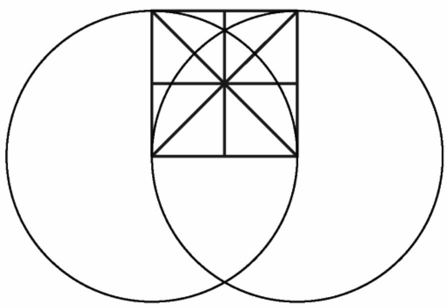

Fig. 7. Illustration of the basic principle of medieval geometry: a bilateral division of form, here of a square (constructed in Figs. 1 and 6), by means of its midpoints, diagonals, and "curved diagonals" (drawing: Center for the Study of Architecture)

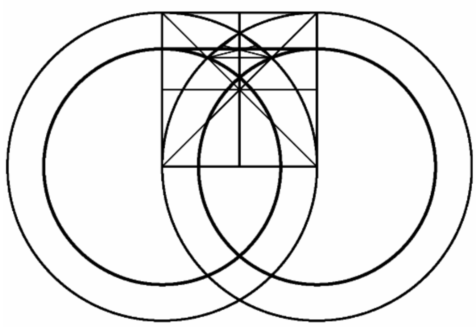

Fig. 8. Derivation of "harmonic" dimensions A and B from a given dimension C: (a) assign circles in Figure 7 the proportion of C; (b) the proportion A will derive from points of intersection between blue circles (radius C) and diagonals of square; (c) draw two concentric red circles of radius A; (d) tangent line to red circles A determines point B on the perpendicular axis line of the square (drawing : Center for the Study of Architecture)

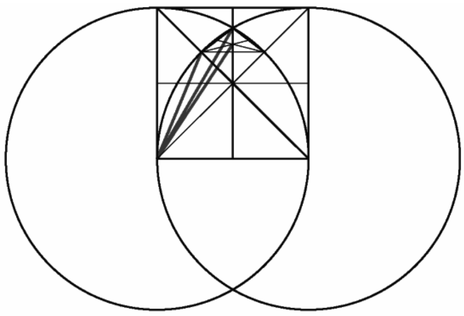

Fig. 9. Simplified illustration of 'harmonic' proportions A, B and C (drawing: Center for the Study of Architecture): C is equal to the radius of the blue circles, the base line of the square, and the side of the equilateral triangle created by this case of Euclid 1.1; C is also the apex of a 105° triangle, whose base is determined by the intersections of the straight and 'curved' diagonals of the square; A is equal to the dimension from the left end of the base line to the left point of the 105° triangle's base (as if this were an x/y graph); B is equal to the dimension from the left end of the base line to the centroid of the 105° triangle (alternate construction method to that seen in Figure 8)

What interests us here is the question whether these three proportions (A, B and C) have an inherent geometric relationship and hence, was there a means of predicting a choice of three "harmonically" proportioned measures? Earlier versions of answers to this question have appeared in the "Latin Euclid" and "Three Measures" articles and most recently in Nexus IV: Architecture and Mathematics.[18] To summarize, we propose that the three measures can be determined directly, using a simple geometric device based on the two flamingos (Euclid's proposition 1.1, Figs. 1, 2). Using the flamingos, construct a square of dimension C (refer to instructions in Figure 6). Bisect the form with remaining midlines and diagonals (Figure 7). The 'curved' and straight diagonals determine point A; a geometric relationship between A and the square determine point B (refer to detailed analysis in Figure 8). An alternate method for determining point B (hence, radius B) is to find the centroid of a triangle described by radius A and radius C (Figure 9). The resulting image is similar to a transverse cut of the church's axial elevation, with transept arms and sanctuary vault (A) lower and to the outside; nave vault at the center (B); and the dome vault at the crossing at the apex of the design (C). Is this a medieval means for predicting a stable three-dimensional solid at large scale? Future research into the history of mechanical physics may help to confirm what remains for now an hypothesis.

If there is a royal road to geometry it begins with Euclid's proposition 1.1. Its importance in the highly innovative design of an eleventh-century church and in the unique thirteenth-century portfolio of Villard serve as evidence for a long-standing tradition of constructive building geometry, itself best understood in the context of the history of applied mathematics—the geometric, gromatic and mechanical engineering traditions—passed on by either oral or written means in a relatively continuous manner in Europe since Antiquity. Within the larger historical framework of traditions in applied mathematics, the Villard portfolio should be recognized as a key monument of practical geometry. As we have seen, study of the drawings reveals a coded use of Euclid, and we may conclude that Villard (and Magister II) were indeed versed in the mechanical arts, through experience if not through theory.

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Acknowledgment

This article is reprinted with permission from "Villard de Honnecourt et la géométrie euclidienne," *Les Sciences au Moyen Âge*, *Pour la Science* [*Scientific American*, French Edition], Dossier (October 2002/January 2003), pp. 108-109. English translation by the author with substantial additional material.

Notes

1. This observation is thanks to Renaud Beffeyte, an expert for ancient and medieval engineering for the department of the Vendée in France, who was trained in the very same oral tradition as Villard de Honnecourt.

2. The first mention of the portfolio (Paris, Bibliothèque nationale, MS fr. 19093, c. 1220/35) dates to 1666. Refer to online bibliography maintained by Villard scholar, Carl F. Barnes, Jr., with continual updates and list of print and online facsimiles, through links at AVISTA (http://www.avista.org).

3. "The science of mechanics…has many important uses in practical life, and is held by philosophers to be worthy of the highest esteem, and is zealously studied by mathematicians, because it takes almost first place in dealing with the nature of the material elements of the universe. For it deals generally with the stability and movement of bodies [about their centres of gravity], and their motions in space…and it contrives to do this by using theorems appropriate to the subject matter. The mechanicians of Heron's school say that mechanics can be divided into a theoretical and a manual part; the theoretical part is composed of geometry, arithmetic, astronomy and physics, the manual of work in metals, architecture, carpentering and painting and anything involving skill with the hands. The man who has been trained from his youth in the aforesaid sciences as well as practised in the aforesaid arts, and in addition has a versatile mind, would be, they say, the best architect and inventor of mechanical devices. But as it is impossible for the same person to familiarize himself with such mathematical studies and at the same time to learn the above-mentioned arts, they instruct a person wishing to undertake practical tasks in mechanics to use the resources given to him by actual experience in his special art." From Pappus, *Mechanics*, viii, Pref. 1-3, ed. Hultsch 1022.3-1028.3, hereafter *Greek Mathematical Works, 2, Aristarchus to Pappus of Alexandria*, trans. Ivor Thomas, Loeb Classical Library (rpt., Cambridge, Mass., and London, Harvard University Press, 1993), pp. 614-21, esp. 615-17.

4. Ibid, p. 619; Vitruvius, *De architectura* 1.1.16.

5. For bibliography, and summary of its relevance to architecture, see Marie-Thérèse Zenner, "Imaging a Building: Latin Euclid and Practical Geometry," in *Word, Image, Number: Communication in the Middle Ages*, ed. John J. Contreni and Santa Casciani, Micrologus' Library 8, ed. Agostino Paravicini Bagliani (Florence, SISMEL, 2002), pp. 219-46, 7 figs. Since that article was written, Menso Folkerts has published an electronic update on medieval Euclid texts entitled "Euclid's Elements in the middle ages:"

(http://www.math.ubc.ca/~cass/Euclid/folkerts/folkerts.html);
full bibliography for Folkerts's work is also available online at
http://www.geschichte.uni-muenchen.de/wug/gnw/personen_folk.shtml.

6. Zenner, "Latin Euclid" (as in n. 5), p. 234, n.71-72. These inscriptions are contemporaneous with the production of the manuscript.

7. Text produced in Regensburg (MS Munich, Bayerische Staatsbibliothek, Clm 14836, fols. 45r-52v); see Zenner, "Latin Euclid" (as in n. 5), p. 234, n. 75.

8. Roland Bechmann, *Villard de Honnecourt. La pensée technique au XIIIe siècle et sa communication*, 2d ed. (Paris, Picard, 1993), p. 320, and p. 321, fig. 200. It would be interesting to determine, based on a study of the inks, whether the two curves, really parabolic arcs, and the two large points were not added at a later date as an *aide-mémoire* for interpreting this animal device. No other drawing in the portfolio is so explicit.

9. Along with bilateral division (hence, symmetry), the concept of rotation was a key element of medieval practical geometry, as illustrated in several mnemonic devices on fol. 19v. For an online facsimile of the Villard portfolio, see
http://www.newcastle.edu.au/discipline/fine-art/pubs/villard/.

10. An excellent photo of the façade may be found online by clicking here. An equally excellent detail of the embracing pair, misidentified as "Justice and Peace," may be found at http://www.art-roman.net/poitiersnd.htm.

11. The straightedge is the geometer's ruler, that is, a ruler without measures to ensure that one works only with proportions. It is more difficult to obtain the same conditions working in a CAD environment.

12. Elements, proposition 6.32: If two triangles having two sides proportional to two sides are placed together at one angle so that their corresponding sides are also parallel, then the remaining sides of the triangles are in a straight line. For online reference to the text of Euclid, see
http://aleph0.clarku.edu/~djoyce/java/elements/elements.html.

13. An earlier foundation on the site was reputedly established by the Irish monk, Saint Columbanus, who was credited as well with the founding of Corbie and St.-Gall.

14. For 3-D modeling of Saint-Etienne in Nevers, taken as an "ideal" Romanesque church type, see
http://perso.wanadoo.fr/fragile/Multimedia/Realisations/NEVERS/NEVERS.html. For a good aerial view, see
http://www.amis-saint-jacques-de-compostelle.asso.fr/c/bo08.jpg.
For interior and exterior detail photographs, see
http://www.art-roman.net/nevers.htm.

15. See Marie-Thérèse Zenner, "Appendix 5: Standard Structural Study," Methods and Meaning of Physical Analysis in Romanesque Architecture: A Case Study, Saint-Étienne in Nevers, PhD. dissertation, Bryn Mawr College, 1994 (Ann Arbor, UMI, 1994, no. 9425215), pp. 370-93, esp. 388-93.

16. Most recently on the Nevers church, see Marie-Thérèse Zenner, "A Proposal for Constructing the Plan and Elevation of a Romanesque Church Using Three Measures," in

Ad Quadratum: The Practical Application of Geometry in the Middle Ages, ed. Nancy Y. Wu, AVISTA Studies in the History of Science, Technology and Art, vol. 1 (Aldershot [England], Ashgate Publishing, 2002), pp. 21-50.

17. The use of the astrolabe for sighting was discussed in the text *Geometria incerti auctoris* (dated before 983). On this see my discussion in "Latin Euclid" (as in n. 5), esp. pp. 230-33.

18. Zenner, "Latin Euclid" (as in n. 5); idem, "Three Measures" (as in n. 16); idem, "Structural Stability and the Mathematics of Motion in Medieval Architecture," in *Nexus IV: Architecture and Mathematics*, ed. Kim Williams and José Francisco Rodrigues (Fucecchio [Florence], Kim Williams Books, 2002), pp. 63-79, with abstract and revision noted in the author's abstract published in the *Nexus Network Journal*, vol. 4, no. 3 (July 2002),
http://www.nexusjournal.com/N2002-Zenner.html.

About the Author

Marie-Thérèse Zenner, an American scholar living in France, specializes in the physical analysis of medieval architecture, viewed within the histories of science and technology and, most recently, the history of mechanics. In 1984, she co-founded AVISTA, an international scholarly society for encouraging interdisciplinary studies of medieval technology, science and art, which sponsors annual sessions at the International Congress on Medieval Studies in Kalamazoo (Michigan), as well as the International Medieval Congress at the University of Leeds, England. The present article joins a series of studies resulting from a Getty Postdoctoral Fellowship (1996-97) on the "sciences of measure" between the times of Vitruvius and Villard. Other recent work includes "Structural Stability and the Mathematics of Motion in Medieval Architecture," in *Nexus IV: Architecture and Mathematics*, ed. Kim Williams and José Francisco Rodrigues (Fucecchio [Florence], Kim Williams Books, 2002), pp. 63-79; with abstract and revision noted in *Nexus Network Journal*, vol. 4, no. 3 (July 2002). Dr. Zenner is editor-in-chief of *Villard's Legacy: Studies in Medieval Technology, Science and Art in Memory of Jean Gimpel*, AVISTA Studies in the History of Science, Technology and Art, vol. 2 (Aldershot [England], Ashgate Publishing, forthcoming in 2003).