

CROSSED-ARCH VAULTS IN LATE-GOTHIC AND EARLY RENAISSANCE VAULTING: A PROBLEM IN BUILDING TECHNOLOGY TRANSFER

P. Fuentes¹, S. Huerta²

Keywords

Rib Masonry Vaults, Building technology transfer, Leonardo, Late-Gothic vaulting

Abstract

Crossed-arch vaults are a particular type of ribbed vaults. Their main feature is that the ribs that form the vault are intertwined, forming polygons or stars and leaving an empty space in the middle. The firsts appear in Córdoba in the second half of the 10th Century. Afterwards, the type diffused through Spain and North Africa, 11th -13th Centuries. These vaults reappear in Armenia in the 13th Century. In the 14th and 15th Century a few examples are found both in England (Durham, Raby) and Central Europe (Prague, Landshut, Vienna). At about the same time, Leonardo da Vinci produced designs for the Tiburio (Ciborium) of Milan cathedral with a cross-arched structure and proposed tests to assess the strength; he also, made use of the same pattern of vault for Renaissance centralized churches. Eventually, the type can be tracked through the 17th (Guarini) and 18th (Vittone) Centuries, until Spanish post war architecture in the 1940-60s (Moya). Some questions arose, which so far, have not been answered. How was it possible that a particular type of vault had such enormous geographical spread? How was it transmitted from Córdoba to the Caucasus? The matter is one of transfer of knowledge, ideas, and technology; it relates both aesthetics and construction.

¹ Polytechnic University of Madrid, paula.fuentes@gmail.com

² Polytechnic University of Madrid, santiago.huerta@upm.es

INTRODUCTION

The extension of the Mosque of Córdoba of the Caliph Al-Hakam the 2nd, was carried out between 962 and 965. Eleven aisles were added to the south wall. The great innovation in this extension was the construction of four lanterns or ciboria covered with vaults. All of them were crossed-arch vaults. These vaults feature arches that don't cross in the center, but they draw a polygon or a star. The first built was the Chapel of Villaviciosa (fig. 1.a), over the former mihrab of Abd-al Rahman the 2nd. The other three vaults were built in the maqsura, before the new mihrab. They follow a symmetrical pattern: the central one (fig. 1.b) is different from the other two which have identical pattern. These vaults constitute a completely new type of vault; so far, no precedent has been found. (Besides they are the first ribbed cross-vaults and some authors have seen in them the origin of later Gothic vaults. See, Torres Balbás (1946).) The next examples appear in the 11th Century also in Spain: the mosque of Bab al-Mardum or Cristo de la Luz (fig. 1.c) and the Chapel of Belén (fig. 1.d). In the 12th to 16th Century the type appears not only in Spain, but also in the North of Africa, Armenia, Persia and Mesopotamia. (In the 17th and 18th centuries Guarini and Vittone used them in some of their buildings. Even in the 20th century Luis Moya build them in Spain in the 1940's-1960's.)

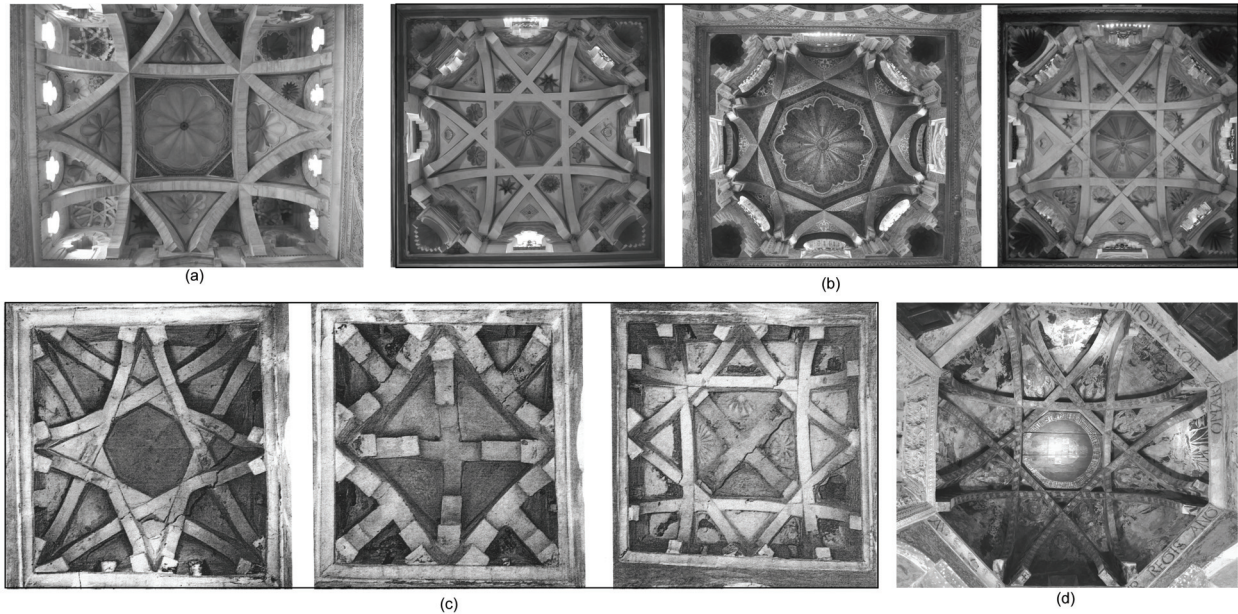


Figure 1: First crossed-arch vaults. Mosque of Córdoba: (a) Chapel of Villaviciosa; (b) Vaults in the maqsura (photo authors). (c) Some vaults in the Cristo de la Luz, Toledo (Ewert 1968). (d) Chapel of Belén, Toledo (photo authors)

The high degree of perfection of Córdoba's vaults both in geometry and construction suggests the existence of previous examples and some kind of evolution, but none has been found so far. Many authors have considered that these vaults are of Eastern origin. But the first crossed-arch vaults in Persia have been dated ca. 1200 a.C., that is more than 100 years after the vaults in Córdoba (fig. 2.a). In any case, their number is quite small in comparison with other types of vault (groined, cloister- or cross-vaults, domes, etc.). Spain is the country with more examples, ca. 40 (for an inventory and monographic study, see Fuentes 2013). Giese-Vogeli (2007) listed ca. 20 in the Islamic architecture. In Armenia the number is similar, around 20, Cuneo (1988) and Fuentes and Huerta (2013). However, these numbers are only tentative, as many vaults were

built in towers, kitchens, chapels and secondary spaces of castles, churches or mosques. Probably, more examples will appear.

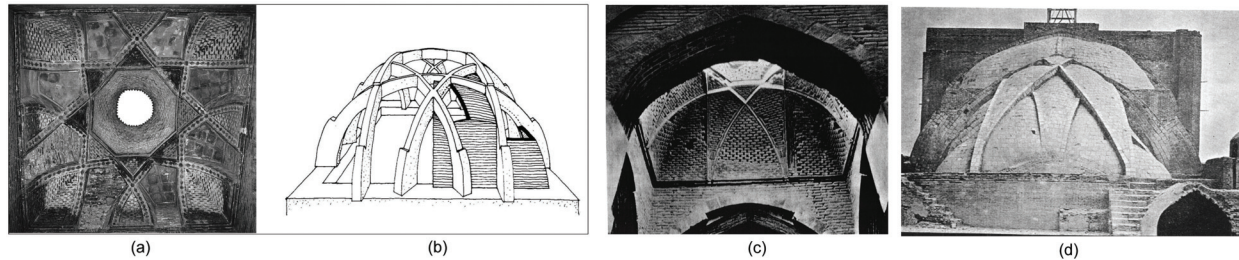


Figure 2: Persian vaults in Isfahan. Isfahan: (a) Vault n°60, the oldest (Pope 1964); (b) Its structure (Galdieri 1981); (c) Crossed-arch vault; (d) Ribs protruding from the extrados of the vault of the great Iwan (Pope 1964)

The transmission of the vault patterns from Córdoba to the Orient through the north of Africa and the Mediterranean sea seems a plausible conjecture. The Mosque of Córdoba was famous in all Islamic countries. The case of Armenia seems different. The similarity of Armenian vaults with the Chapel of Villaviciosa is striking (fig. 3). Until the 1970's the vaults in Armenia were dated ca. 1000 a.C., that is they were thought to be contemporary with those of Córdoba. More recent scholarship place all Armenian crossed-arch vaults after 1200 (for an encyclopedic study, see Cuneo (1988) where all the relevant literature can be found). In a recent book Hanisch (2009) has argued forcefully about the relationship with west Europe and Armenia during the Middle Ages. Hanisch centers his argument on the Armenian influence, but some of the Armenian master masons who worked in the West could have come back to their country and the influence could have existed in both directions.

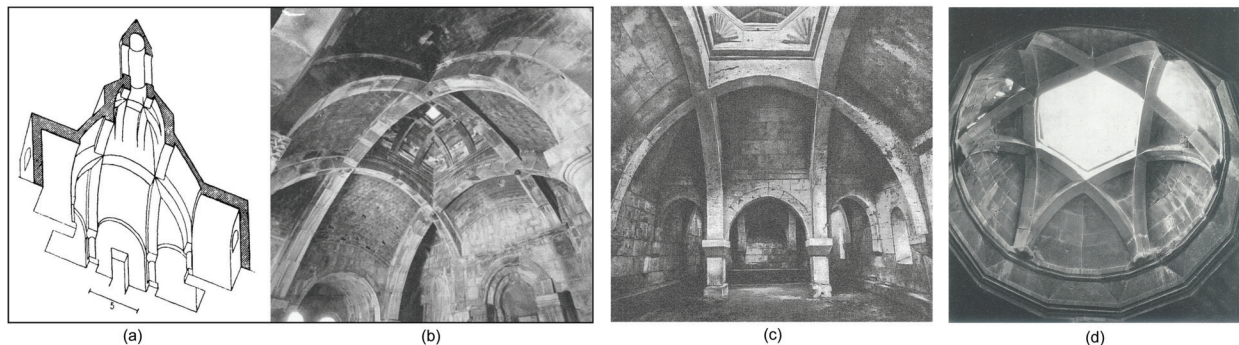


Figure 3: Armenian vaults. (a), (b) Gavit of the church of S. Nšan, Halbat (Choisy 1899; Cuneo 1988); (c) Refectory of Halarcin (Fuentes and Huerta 2013); (d) Xorakerti Vank (Cuneo 1988)

EUROPEAN MIDDLE-AGES

Some very simple examples appear already in the French Romanesque. They appear in secondary spaces, solving particular problems, and they are so rudimentary as to be considered an independent invention. The first covers the first floor of the tower facade of Saint-Michel in Saint-Mihiel (fig. 4.a). The second is in the tower of Saint-Aubin of Angers (fig. 4.b). In Italy, a very singular case is the narthex of St. Evasio in Casale Monferrato, where the four crossing arches cover an enormous space of over 15 m (fig. 4.c). The church is dated in the 12th Century, but the date of construction of the narthex is uncertain, possibly much later (Castelli and Roggero 2001). In this case, both Islamic and Armenian influences are possible.

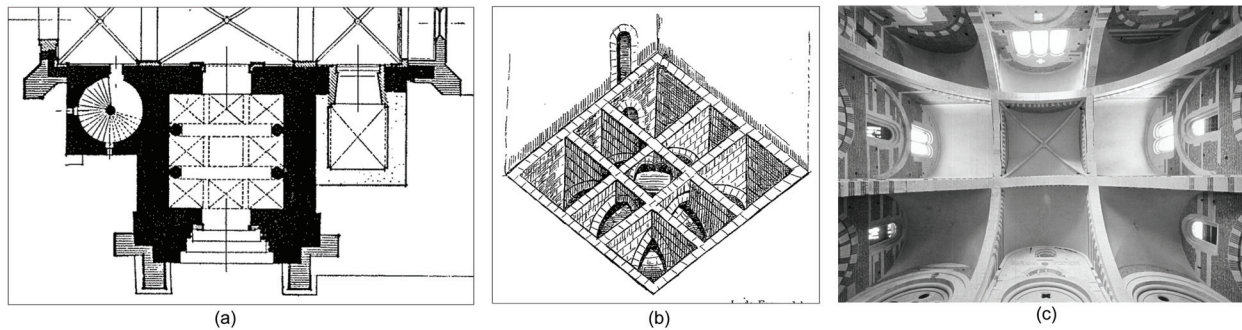


Figure 4: (a) Saint-Mihiel; (b) Saint-Aubin of Angers (Fuentes 2013); (c) St. Evasio (Castelli and Roggero 2001)

Turning now to late Gothic architecture, we may find several examples. In England, John Lewyn, master mason of Durham Cathedral, built two crossed-arch vaults in two kitchens. One is in Raby Castle (fig. 5 c,d) where the vault has only four arches, covering a span of about 9 meters; it follows the pattern of the Chapel of Villaviciosa. The Kitchen of the Dean of Durham (fig. 5 a,b) has 11 meters span, and consists of eight ribs which follow the pattern of the side vaults of the maqsura (fig. 1.b). It was built between 1368 and 1370. Momplet Mínguez (2014) has suggested the possibility that John Lewyn knew the Spanish examples, due to the support provided by King Edward III of England to Pedro I of Castile, after being deposed by Henry of Trastámara. John Lewyn could have travelled to Spain as military engineer and he could have seen the vaults in Córdoba. Lewyn's vaults exerted no influence in English Gothic.

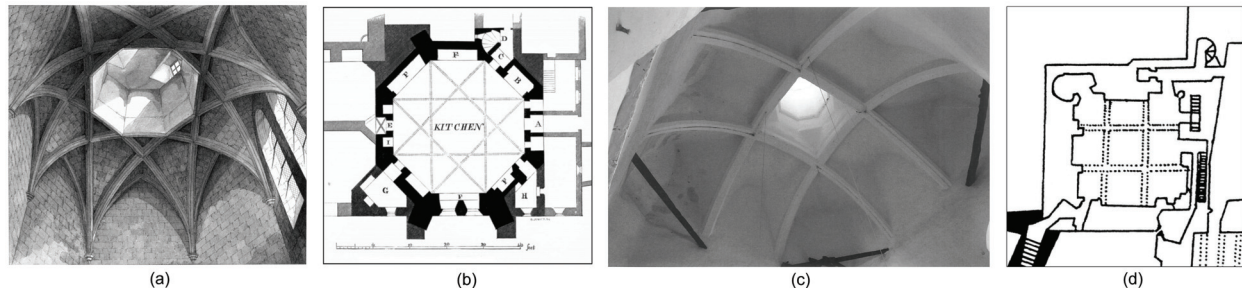


Figure 5: Crossed-arch vaults by John Lewyn. (a), (b) Deanery kitchen in Durham (Hislop 2007); (c), (d) Raby Castle kitchen (Momplet Mínguez 2014)

At about the same time, in the second half of the 14th Century, Peter Parler is called to Prague to continue the work of the cathedral, where he worked until his death. Parler designed several vaults with parallel ribs which do not cross in the middle. After Fehr (1978) he began with the construction of the vaults of the sacristy. However, the main vault of this type is in the Wenzelskapelle (fig. 6 a, b, c), completed in 1367, where the vault covers an square of 10.5 meter side. There, the parallel ribs of the vault form an eight-pointed star; however, the pattern is different from the vault of Durham or those in Córdoba. The ribs cross leaving in the center two squares rotated 45 degrees, one inscribed in another, instead of an octagon. The vault was copied afterwards in the Heiliggeistkirche in Landshut (fig. 6.d) and in the tower of the fortress of Tucharaz, in the Czech Republic. On the possible influences on Parler there are different opinions. Pevsner in 1959 suggested a possible English influence and many authors have followed this theory. Baumüller (1994) disagrees, but recently the possibility of a travel of Parler to the south-west of England has been proposed (Crossley 2003).

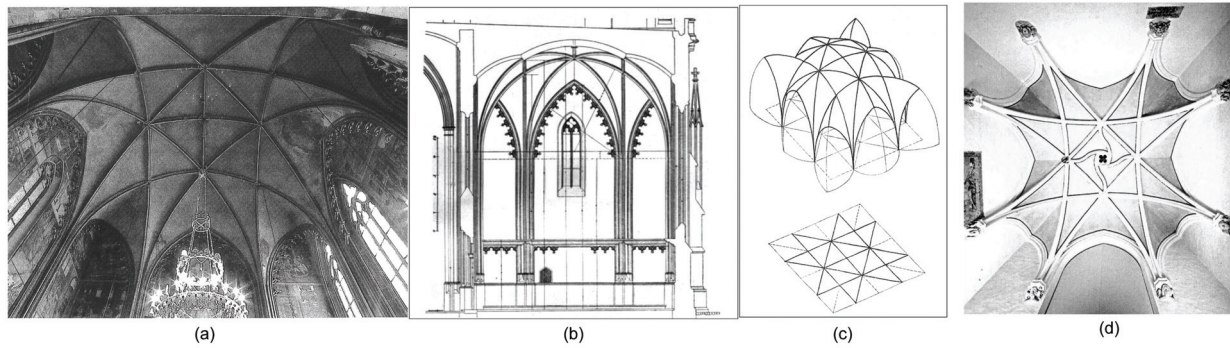


Figure 6: (a) Wenzelskapelle in Prague cathedral (Schurr 2003); (b) Section (Podlaha 1906); (c) Geometric analysis (Mencel 1974); (d) Heiliggeistkirche in Landshut, vault of the sacristy (Látal 2010)

The Wenzelskapelle may have influenced the star vaults which were very common in central Europe in the 15th and 16th Centuries. The most popular pattern builds a regular eight-pointed star as in Córdoba; however, the ribs are interrupted in the middle forming another star (see a few examples in fig. 7). As far as we know, there is only one case which follows the Islamic pattern of Córdoba: one of the vaults of the octagon of the south tower of Vienna Cathedral (fig. 7.g), placed in a place of difficult access. It appears that late-gothic architects dislike the “Islamic” star. There were some exceptions and, around 1500, Hans Hammer and Albrecht Dürer made some sketches of true crossed-arch vaults (Fuentes 2013).

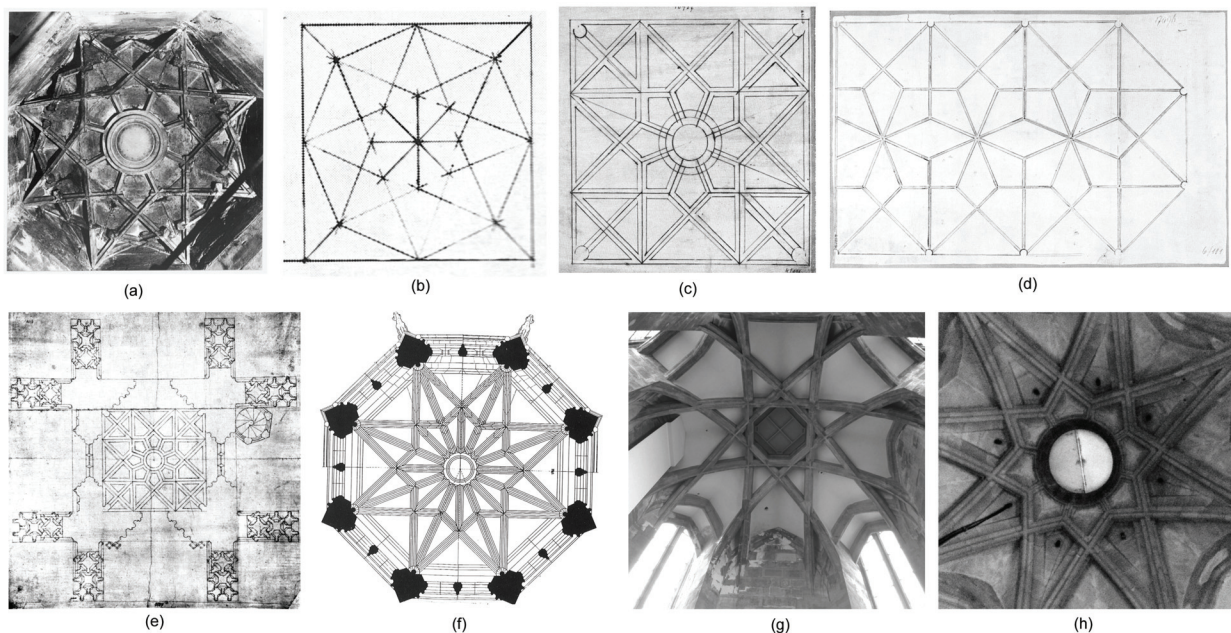


Figure 7: A selection of star vaults based on the octagon. (a) Collegiale Saint Thiebaut; north tower (Fuentes 2013); (b) to (e) Tracings from the Wiener Sammlung (Koeopf 1969); (f) vault of the tower of the Esslinger Frauenkirche (Koeopf 1980); (g), (h) vaults in the octagon of the south tower of Vienna cathedral (photos Cristina Díaz Moreno)

RENAISSANCE

In the late 15th Century, Leonardo da Vinci also showed interest in crossed-arch vaults. According to Torres Balbás (1952), Leonardo would have known the vaults of Córdoba either through Pietro Monti, a Milanese friend who had spent several years there, other through Gonzalo de Ayora, from Cordoba, who spent several years in the court of the Sforza in Milan, and probably met Leonardo da Vinci and Bramante. Among several of Leonardo's manuscript appear several drawings in which he shows interest in different geometric patterns having as basis the eight-pointed star. In some of them is not clear if the star is the projection of a vault, or just a geometric pattern generating the plan, but it has clearly great importance for him as the star appears clearly drawn and sometimes emphasized by thicker lines (fig. 8).

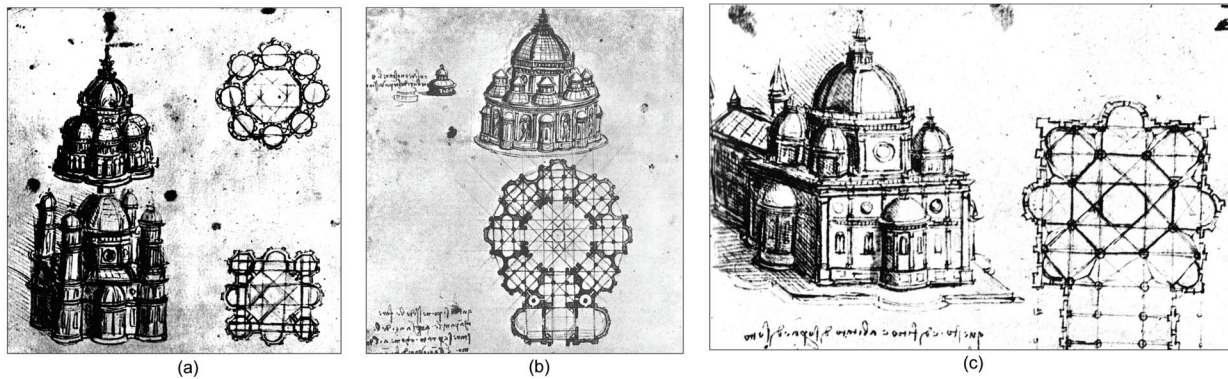


Figure 8: Dome designs by Leonardo using the eight pointed star. (a) Paris Ms. B, f. 25v; (b) Ashburnham Ms. 2037, f. 5v; (c) Paris, Ms. B f. 24r. (Guillaume 1987)

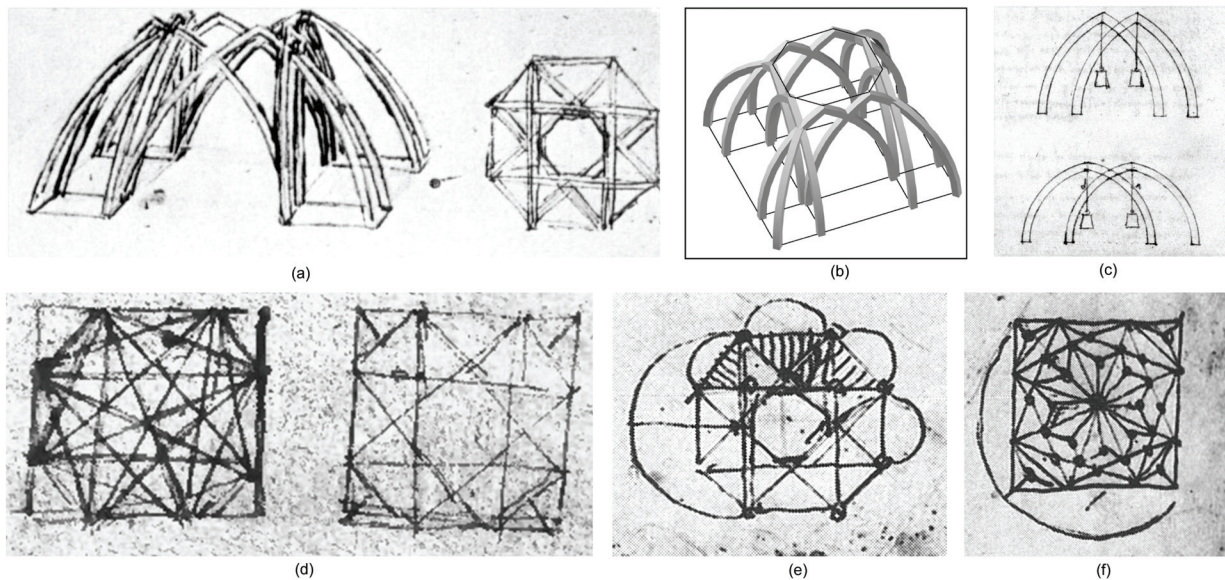


Figure 9: Leonardo's drawings on crossed-arch vaults. (a) Paris Ms. B, f. 27r; (b) Perspective (Fuentes 2013); (c) Codex Madrid, I, fol. 139r; (d) Paris Ms. B, f. 10v; (e), (f) Codex Atlanticus, ff. 223 r-a

Crossed-arch vaults also appear in the designs made by Leonardo for the Tiburio Milan Cathedral. In 1488 various artists presented their projects for the construction of the Tiburio; among

them were Bramante, Pietro da Gorgonzola and Leonardo da Vinci (Fergusson 1977). Although the model of Leonardo is not preserved, yet several drawings are scattered in several Codices. In figure 9.a there are two structures: a perspective drawing and a plan which do not match each other. On the right there is the plan of a crossed-arch vault, with the ribs drawn with their thicknesses. On the left there is a completely original structure of intersecting arches to support the octagon of the Tiburio. The interest of Leonardo on its strength is confirmed by the drawings on figure 9 (c). Figure 9.d shows two sketches for vaults; in the same folio, a text just above says: “a ragion d'una volta, cioè il terzo del diametro de la sua camera del tedesco in domo”. The “tedesco” has been identified as Johannes Mayer by Calvi (1925). Johannes Mayer was a Dominican monk native of Vienna, who according to Marston and Rossi (1982) arrived to Milan in 1483. Soergel (1958) also suggests a relationship with the loggia of St. Stephen's Cathedral in Vienna, where crossed-arch vaults appear in the south tower (fig. 7.g, above). Finally, in fig. 9 (e) and (f) we find two original patterns from Córdoba: the star of eight points (with the arches shown in elevation) and an extremely gothic layout within the two rotated squares of the vault before the mihrab (fig. 1.b).

CONCLUSIONS

- Crossed-arch vaults appear in the Mosque of Córdoba in the 2nd half of the 10th Century.
- This type spread through Spain and North Africa in the 11th Century, eventually reaching Persia and Armenia. The ways of transmission are unknown, but there is abundant evidence of masons travelling from one country to another.
- In England, John Lewyn, seems to be a documented example of this kind of transmission, as there is evidence which support his stay in Spain as military engineer.
- In Central Europe the type has its origin in the creativity of Peter Parler. There is no firm evidence of any contact with Spain or any Islamic country, and, in fact, there is only one example of a true crossed-arch vault, among hundreds which have the same geometric basis. Some architects (Hammer, Dürer) made drawings but it appears that they never built a crossed-arch vault.
- Eventually, in the Italian Renaissance, Leonardo da Vinci showed a great interest in the application of the octagonal star. He used this geometry in plan design, but there is abundant evidence of his intention of building a similar vault for the Tiburio of Milan. There are documents which suggest both influence from Spain and the central European gothic geometric tradition.

REFERENCES

- A Baumüller, B. *Der Chor des Veitsdomes in Prag, die Königskirche Kaiser Karls IV.* Berlin : Gebr. Mann Verlag, 1994.
- Calvi, G. L. 1925. *I manoscritti di Leonardo dal punto di vista cronologico, storico e biografico.* Bologna.
- Castelli, A. and D. Roggero. 2001. *Il duomo di Casale Monferrato.* Casale Monferrato: Fondazione Sant'Evasio.
- Crossley, P. 2003. “Peter Parler and England. A Problem Revisited.” *Wallraf-Richartz-Jahrbuch*, 64 (53-82).
- Cuneo, P. *Architettura Armena dal quarto al diciannovesimo secolo.* Roma : De Luca Editore.

- Ewert, Ch. 1968. *Spanisch-islamische Systeme sich kreuzender Bögen. I.* Berlin: Gruyter.
- Fehr, G. 1978. "Die Wölbekunst der Parler." A. Legner, ed. *Die Parler und der schöne Stil 1350-1400. Europäische Kunst unter den Luxemburgern, Vol. 3.* Köln. (45-48).
- Fergusson, F. D. 1977. "Leonardo Da Vinci and the Tiburio of Milan Cathedral." *Architectura*, 7 (175-92).
- Fuentes-González, P. 2013. *Bóvedas de arcos entrecruzados entre los siglos X y XVI. Geometría, construcción y estabilidad.* PhD. Polytechnic University of Madrid. (http://oa.upm.es/22174/2/PAULA_FUENTES_GONZALEZ-b.pdf; accessed 31-1-2015)
- Fuentes, P. and S. Huerta. 2013. "Las bóvedas de arcos entrecruzados en Armenia." S. Huerta, F. López Ulloa eds. *Actas del Octavo Congreso Nacional de Historia de la Construcción.* Madrid: Instituto Juan de Herrera (335-346).
- Galdieri, E. 1981. "Contributi alla conoscenza delle strutture a nervature incrociate." *Revista degli Studi Orientali*, 57 (61-75).
- Giese-Vögeli, F. 2007. *Das islamische Rippengewölbe. Ursprung, Form, Verbreitung.* Berlin : Gebr. Mann Verlag.
- Guillaume, J. 1987. "Leonardo and Architecture". Paolo Galluzzi ed. *Leonardo da Vinci: Engineer and Architect.* Quebec: Montreal Museum of Fine Arts (207-255).
- Hanisch, H. 2009. *Über das Wirken armenischer Bauhandwerker im frühen Mittelalter.* Brezgenz: Voralberger Landesmuseums.
- Hislop, M. J. B. 2007. *John Lewyn of Durham. A medieval mason in practice.* Oxford: John and Erica Hedges.
- Koepf, H. 1969. *Die gotischen Planrisse der Wiener Sammlungen.* Wien: H. Böhlau Nachf.
- Koepf, H. 1980. *Die Esslinger Frauenkirche.* Esslingen a. Neckar : Stadtarchiv, 1980.
- Mencl, V. 1974. *Ceské stredoveké klenby* [Czech medieval vaults]. Praga: Orbis. (In Czech)
- Momplet Mínguez, A. 2014. "De Córdoba a Durham: el viaje de una arquitectura andalusí." *Goya*, 346 (3-14).
- Podlaha, A. and K. Hilbert. 1906. *Metropolitní Chrám Sv. Víta v Praze.* Praz: Ceska Akademie.
- Pope, A. U. and Ph. Ackerman. 1964. *A Survey of Persian Art.* London: Oxford University Press
- Marston, Searle and Rivington. Rossi, M. 1982. "Giovanni Nexemperger di Graz e il tiburio del Duomo di Milano." *Arte Lombarda*, 61 (5-12).
- Schurr, M. C. 2003. *Die Baukunst Peter Parlers.* Ostfildern: Jan Thorbecke Verlag.
- Soergel, G. 1958. *Untersuchungen über den theoretischen Architekturentwurf von 1450-1550 in Italien.* Ph.D. Philosophischen Fakultät, Universität Köln.
- Torres Balbás, L. 1946. "Bóvedas romanas sobre arcos de resalto." *Archivo Español de Arqueología*, 64 (173-208).
- Torres Balbás, L. 1952. "Leonardo da Vinci y las bóvedas hispano musulmanas." *Al-Andalus*, 17 (438-441).