

## Functionalism and Caprice in Stonecutting. The Case of the Nativity Chapel in Burgos Cathedral

Miguel Ángel Alonso Rodríguez, Ana López Mozo, José Carlos Palacios Gonzalo,  
Enrique Rabasa Díaz  
Technical University of Madrid, Spain

José Calvo-López  
Polytechnic University of Cartagena, Spain

Alberto Sanjurjo Álvarez  
San Pablo-CEU University, Madrid, Spain

**ABSTRACT:** Starting from the inaugural text of Philibert de L'Orme, stereotomic treatises and manuscripts are subject to the opposing forces of reason and fancy. The Nativity Chapel in Burgos Cathedral provides an outstanding case study on this subject. It was built in 1571-1582 by Martín de Bérriz and Martín de la Haya, using an oval vault resting on trumpet squinches to span a rectangular bay. Bed joints and rib axes are not planar curves, as usual in oval vaults. This warping is not capricious; we shall argue that it is the outcome of a systematic tracing method. As a result of this process, the slope of the bed joints increases slightly in the first courses, but stays fairly constant after the third course; this solution prevents the upper courses from slipping. Thus, in the Nativity Chapel of Burgos Cathedral, the constraints of masonry construction fostered a singular solution verging on *capriccio*. It is also worthwhile to remark that the warping of the joints is not easily appreciable to the eye and that the tracing process does not seem to start from a previous conception of the resulting form. All this suggests that we should be quite careful when talking about the whimsical character of Late Gothic and Early Renaissance; in some occasions, apparent caprice is the offspring of practical thinking.

### FUNCTIONALISM VERSUS CAPRICE IN STONECUTTING

The third and fourth books of *Le premier tome de l'architecture* stand as the first printed text on stonecutting technology. After explaining a number of problems in this field, Philibert de L'Orme includes a strange parable, (L'Orme 1567, 65r - 67r). A gentleman has inherited an old house; a fair number of additions along the centuries have led to a most irregular plan. Wishing to keep the house of his ancestors, but at the same time to enjoy a mansion *à la mode* with a Renaissance symmetrical plan, he engages with remarkable cunning in the regularization of the layout, adding a room here and a belvedere there; in this process, he overcomes the constraints imposed by the existing constructions through the use of a fair number of stereotomical pieces, such as *trompes* or oblique arches.

However, Philibert's practice and his own treatise go much further than this rigid functionalism. He was commissioned to build in a quite constrained corner of the Chateau de Anet a small cabinet, to be used by Henri II during his frequent visits to his lover, Diane de Poitiers. To overcome these restrictions, Philibert placed the whole cabinet over a trumpet squinch and enclosed it within an undulating wall; the cross-section of the intrados surface of the squinch is a surbased arch whose springings rest at uneven heights. Philibert explains in his treatise, with evident delectation, how the niceties of *art du trait* allow him to overcome all these challenges, in part self-imposed by his design choices (L'Orme 1567, f. 88r - 106v; Sanabria 1989, pp. 295-298; Evans 1995, pp. 183-189; Potié 1996, pp. 99-103; Trevisan 1998; Trevisan 2000; Fallacara 2003; Lenz, 2007). Other pieces in Philibert's treatise, such as hemispherical vaults divided by spiral or fan-shaped joints, have no functional explanation and cannot be understood if not as a demonstration of Philibert's masonic cunning; in fact, he boasts about his ability when explaining a vaulted spiral staircase or *Vis de Saint-Giles*. (L'Orme 1567, f. 119r, 123v - 125v; Carlevaris 2000; Rabasa 2003; Calvo et al. 2005, pp. 123-136; Calvo, in press; Sanjurjo, in press).

### Patronal whimsy and masonic pride

Thus, from the very start, stereotomical treatises seem to be subject to the opposing forces of functionality and caprice, reason and whim. In one page, they argue for the utility of skew passages or trumpet squinches to solve planning problems; in the next one, they boast about the cunning of the architect that placed a corner

window just to show his mastery of the art of stonecutting (San Nicolás 1633, f. 69v). Caramuel remarked about a skew arch in the Monastery of La Espina that "the architect designed it not because it was necessary for this place, but to leave a witness of his cunning with an extraordinary piece". (Caramuel 1678, VI-12; see also; Rabasa 1994, p. 152). These displays of virtuosity seem to be fostered by two different factors. Late Gothic and Early Renaissance aristocratic patrons had a strong flair for the rich, the strange and the exotic (Díaz del Corral 1980, pp. 283-284; Díaz del Corral 1992; Calvo et al. 2005, pp. 32; Sobrino 2005; Etlín, in prep.). At the same time that they collected gems, fowls or rhinoceri, they funded the construction of extraordinary masonry pieces. Only this peculiar psychology on the part of both secular and ecclesiastical patrons can explain such pieces as vaults with spiral joints in the vestry of Murcia cathedral and the narthex of the church of San Juan de los Caballeros in Jerez de la Frontera, or the double spirals of the Anet chapel, projected into the pavement. (Potié 1996, pp. 114-120; Rabasa 2003; Calvo et al. 2005, pp. 123-136). It is important to remark that most of these places were not accessible to the public; all this brings to mind the words of the Emperor Charles V when he saw the crossing tower of Burgos cathedral, stating that such a jewel should not be placed in open view, but rather in a case, to see it only at the demands of caprice.

However, patronal whimsy was not the only force driving these displays of virtuosity. Other vaults with spiral joints are placed in even more secluded places, such as tower-stairs in the cathedral of Plasencia or the palacio de los Guzmanes in León and a vault in the church of Santa María La Coronada of Medina Sidonia (Rabasa 2003, pp. 1687-1688; Calvo et al. 2005, pp. 135-136; Sanjurjo and Rabasa, in press); probably they were intended as a demonstration of skill for other masons. Besides, from the mid-sixteenth century on, the posts of master mason in Spanish cathedrals or in the Kings' works were often granted as a result of contest or *oposición*, which invariably brought about a confrontation between professional architects and masons on one side and figurative artists on the other side. These displays of stereotomic ability allowed masons and architects to shine in *oposiciones* and have their way against figurative artists. In the contest for the post of master mason in Granada cathedral held in 1577, Francisco del Castillo, descendant of a well-known family of Spanish masons, but perfectly acquainted with Italian architecture, since he had worked for seven years in the Villa di Pappa Giulio, together with Vignola and Ammanati, stressed his knowledge of stonecutting: "for I know how to ... trace and dress this stone without losing material, ..., making templates ..., cerces, bevells and *saltareglas* and stonecutting tracings that other contenders do not know since they have not put them into practice" (Moreno 1989, pp. 16, 42-44). Later on, masons not only tried to present their stereotomic knowledge as a part of their résumé, but also to include stonecutting exercises in these *oposiciones*, while figurative artists did their best to bring these exercises closer to their field (Blasco 1991, p. 166). In other words, stereotomy played the role of a showcase of the geometrical knowledge of master masons. This explains the presence, both in the *oposiciones* and in actual building practice, of such elaborated building types as corner windows, or quadrant rear arches; Juan de Portor y Castro, when dealing with the *Caracol volado de ojo redondo en una planta cuadrada*, that is, a square-plan stair with a round well, cantilevered from the exterior wall, remarks that this tracing is not frequently used in practice; however, is a fit piece at an *oposición*, and in fact Juan de Aranda Salazar presented it in the *oposición* against Bartolomé de Lechuga that gave him the post of master mason in Granada cathedral, held around 1631 (BNEb, f. 23; see also Galera 1977, pp. 109-110 and Gómez Martínez 1998, p. 38).

## THE NATIVITY CHAPEL IN BURGOS CATHEDRAL

### Foundation and construction of the chapel

On 26 April 1570, the Chapter of Burgos Cathedral concluded an agreement with Ana de Espinosa, widow of Pedro González de Salamanca, concerning the foundation of the Nativity Chapel. With that purpose, the Chapter granted a lease of the chapels of Saint Martin and Saint Giles, allowing Espinosa to demolish the wall between both chapels, provided that neither the pillars nor other walls were damaged; besides, the design of the new chapel was subject to approval by the *fabriquero* and master mason of the cathedral. Also, the founder should provide the chapel with an altarpiece, a grille, a sacristy, choir stalls, organs and funds enough to maintain a main chaplain, four lesser chaplains and two acolytes, all of them appointed by the cathedral chapter. (AHCB a).

A tablet on the chapel wall reads "Anno Dni 1571", indicating quite probably the starting date of actual construction. In fact, on 4 June 1572, Ana de Espinosa signed her last will, confirming the foundation of the Nativity Chapel, and stating her wish to be buried on the *carnero* or crypt of the chapel, which was being built at that moment according to an agreement with the mason Martín de Bériz (AHCB b; AHCB c; Rico 1985, 367). On 14 January 1576, Martín de Bériz won an important contract at the Escorial; along with Juan de la Puente he took charge of the construction of the north tower, on the left side of the narthex of the *basílica* or main church. (ABMSLE a; Bustamante 1994, 434). He could not carry out the commission to the end, since in January 1578 he was dead and the King dispensed his heirs from the obligation to refund the money given to Bériz in order to build the tower. (APSLE a; Bustamante 1994, 497).

On 11 July 1590, an inventory of the ornaments of the chapel was made. On 1 February 1591, the cathedral chapter commissioned Jerónimo de Herrera and Juan de Ochoa Corcuera to visit the chapel; their report makes clear that the chapel was finished and furnished with gold, silver and ornaments (AHCB d; AHCB e; AHCB f). What is more, on 1 March 1592, the chaplain Miguel Martínez presented a full series of accounting

reports for the chapel, spanning the years 1578 to 1590 (ACHB g). These documents include payments to Domingo de Bériz, heir to Martín de Bériz, for his commission as master mason of the chapel. However, Martín de la Haya received a salary for his post as master mason of the chapel from 1578 to the last months of 1582; there are also payments for Hontoria stone along the same period. Thus, Martín de la Haya, seems to have been responsible for the later stages of construction, such as the vault, while Martín de Bériz must have carried on only the beginning of construction, including the crypt and, possibly, the first courses of the walls.

### The vault in the Nativity Chapel

Although the extinct chapels of Saint Martin and Saint Gilles stand at the beginning of the cathedral ambulatory, it is easy to surmise that they had rectangular plans, with their shorter sides along the aisle wall, such as the present-day Main Vestry of the cathedral, which stands at the other side of the presbytery. The union of both chapels gave as a result a rectangular area, with its longer side along the ambulatory wall. The pillar at the intersection of the dividing wall with the aisle wall was of course to be kept, resulting in a double entrance from the deambulatory.

The builders of the chapel choose to span this rectangular plan with an oval vault over a low drum, using four trumpet squinches to solve the transition between the rectangle and the oval. These squinches are decorated with ribbons with *rollwerk* endings and medallions of Saint Augustine, Saint Jerome, Saint Ambrose and Saint Gregory. At first sight they resemble asymmetric trumpet squinches or *pechinas en viaje*, which are fairly common in the literature and the building practice of the period (BNEa, f. 3; Vandelvira c. 1580, f. 8v - 9v; Palacios 1990, pp. 30-31), but in fact the intrados surfaces of the squinches are cones of revolution and the asymmetry only comes as a result of their intersection with the oval cylinder of the drum. Besides, our survey has confirmed that the intersection line is planar, in accordance with the theory of quadric surfaces.

Over these squinches, the drum supports an oval cornice. The actual oval vault springs from this cornice; it is decorated by radial ribs and four rich panels of the Evangelists. However, careful inspection of these coffers, or a photograph taken from the centre of the chapel floor, show that the ribs which divide the vault into coffers are warped and do not follow vertical planes, as usual in coffered vaults, such as the ellipsoidal vault in the Seville chapter hall. Although this feature seems at first sight capricious, we should take into account that this layout allows the ribs to meet the bed joints at approximately right angles, preventing dents in voussoir edges. The pillar that was not to be damaged according to the 1570 agreement intersects the cornice and the vault in an awkward manner. An oval oculus gives way to the light that falls from the lantern, which is hexagonal in plan and decorated with a rich lattice, resembling at a lesser scale the well-known vault over the cathedral crossing or *cimborrio* praised by Charles V.



Figure 1: Vault over the Nativity Chapel in Burgos Cathedral; (Photograph by A. Sanjurjo)

### The geometry of the vault

We have carried out a survey of the vault, using a Riegl LMS-Z420I long distance 3D laser scanner to gather point clouds representing the geometry of the intrados surface of the vault, using the coordinates of a number of retro-reflective targets, taken with a Leica TCR 1105 laser total station in order to reference mutually and join these point clouds. Additionally, a number of significant points, such as those on the ribs and joints, have been taken manually using the total station.

The intrados surface of the vault measures 10.2 m long, 7.2 m wide and 4.0 m high. It is not easy to put forward a simple geometrical model of this surface, such as an ellipsoid or a surface generated by the revolution of an oval, since the ribs which divide it stand below the coffers, and besides, the panels of the Four Evangelists make the tracing of straightforward longitudinal and transversal sections quite difficult. However, it will not be essential to our reasoning to ascertain the exact nature of the surface; as we will see, most probably the vault tracing was based in a number of control points.

The survey puts into evidence a number of unusual facts. The apparent bed joints are not horizontal lines, but rather warped curves, with their highest points placed along the longitudinal axis of the vault, as the longitudinal section and the transversal section in Fig. 6 show clearly. These warped curves are fairly symmetrical about both planes of symmetry of the vault, longitudinal and transversal; thus, the warping of the bed joints does not seem to be caused by movements of the vault nor from settlements of the foundations.

Other details suggest that the warping of the bed joints is intentional. If all the points that represent bed joints in the survey are rotated along a vertical axis and brought to the same plane, they are fairly collinear, as shown by Figs. 3 and 4; in fact, considering separately each quadrant of the vault, the colinearity is almost perfect. That means that the apparent bed joints are placed at the intersection of a number of cones of revolution with the intrados surface of the vault. This leads us to think that bed joints are surfaces generated by the rotation of a straight line around a vertical axis, although of course this cannot be checked without dismantling the vault. The masons could have used a *cintrel*, that is, a rope or wooden bar attached to a central pole placed at the vertical axis of the vault, to control the shape of the bed joints (Fig. 5).

Besides, the slope of the generatrices of the cones increases slightly in the first courses, but stays fairly constant after the third course. If the vault was built without a strong centering, this limitation of the slope of the bed joints could have prevented the courses from slipping. However, there is another fact that can explain this strange progression of the bed joint slopes. If we consider the meridian sections that pass through the starting points of the ribs and divide these meridian sections into equal parts, the division points fit into the bed joints within reasonable tolerances. Although this explanation is rather simple, it is not obvious, since the meridian joints are not materialized by the ribs, which are not placed in vertical planes as we have seen.

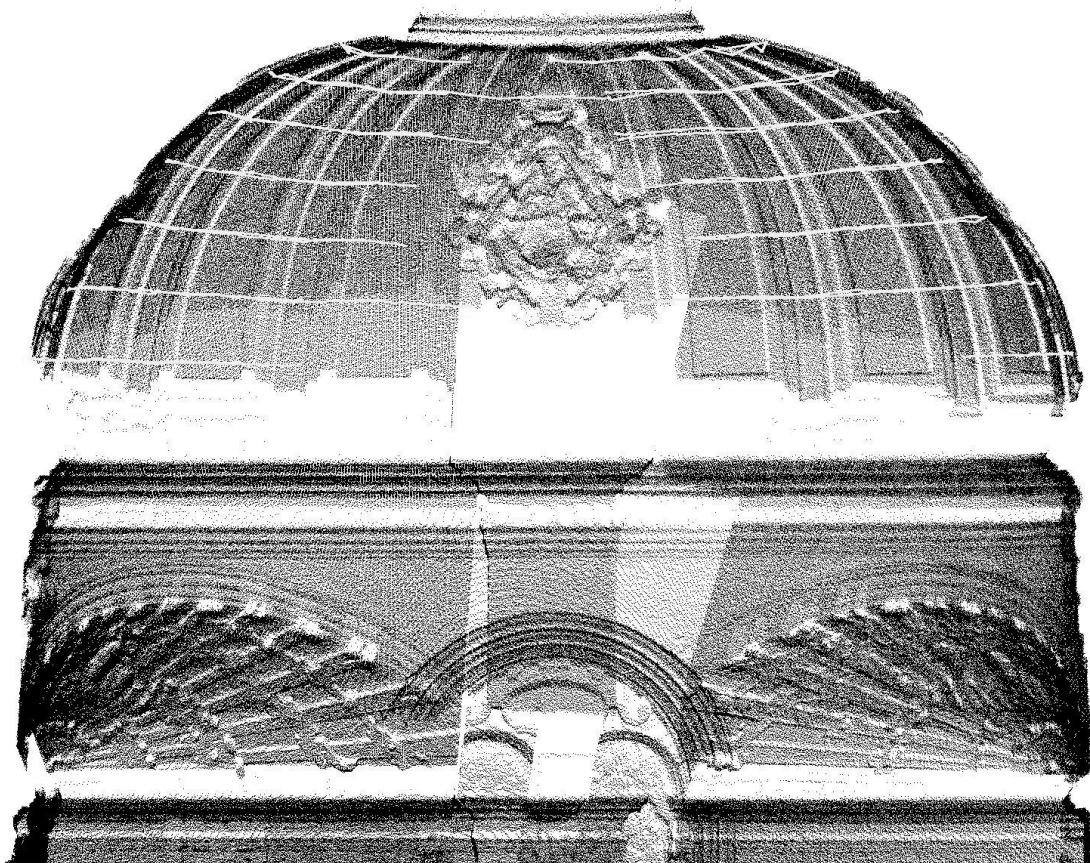


Fig. 2: Point cloud depicting the longitudinal section of the vault over the Nativity Chapel in Burgos Cathedral

### Warped versus planar curves

Thus, the stereotomical solution of the Burgos vault departs clearly from the models for oval or elliptical vaults in sixteenth- and seventeenth-century treatises and manuscripts (Vandelvira c. 1580, f. 72r - 78r; Derand 1643, p. 398-400; Frézier 1737: 2, 400-405). By contrast, it resembles at first sight Gaspard Monge's solution for the National Assembly of the French Revolution (Monge 1795; Leroy [1844] 1877, pp. 254-256, planche 44). Monge devised a solution for a vault whose intrados surface was a half-ellipsoid with three-different axes; that is, an ellipsoid that is not generated by the revolution of an ellipse nor, in fact, any other figure. Besides, Monge added two constraints on the problem: bed joints should be orthogonal to the intrados surface and materialize non-warped surfaces; in geometrical terms, the bed joints in Monge's solution are developable ruled surfaces generated by normals to the intrados surface. As Rabasa has stressed (1996b, pp. 32-34; see also Sakarovitch 1997, pp. 309-313), both constraints are not strictly necessary in terms of stonecutting technique. Orthogonality between intrados and bed joints is advisable, to prevent dents in voussoir edges during the placing process, but of course, strict perpendicularity in each point of the edge is not necessary; a fairly large angle is sufficient. Developable bed joints allow the use of flexible templates in these joints; however, a fair number of stonecutting treatises suggest or imply the use of flexible templates in intrados faces (Gelabert 1653, p. 90; see also Rabasa 1996a, p. 429 and Calvo 2002a, pp. 338-342) but not in bed joints.

Of course, the builders at Burgos surely did not think in such abstract terms as Monge; in fact, their solution departs from Monge's one in some important aspects. To start with, the higher points in the bed joints of the Burgos vault are placed at the longitudinal section, while in Monge's solution they lie on the transversal section. Besides, in Burgos the revolution surfaces in the bed joints generally do not seem to intersect the intrados at right angles; in other words, the need to keep the centering at a minimum has prevailed over the convenience of preventing dents. By contrast, the builders seem to have tried to prevent dents in the edges where each voussoir meets the next one in the same course, playing with the tracing of the vault ribs.

Besides, we have seen that the bed joint surfaces seem to be cones of revolution, which are developable surfaces. However, this trait does not seem to derive from the wish to use flexible templates. As we have seen, Spanish stonecutting manuscripts use flexible templates based on cone developments for the intrados of trumpet squinches and even for hemispherical vaults, substituting cones for portions of the sphere (Vandelvira c. 1580, f. 60v-61v; Rabasa 1996a, p. 429-431); however, they do not use cone developments for bed joints, that were usually dressed with a square with a curved arm, the *baivel*. Thus, the cones in the bed joints of the Burgos vault seem to be connected with another instrument, the *cintrel* or wooden bar use to dress the voussoirs before their placement and also with a desire to simplify tracing procedures, as we shall explain in the next section.

### A hypothetical tracing for the vault

Thus, no stonecutting treatise or manuscript, nor any tracing or written description, gives a hint about the tracing method used by the vault builders. However, the geometry of the vault offers enough grounds to put forward a hypothesis about these tracing procedures. Fig. 3b shows points from the apparent bed joints transferred to a meridian plan by means of a rotation around a vertical axis. As a result of this operation, all points from the same joint are collinear, that is, they are placed over the same straight line. Thus, the apparent bed joint, although warped, belongs to an inverted cone of revolution. Quite probably, the actual joint surface, starting from this line and going into the interior of the masonry, is also a part of this cone, although of course we are unable to check this fact empirically.

The horizontal projections of the apparent bed joints are a number of fairly similar ovals or ellipses; in this case, it is not easy to ascertain which kind of curve was used in the tracing process, since it is possible to construct an oval which fits quite closely an ellipse of the same proportion between axis lengths. Besides, Renaissance masons used both four-centre ovals and a number of affinity-based constructions which furnish points of an ellipse (Dürer 1525, C3v; Serlio 1545, pp. 13v-15r, 17v-18v; Calvo 2002b; Huerta 2007, pp. 222-233; Alonso et al., in prep.). Thus, the apparent bed joints can be understood as intersections of oval or elliptic cylinders with the inverted cones of revolution.

Taking all this into account, we can put forward a hypothesis for the design and execution process (Figs. 3 and 4). As a first step, the base line can be traced in plan, either as a four-centre oval or by means of an affinity-based construction. After doing this, we have constructed a cross-section and a longitudinal section, dividing each of them in an equal number of parts, leaving aside the oculus of the lantern. Once this is done, we have brought these divisions to the plan, in order to determine the axes of the ovals or ellipses which represent the horizontal projections of the joints. The result of this operation is a series of almost exactly similar ovals or ellipses. If we transfer both sections of the vault to the same vertical plan, by means of rotation (Fig. 3c), the lines that join the division points furnish the slopes of the cones of revolution.

This diagram, joining the longitudinal and transversal sections of the vault in the same plane, furnishes a method to determine the spatial location of any point of the warped lines, in combination with the plan (Fig. 4). Taking the position of the point from the plan, it can be rotated around a vertical axis in order to transfer it to a frontal plane; then, the point can be brought to the elevation and raised to the slope line that corresponds to each bed joint, in order to determine its height.

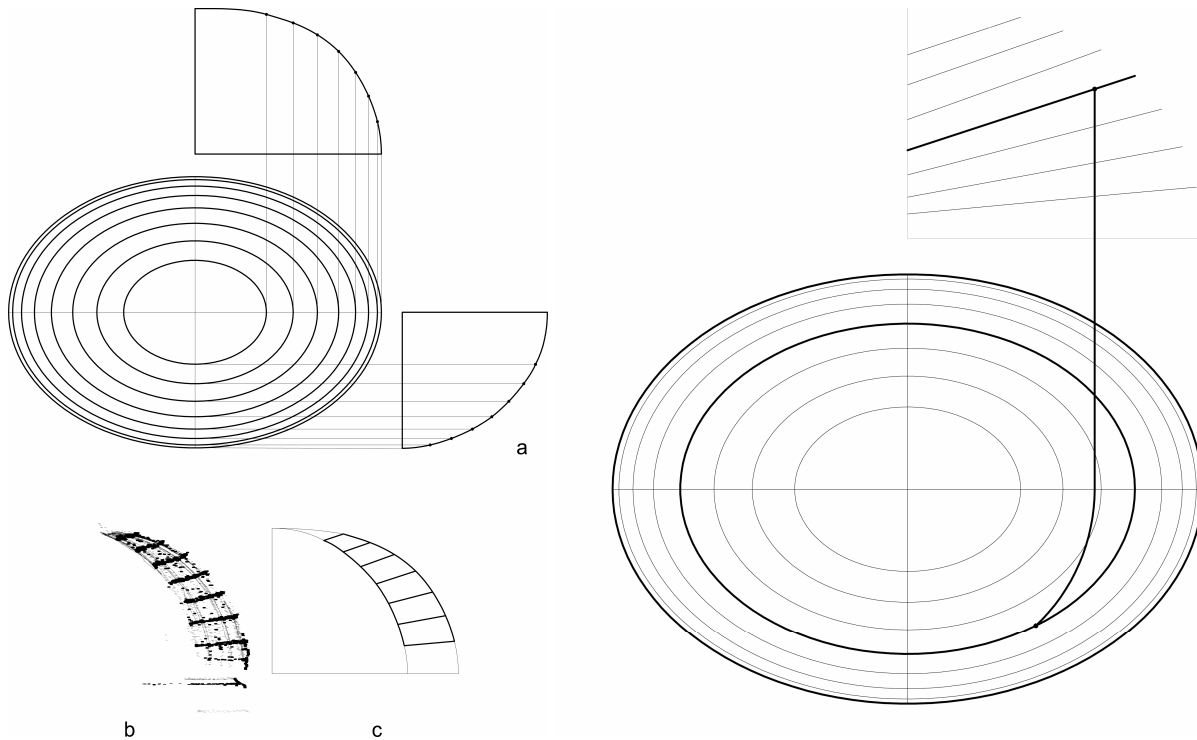


Figure 3 (left): Construction of the horizontal projection of the bed joints; (Drawing by E. Rabasa)  
 Figure 4 (right): Determining the spatial positions of voussoir corners; (Drawing by E. Rabasa)

This procedure is quite appropriate for the Burgos vault, since the vault coffers are not placed along meridian planes. Besides, this operation can be carried on physically, using a *cintrel* and a plumb line; the *cintrel* can be used also to check the dressing of the bed joints. Thus, this method can be used to control the execution in place and, at the same time, to determine the spatial position of each corner of the voussoir. Using these locations, the mason can compute the distances between voussoir corners, and construct a template for the intrados face of the voussoir (Vandelvira c. 1580, f. 75 r.; Palacios 1990, pp. 172-173).

We have carried on this process graphically; the result, shown in Fig. 6, includes a series of warped lines which resemble clearly the actual lines in the vault. In spite of the presence of sculptures and the projecting cornice, that do not allow determining exactly the geometrical shape of the vault, in particular the plan and the longitudinal and transversal sections, the result of our hypotheses fits closely the points gathered in the survey. The entire process is independent from the nature of the starting lines, either elliptical or oval. In fact, it is not easy to put forward any hypotheses for the shape of the longitudinal and transversal sections. Probably they do not meet in a point at the top of the vault; of course this is not a problem, since this area is taken by the lantern. All this leads us to think in the design process for the vault strictly as a method for the spatial placement of points and lines, which does not start from the conception of a prior geometrical shape for the whole member; in particular, the process does not involve the pre-conception of an ellipsoid, an idea that was not known in the period.

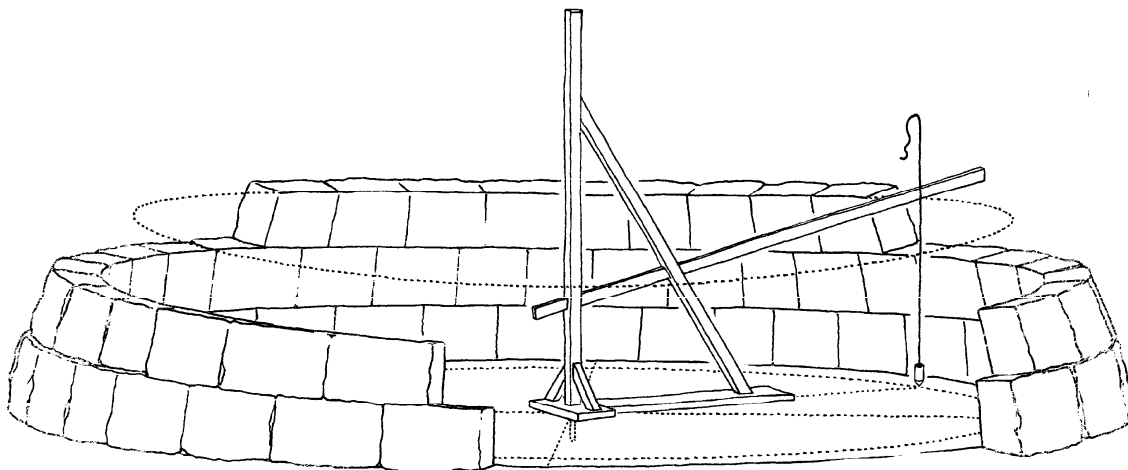


Fig. 5: Determining the spatial positions of voussoir corners and controlling placement; (Drawing by E. Rabasa)

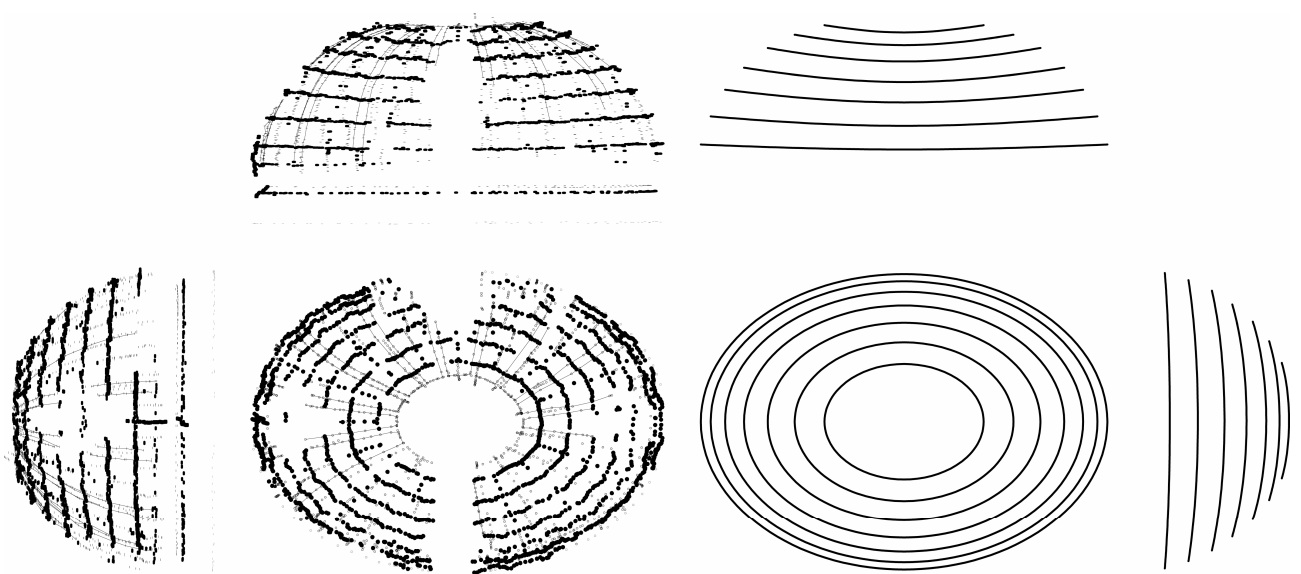


Figure 6: Comparison with the actual geometry of the vault; (Drawing by E. Rabasa)

## CONCLUSIONS

Thus, in the Nativity Chapel of Burgos Cathedral, the constraints of masonry construction - the convenience of limiting the slope of the bed joints and, at the same time, keeping voussoir faces as orthogonal as possible - fostered a singular, idiosyncratic solution verging on *capriccio*. This explains two remarkable traits of the vault and its tracing process. First, the warping of the joints is not easily appreciable by the naked eye. Second, the intrados surface does not seem to correspond with a clear-cut geometrical form, such as an ellipsoid or a surface generated by the revolution of an oval shape, but is rather the result of a "blind" process that does not envisage the final form. If there is any whimsy here, it belongs to the tracing process, as in so many Late Gothic examples, and not to a pre-conceived result.

These practices should be added to the sources of strange stonecutting solutions outlined at the beginning of this paper. Thus, apparent caprice can be the result of patronal whimsy, as in the chapel of Anet or the Murcia and Jerez spiral vaults; of masonic pride and desire for self-promotion, as in Plasencia and León vaults and the Granada *oposiciones* of 1577 and 1631 and many others; of the constraints of actual working-site problems, as in the Burgos chapel; and of the desire to find a practical application for an abstract mathematical result, as in Monge's ellipsoid. Of course, all these factors can be intermingled. At the Anet vault, patronal whimsy combines with typically Philibertesque boasting; the curved ribs in the Burgos vault prevent dents when placing the voussoirs, but can be explained at the same time as an expression of exotic richness, right below and a few decades after the jewel of Charles V. All this suggests that we should be quite careful when talking about the whimsical character of Late Gothic and Early Renaissance; in some occasions, apparent caprice is, at least in part, the offspring of practical thinking.

## REFERENCES

- Alonso et al., in prep.: Transformations of the Circle, Parallel Projections and Revolution Surfaces in Early Modern Stonecutting Literature and Practice.
- Bustamante, A., 1994: *La octava maravilla del mundo*. Madrid: Alpuerto.
- Blasco, B., 1991: Sobre el debate entre arquitectos profesionales y arquitectos artistas en el Barroco Madrileño. Las posturas de Herrera, Olmo, Donoso y Ardemans. *Espacio, Tiempo y Forma. Serie VII*. 4, pp. 159-194.
- Calvo, J., 2002a: Superficies regladas desarrollables y alabeadas en los manuscritos españoles de cantería. In *IX Congreso Internacional de Expresión Gráfica Arquitectónica*, A Coruña, pp. 313-318.
- Calvo, J., 2002b: La semielipse peraltada. *Arquitectura, mecánica y geometría en las últimas décadas del siglo XVI*. In: *El Monasterio del Escorial y la arquitectura*, El Escorial: Instituto Escorialense de Investigaciones Artísticas e Históricas, pp. 417-345.
- Calvo, J. et al., 2005: *Cantería renacentista en la catedral de Murcia*. Murcia: Colegio de Arquitectos.
- Calvo, J., in press: "La literatura de la cantería". In: Palacios, J. C. and Sanjurjo, A. (eds. : *El arte de la piedra*, Madrid: Universidad San Pablo-CEU.
- Carlevaris, L. 2000: Le volte di de l'Orme. Problemi di ricostruzione di alcuni Traits. In: Migliari, R. (ed): *Il disegno e la pietra*, Roma: Gangemi, pp. 81-92.
- Caramuel, J., 1678: *Arquitectura civil recta y obliqua ...* Vigevano: Episcopal Press.
- Díez del Corral, R., 1980: Lorenzo Vázquez y la casa del Cardenal ... *Mendoza. Goya* 155, pp. 280-285.
- Díez del Corral, R., 1992: *Arquitectura y magnificencia en la España de los Reyes Católicos*. In: *Reyes y Mecenas ...*, Madrid: Ministerio de Cultura, pp. 55-78.
- Dürer, A., 1525: *Underweysung der messung mit dem zirkel und richtscheyt ...* Nuremberg: s. n.
- Etlin, R., in prep.: *La Stéréotomie française : la généalogie d'une architecture acrobatique*.
- Evans, R., 1995: *The projective cast*. Cambridge, Mass.: MIT Press.

- Frézier, Amédée-François, 1737-1739: *La théorie et la pratique de la coupe des pierres ... ou traité de stéréotomie ...* Strasbourg-Paris: Jean Daniel Doulsseker-L. H. Guerin.
- Fallacara, G., 2003: The formal unity of aerial vaults texture: The 'trompes'... In: Huerta, S. (ed): *Proceedings of the First International Congress on Construction History*, Madrid, pp. 839-850.
- Derand, F., 1643: *L'architecture des voûtes ...* Paris: Sébastien Cramoisy.
- Galera, P., 1977: *Arquitectura de los siglos XVII y XVIII en Jaén*. Granada: Caja de Ahorros.
- Gelabert, Joseph. 1653: *De l'art de picapedrer*. (Ms. in the library of Consell Insular de Mallorca. Facsimile ed. 1977, Palma de Mallorca, Diputación de Baleares).
- Gómez Martínez, J., 1998: *El gótico español de la Edad Moderna. Bóvedas de Crujería*. Valladolid: Universidad de Valladolid.
- Huerta, S., 2007: Oval Domes. History, Geometry and Mechanics. *Nexus Network Journal* (9) 2, pp. 211-248.
- L'Orme, Ph. de, 1567: *Le premier tome de l'architecture*. Paris: Féderic Morel.
- Leroy, Ch.-F.-A., 1844: *Traité de stéréotomie comprenant les applications de la géométrie descriptive a la ... coupe des pierres ...* Paris: Bachelier, Carilian-Goeurt et Dalmont.
- Lenz, M., 2007: The squinch of Anet. In Nowacki H. and Lefevre W. (eds): *Creating shapes in civil and naval architecture*, Berlin: Max-Planck-Institut für Wissenschaftsgeschichte, pp. 159-175.
- Monge, G., 1795: Stereotomie. *Journal de l'Ecole Polytechnique* 1, pp. 1-14.
- Moreno, A., 1989: *Los Castillo, un siglo de arquitectura en el Renacimiento andaluz*. Granada: Universidad.
- Palacios, J. C., [1990] 2003: *Trazas y cortes de cantería en el Renacimiento Español*. Madrid: Munilla-Lería.
- Potié, Ph., 1996: *Philibert de l'Orme*. Marseille: Parenthèses.
- Rabasa, E., 1994: Los arcos oblicuos en la traza de cantería. *EGA* 2, pp. 145-163.
- Rabasa, E., 1996a: Técnicas góticas y renacentistas en ... las bóvedas de crujería españolas del siglo XVI. In: *Actas del Primer Congreso Nacional de Historia de la Construcción*, Madrid, pp. 145-153.
- Rabasa, E., 1996b: Arcos esviados y puentes oblicuos. El pretexto de la estereotomía en el siglo XIX. *OP* 38, pp. 18-29.
- Rabasa, E., 2003: The single coursed ashlar vault. In: Huerta, S. (ed): *Proceedings of the First International Congress on Construction History*, Madrid, pp. 1679-1689.
- Rico, M., 1985: *La Catedral de Burgos, patrimonio del mundo ...* Vitoria: Heraclio Fournier.
- San Nicolás, F. L. de, 1633: *Arte y uso de Arquitectura*. s. l.: Imprenta de Juan Sánchez.
- Sakarovitch, J., 1997: *Epures d'architecture*. Basel-Boston-Berlin: Birkhäuser.
- Sanabria, S. L., 1989: From Gothic to Renaissance Stereotomy. *Technology and culture* (30) 2, pp. 266-299.
- Sanjurjo, A. and E. Rabasa, in press, *Detalles y soluciones singulares en la iglesia de Medina Sidonia*, Medina Sidonia, Ayuntamiento de Medina Sidonia.
- Sanjurjo, A., in press: *La Vis de Saint-Gilles : analyse du modèle dans les traités de coupe des pierres et de son influence sur les traités espagnols de l'âge moderne*. In: Sakarovitch, J., et al., (eds): *Premier congrès francophone d'histoire de la construction*.
- Serlio, S., 1545: *Il primo libro d'architettura ... Le premier livre d'architecture*. Paris: Iehan Barbé.
- Sobrinó, M., 2005: Leoneras medievales. *La aventura de la Historia*, 78.
- Trevisan, C., 1998: Le proporzioni nascoste nel trait della trompe di Anet. *Disegnare Idee Immagini* 16, pp. 59-66.
- Trevisan, C., 2000: "Sulla stereotomia, il CAD e le varie trompe d'Anet". In: Migliari, R. (ed): *Il disegno e la pietra*, Roma: Gangemi, pp. 27-53.
- Vandelvira, A., c. 1580: *Libro de trazas de corte de piedras*. (Ms. in the library of the Madrid School of Architecture. Facsimile ed. 1977, with transcription by G. Barbé. Albacete: Caja Provincial de Ahorros)

Archivo Histórico de la Catedral de Burgos (AHCb):

- AHCb a: Volumen 39, ff. 759-761  
 AHCb b: Volumen 20, ff. 607-620  
 AHCb c: Volumen 20, ff. 623-631  
 AHCb d: Volumen 20, ff. 780-783  
 AHCb e: Volumen 20, ff. 598  
 AHCb f: Volumen 20, ff. 599-606, 657-769  
 AHCb g: Volumen 20, ff. 731-763

Archivo de la Biblioteca del Monasterio de San Lorenzo de El Escorial (ABMSLE):

- ABMSLE a: V-4, ff. 118-123

Archivo General de Palacio. Patrimonio Nacional. San Lorenzo de El Escorial (APSLE):

- APSLE a: Leg. 1829

Biblioteca Nacional de España. Madrid (BNE):

- BNE a: Ms. 12.686, ascribed to Pedro de Albiz, c. 1540  
 BNE b: Ms. 9114, by Juan de Portor y Castro, 1708.

## ACKNOWLEDGEMENTS

This paper is part of a research project funded by the Ministry of Science and Innovation of Spain (BIA 2006-13649). The authors wish to express their gratitude to Richard Etlin for his kind comments, to the Chapter of Burgos Cathedral for their cooperation during the survey of the vault and to the staff at the Historic Archive of the cathedral for their help during our archival research.