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CONFERENCE PAPER

About the Sources of the Vaults of San Lorenzo in Turin

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Abstract
This contribution deals with the late 17th century baroque church of San Lorenzo in Turin, designed by Guarino Guarini; it discusses the geometry and possible sources of the vaults of the church, including stellated polygons, raised oval arches and conical approximations to the oval intrados of these arches.

Keywords Guarino Guarini · San Lorenzo in Turin · Stellated polygons · Raised oval arches · Conical developments · Ribbed vaults

Introduction

Guarino Guarini's ribbed vaults in San Lorenzo in Turin have been connected with Islamic sources. This has led to the hypothesis of a trip to Lisbon when building Saint Mary of the Divine Providence in Lisbon. Lately, this idea has been discarded when the date of the Portuguese church has been put back to the 1680s.

Further, the connection with Islamic sources relies almost exclusively in visual observation from the church floor. By contrast, the vertical layout of San Lorenzo, although clearly shown in Guarini's *Dissegni di architettura civile ed ecclesiastica* (1686), and the intrados surface of the ribs, have not been taken into account, except for a study by Marco Boetti (2006).

In this contribution, I will deal with some possible sources of Guarini's design, starting from the planar layout of the ribs, their shape, and the nature of the intrados surface, which is conical rather than cylindrical, as pointed by Boetti.

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The Research

a. Plan layout.

The vaults of San Lorenzo in Turin have been connected with Islamic architecture, taking into account that ribs do not cross at the centre of the plan, a usual feature of Muslim domes. In San Lorenzo and some Islamic examples, such as the vaults over the *maqsura* in the mosque of Córdoba, as well as the Qubba Ba'adiyn in Marrakesh, the geometry of the vault is based on an octagon, with ribs springing from each vertex of the octagon to both directions. However, in the central dome of the *maqsura* and the lantern of San Lorenzo, ribs go from one vertex to the second next one. Thus, the path of the ribs jumps to the second, the fourth and the sixth vertex and then returns to the starting vertex. As a consequence, the ensemble of the ribs is decomposed in two interlocking squares, a typical motif in Muslim architectural decoration. By contrast, in the vaults at the sides of the *maqsura* (Fig. 1) and the main dome in San Lorenzo (Fig. 2), ribs leap to the third and sixth vertex and then to the ninth one, which is of course the first one after the starting vertex. As a result, the path of the ribs does not decompose into squares or other simple figures.

However, ¿are there other possible, non-Islamic sources for Guarini's rib patterns? Thomas Bradwardine's *Geometria Speculativa*, written in the 14th century and published in 1495, includes two stellated octagons. In the *Octogonus primi ordinis* each side of the octagon is extended until it meets the second next side; the result is exactly the same as the one in the *maqsura* in Cordoba and San Lorenzo's lantern. In the *Octogonus secundi ordinis* (Fig. 3) the sides of the original octagon are protracted until each side meets the third next side, just as the vaults at both sides of the Córdoba *maqsura* and the main dome in San Lorenzo. Also, the vault over the presbytery takes the shape of Bradwardine's *Exagonus primis ordinis*, resulting from the extension of each side of a hexagon until it meets the prolongation of the second next side.

Thus, Bradwardine or other treatises dealing with stellated octagons are a plausible source for the planar layout of the ribs in San Lorenzo. This does not leave Islamic sources completely out of the picture, since Bradwardine was influenced by Al-Kindi, in particular in the field of trigonometry. The reader may object that the Córdoba vaults and others in the Islamic world are actual constructions, while Bradwardine's stellated octagons are just simple planar schemes. However, the elevation layout and the intrados surfaces in Turin have little in common with these Islamic vaults, as we will see in the next sections and thus the similarities between San Lorenzo and Muslim vaults are restricted to the planar layout.

b. Elevation layout.

In the section of the church included in *Dissegni* … (Guarini 1686: 11), some ribs are placed obliquely, as a result of the octagonal geometry, and thus are deformed in the elevation. However, two ribs are parallel to the projection plane of the elevation, and thus are shown in true form. This makes clear that all ribs in the main dome are raised

Fig. 1 Córdoba, Mosque, side vaults over the maqsura. 961–976

arches (Fig. 4). The tangents at the start of these arches are approximately vertical, but it is not easy to tell whether they are oval or elliptical.

Raised elliptical or oval arches, in contrast with surbased or pointed ones, are not frequent. However, François Derand, pointed out as an essential source for Guarini's stereotomy by La Greca (Guarini, Carboneri and La Greca 1968: 289–290, note 1) includes them in his treatise, in particular for rectangular groin vaults. In this kind of vaults, if all perimetral arches are round ones, the keystones of the short side arches are placed below the keystones of the long side ones, and the simple usual solution for groin vaults, involving cylindrical surfaces, cannot be used. Derand solved this problem in the Parisian church of Saint-Paul-Saint-Louis laying out the short side arches as raised oval ones (Fig. 5). He included this solution in his treatise, using also raised oval arches when illustrating a buttress-dimensioning rule, showing that pointed and oval raised arches require less buttressing that round or segmental arches (1643: 16–17, 329–335).

Fig. 2 Turin, San Lorenzo, main dome. Guarino Guarini, 1670–1696

All this had a precedent in the church of the Jesuit college of La Flêche, built by Étienne Martellange, where Derand had taught Mathematics. Also, there are earlier Spanish precedents for this unusual shape. Raised oval or elliptical arches are used in the Escorial complex in the corridors leading to the main dome. Also, Derand's buttress dimensioning rule is explained, in a slightly different form, in a stonecutting manuscript by Ginés Martínez de Aranda (1986: 46–47). In addition, this author had used surbased and raised oval arches in the reconstruction of the old Cathedral in Cádiz, in order to adjust to the different spans between walls and columns in the old church.

c. Intrados surface.

Another detail sets San Lorenzo vaults apart from Islamic ones. As Marco Boetti (2006) pointed out, the intrados surface of the Turin vaults is conical, while those in Islamic vaults are cylindrical. As a result, the intersections between intrados sur-

Fig. 3 *Octagonus secundi ordinis*. Bradwardine, 1495

faces are smooth, while their counterparts in Islamic examples show hard and neat intersections.

Where did Guarini take this idea from? Derand (1643: 354–357) offers an efficient procedure to control the form of the voussoirs of hemispherical domes, in particular their intrados surfaces. Since the sphere is a non-developable surface, he substitutes cone frustums for spherical areas between two parallels, that is, vault courses. Next, he offers a similar solution for an oval or elliptical surbased vault (1643: 358–359). In these standard solutions, courses are horizontal; however, Derand (1643: 360–381) furnishes a number of alternative solutions with vertical courses, again substituting cones for spherical areas. Guarini (1671: 588–589) offers similar solutions for complex divisions of the sphere (Fig. 6).

These methods are not Derand's inventions. The idea of substituting cones for spherical areas seems to have originated at the same time in Spain and France during the 16th century. A full-size drawing in the rooftops of Seville Cathedral, dated in 1543–1544 (Ruiz de la Rosa and Rodríguez Estévez, 2011), shows that this

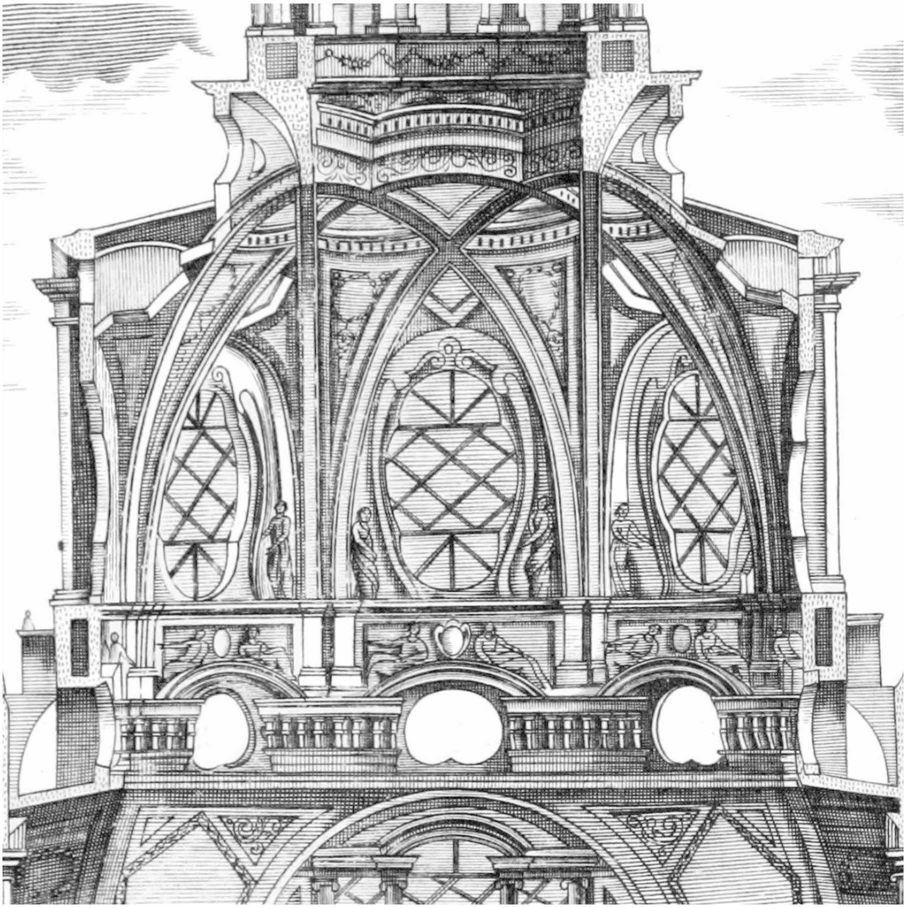

Fig. 4 Section of the church of San Lorenzo. Guarini 1686

technique was used in Spain in this period for simple spherical vaults. Philibert de L'Orme includes it in *Le premier tome de l'architecture* (1567: 111v-112v, 113r-117), although he starts with a complex example with vertical courses and his explanations are not clear. He uses also cone developments for surbased oval vaults (1567: 117r-118v), although he combines them with squaring, a conceptually simpler stonecutting procedure. In contrast, Alonso de Vandelvira (1977: 2, 71v-78r) relies mainly in templates and cone developments to control the intrados surfaces of oval vaults.

Startingly, this technique was used also for rib vaults. Vandelvira (1977: 2, 96v) applies it to control the shape of ribs. Further, the personal notebook of Alonso de Guardia (see Rabasa 1996: 429–431) uses the cone development method to get templates for diagonal ribs – which of course pass through the centre of the vault – and tiercerons – which do not pass through the centre of the vault. I am not implying that Guarini or Derand knew this obscure manuscript, or even the better known one by Alonso de Vandelvira, but the issue of raised arches suggests that Derand had some knowledge about Spanish stonecutting practice.

Fig. 5 Paris, Saint-Paul-Saint-Louis, nave vaults, detail. François Derand, 1627–1641

Conclusion

The planar layout for the vaults in San Lorenzo seems to derive ultimately from Muslim sources, but rather than direct observation by Guarini of actual Islamic vaults, a transmission through Al-Kindi, Bradwardine or other sources seems more likely. While the planar layout of the Turin vaults resembles closely Islamic ones, in particular the ones over the *maqsura* in the mosque of Córdoba and the neighbouring areas, the elevation layout and the intrados surface depart clearly from these particular Islamic examples.

The raised arches seem to derive from Derand, although there are a number of precedents in the Jesuit college of La Flêche, Cádiz old cathedral and the corridors in the Escorial. The use of conical developments for spherical and ellipsoidal surfaces is common in French and Spanish stonecutting manuscripts, in particular Derand and Vandelvira; also, it is applied by Vandelvira and Guardia to ribbed vaults.

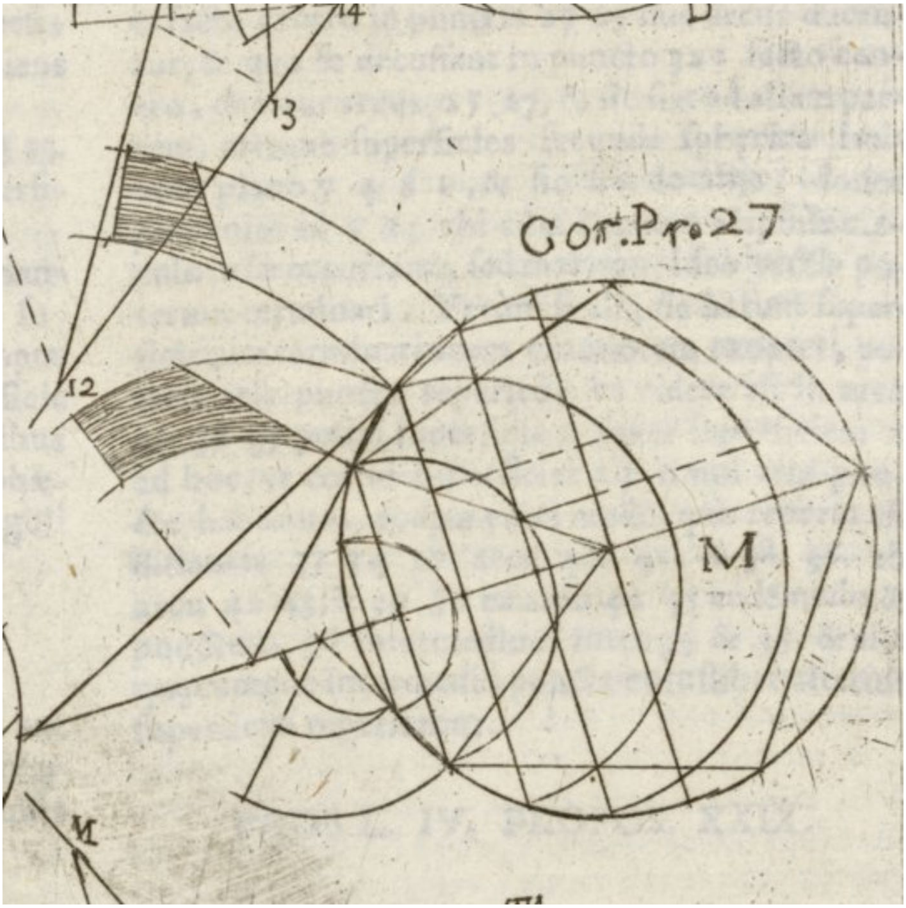

Fig. 6 Computing the intrados shapes of spherical vaults using cone developments. Guarini 1671

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Declarations

Conflict of Interest The single author states that there is no conflict of interest.

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José Calvo-López has a degree in architecture from the Universidad Politécnica de Madrid and his PhD dissertation was awarded the Extraordinary Doctoral Prize in 2002. He is currently Full Professor at the Universidad Politécnica de Cartagena and former Dean of the School of Architecture and Director of the Masters' degree in Architectural Heritage. He has published research papers on stereotomy, bricklaying, spatial representation, and architectural proportion. He has been a Visiting Professor at Università IUAV and has participated in seminars or given lectures at the Max-Planck-Institut für Wissenschaftgeschichte, Centre Alexandre Koyré (CNRS), Centre d'Etudes Superieurs de la Renaissance (CNRS), Università di Palermo, University of Texas at Austin, Politecnico di Torino, Università di Padova and University of Liverpool. Recent publications include *Stereotomy. Stone Construction and Geometry in Western Europe 1200–1900* for the series "Mathematics and the Built Environment" published by Springer Nature. He is a member of the board of the Spanish Construction History Society, the Editorial Advisory Panel of *Construction History* and the Editorial Board of *Nexus Network Journal*.