San Félix de Torralba de Ribota; Geometric Characterization of Fortified Churches

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Abstract

In the mid 14th century, between 1356 and 1369, during the so-called "War of the two Peters" in Spain, small churches were built in a series of border enclaves, such as the Church of Santa María in Tobed, the one of San Martin in Morata de Jiloca and San Felix in Torralba de Ribota. Those churches would form part of a new typology called Fortified Churches, "because of their strong military character, provided by their compact external volumes, and their towers-buttresses" [Borras Gualis 2006].
The aim of research is the formal definition of an architectural typology with a high level of heritage interest. Virtual construction, through the combination of photogrammetric and laser scanning techniques, made it possible to achieve an accurate survey on which to make graphic analyses with the required precision, thereby obtaining the regulatory outlines used for the architectural design of the building.
The precision obtained is of great interest in characterizing the shape, especially the curvature of the arches, the plements and other non-rectilinear elements, in order to generate a comparable database.

Keywords: Mediterranean Gothic, Strength-Churches, Laser Scanner, Photogrammetry, Geometric characterization arcs.

Introduction

In the mid 14th century, between 1356 and 1369, the so-called "War of the two Peters", occurred between Peter I "the Cruel" of Castile, and Peter IV "the Ceremonious" of Aragon. The war originated from a dispute over the control of Murcia, and hence the Aragonese supremacy in the western Mediterranean. It came within the European Hundred Years' War, between England and France. Castile had the support of Genoa, aligned within the English area of influence, and the Crown of Aragon was allied with its Italian territories within the French sphere, which represented a war at the continental level and of multiple interests.
This war did not develop constantly with battles, but it was more discontinued over time. It caused battles and conquests in bordering territories between both kingdoms, particularly in the Kingdom of Valencia and Aragon, in the areas of Alicante, Valencia, Teruel and in the Calatayud-Tarazona area. This latter area was of particular significance in the defence of the Kingdom, the control of the valleys of Jalón and Jiloca, which were natural access routes between Castile and Aragon. Hence, Peter IV ordered the important municipalities of Calatayud, Ariza, etc. to be fortified. He also obliged the locations that could not be fortified, to be abandoned, so as not to give advantage to the Castilian troops in the event of a possible military campaign, as the city of Tarazona had fallen to Peter I. The main destination for people from all locations considered unprotected

or impossible to defend was Calatayud, where in spring 1357, the arrival was expected of inhabitants from Torralba de Ribota, Aniñón, Cervera de la Cañada, Clarés, Vadill, Viver de la Sierra and Embid de la Ribera [Lafuente 2009, p. 540].

In this context, outstanding Aragonese figures and Military Orders collaborated with Peter IV, defraying the construction of small churches in a series of border enclaves. Some of the most outstanding were the Church of Santa María in Tobed, San Martin in Morata de Jiloca and San Félix in Torralba de Ribota. This work is focused on the latter church.

These small churches would form part of a new typology called Fortified Churches, "because of their strong military character, provided by their compact external volumes, and their towers-buttresses" [Borrás Gualis 2006, p. 301]. They are factories built in the Gothic-Mudejar style, and are based on a layout of a single nave floor and side chapels, which house the towers-buttresses. An outside gallery was built on the side and head chapels on the main floor, to be used as a sentry path. It should be noted that in spite of the name, only a limited defensive capacity can be observed (fig. 1).

They have three features that make them prominent: the first is that military orders participated in their construction and were the custodians of the building; the second feature is the construction by converts such as Mahoma Rami or Mahoma Calahorri; and the third is the typology and construction resources used, as the buildings were made in a brickworks, hence the most "industrialized" materials of the age, as well as cheap and fast in areas lacking stone for construction, were used.

The first historic-artistic study on the church of San Félix of Torralba de Ribota, is the article entitled *Iglesias gótico-mudéjares del arcedianado de Calatayud*, by José María López Landa (Calatayud, 1878-1953), published in the Arquitecura magazine in 1923 [Borrás Gualis 2011, p. 65]. This text quotes the decree in 1367 by Bishop Pedro Pérez Calvillo, ordering the construction of a new church to replace the old parish church destroyed in the war of the two Peters [López Landa 1923, pp. 126]. The document allows an approach to the dating of the original wall of the church, together with another heraldic-type data, the weapons of the Bishop of Tarazona, Juan de Valtierra (1407-1433), placed in the high chorus.

The ground floor is a single nave with a straight apse and rectangular floor, which forms a single interior space, covered with a combination of single ribbed vaulting and small sections of pointed barrel vault. Their generatrix outline is the perpend arches of the ribbed vaulting. Structurally, the thrust caused by the vaults are absorbed by the perimeter towers-buttresses, three on each side

Fig. 1. Exterior side view of the church of San Félix de Torralba de Ribota. Photograph of the authors.

of the nave. The straight head wall is formed of three chapels, covered with a single ribbed vault, and linked with side chapels. The "paso de ronda" (sentry path) goes above the side chapels, the three head chapels and crosses the choir. A large rose window was constructed over the choir, and the main door opens underneath. The whole building was in brickwork, with the interior coated and decorated in pressed brick and polychrome painting of geometric objects. The windows on the upper floor were built with great decorative richness, in structural plaster from the workshop of Mahoma Ramí. [Borrás Gualis 2011, p. 87].
The construction period is limited between 1367 and 1433. With this information and a typologic and formal analysis, Gonzalo Borrás [Borrás Gualis 2011, pp. 84-88] proposes two construction periods in a way that the first one, dated in the last quarter of the 14th Century, would represent the construction of the whole masonry of the church, probably a Master Mahoma Calahorri's work; except for the most occidental module, which closes the church together with the main façade and the two side towers, that would belong to the second period around 1420, work attributed to the Master Mahoma Rami.

Fig. 2. Interior view of the nave of the church of San Félix de Torralba de Ribota. Photograph of the authors.

The study of ribbed vaults and their geometric layout is of special importance for the study. Accepting the main role of the nerves to the formal definition of a ribbed vault, the importance of an accurate geometrical analysis is essential to know the nature of the designs. As Willis already pointed in the 19th Century [Willis 2012 pp. 25, 34], it is desirable to find out the accurate curvatures of the nerves because they are the result of different rules to get geometric centres and radios according to time and nationality of different schools.
This claim supports the necessity to define accurately the geometry of the vaults to be able to analyse the regulating lines and check if they differ in relation to its authorship, materiality and other aspects –although it has been asserted that materials and technics did not define any shape generator of a style in Aragón [Ibáñez 2008, p. 44], it has to be confirmed through an accurate geometrical analysis. The lack of this kind of surveys justifies the interest for this research, which is part of a larger and more ambitious project where it is expected to obtain results impossible to be achieved with the analysis of individual cases (fig. 2).
There is documentation on a significant number of interventions on the original factory between the 18th, 19th, 20th and 21st centuries [Borrás Gualis 2011, pp. 71-73]. Owing to its significance, it is important to highlight the intervention of the first half of the 18th century, which included blocking off the main entrance to accommodate a choir which projected on the ground floor, with a polygonal closure. A semicircular arch was made as the new entrance to the temple, located on the Gospel Side. Time would have an impact on the state of the building, mainly as a result of urgent problems of damp, owing both to leaks and capillarity processes.
As a result of this unsustainable situation, it was decided to intervene. From 1953 to the sixties, Fernando Chueca Goitia took charge of the restoration of the church, intervening in various stages [Hernández Martínez 2012 pp. 13-26]. The roof structure was fully replaced, and it was attempted to return the construction to its unitary nature of the original typology. The lower choir was demolished, which had been added in the baroque period, and which blocked the original entrance. The arches of the outside galleries were opened and all elements that had been practically lost

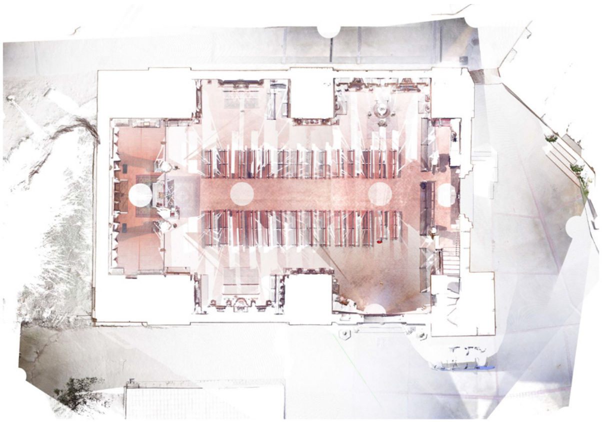


Fig. 3. View of the digital sectioned model. Own elaboration.

Fig. 4. Plan view of the digital model at + 4.00 m. Own elaboration.

were restored (or reconstructed). These included the rose window of the main façade, carved in gypsum. New elements were even added such as the ligneous eaves covering the baroque entrance.

In the last quarter of the 20th century and the beginning of the 21st century, work was performed by the architect Joaquín Soro [Borrás Gualis 2011, pp. 73-78], chiefly directed at solving the endemic problem of damp, and its serious consequences on the structure and decoration of the temple.

The aim of research is the formal definition of an architectural typology with a high level of heritage interest, through the precise documentation of buildings studied. Virtual construction, through the combination of photogrammetric and laser scanning techniques, has made it possible to achieve an accurate survey on which to make graphic analyses, with the required precision, thereby obtaining the regulatory outlines used for the architectural design of the building. This will enable a comparative study of the traces used in the different buildings of the typology. The survey process chosen also enables a suitable record of other formal aspects, which characterize the building under study, such as the valuable pressed brick and painted decoration, or the outstanding moveable property heritage of the temple [Lacarra Ducay 2011, pp. 105-162] within its context.

Methodology

Before tackling the field work, an assessment was done on the state of the studies concerning the building under analysis. This work had to be based on the documentary study of the revision of different archive and bibliographic sources. Fortunately, the San Félix Church of Torralba de Ribota has been researched from various viewpoints, as thorough historic and artistic studies have made it possible to tackle the analysis raised with sufficient basic guarantees.

The study of documentary sources is essential to evaluate the authenticity of the dimensional elements and values to be recorded. It has therefore been of particular importance to know the documented actions on the building. However, it is considered necessary to complement it with the critical, on-site analysis of the building using wall stratigraphy, to contrast the authenticity of data to be taken.

After this phase, there is sufficient knowledge to plan the field work, which is essential to collect effective data As Gil [Gil 2016, p. 46] explains, the selection of the survey method of the building will depend on factors like the type of monument or the level of detail required. When millimetre detail is required along with documenting large areas, it is advisable to use a laser scanner, for its convenience and speed. Photogrammetry is a more economical and efficient process and is recommended for individual elements, such as columns or statues. To record roofs and ceilings, close-range aerial photogrammetry is recommended with the help of a drone.

In this case, the survey of the building was carried out using a combination of laser scanning and close-range aerial photogrammetry. With the combination of both, a complete model of the outside and inside of the building was achieved.

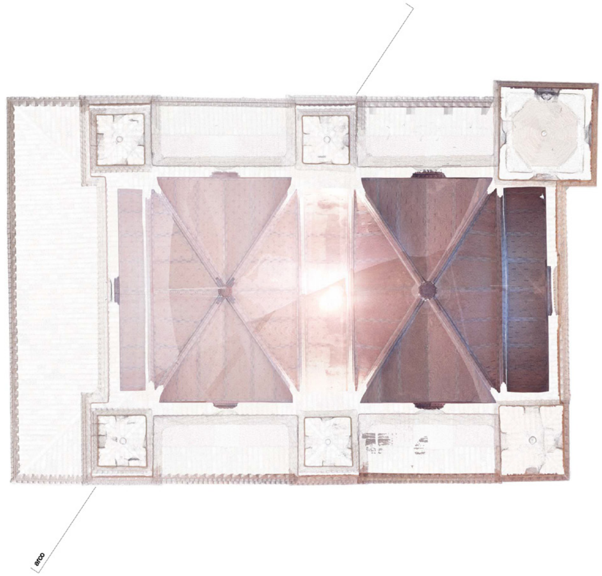
A Faro Focus3D X 130 laser scanner was used, with a range of between 0.6 and 130 m., which enables a distance accuracy of up to ±2 mm. Fourteen stations were made: four inside, one inside-outside (at the door threshold) and nine outside. The density of the point cloud was 6 mm., and not only volumetric information was collected, but also colorimetric, in order to register the materials and paints of the building. The scanner, therefore, was able to take data from the inside and from all the façades.

A DJI drone was used for the photogrammetric register, with its own integrated DJI camera, model FC350, with a focal distance of 20 mm. (wide angle), and a fixed diaphragm aperture of 2.8. Photographs of 4000 x 2250 pixels were taken, the majority at an oblique angle. This enabled a fairly good capture, not only of the roof, but also of the façades, in this case from a high level, unlike the scanner. The 96 photographs used were processed with Photoscan software, and a cloud of 4,700,000 points was obtained, which was limited to the +10m level of the building, taking level 0 as the ground level inside the church. Information of the façades under +10m was hence entrusted only to the laser scanner, as it is more detailed.

The combination of information from the laser scanner and the photogrammetric process, a total of fifteen cloud points, was done with Autodesk Recap software. Firstly, all scanner stations were loaded, and were referenced between them, using common points,

Fig. 5. Aerial view of the digital model. Own elaboration.

Fig. 6. Floor plan obtained from the digital model. Own elaboration.



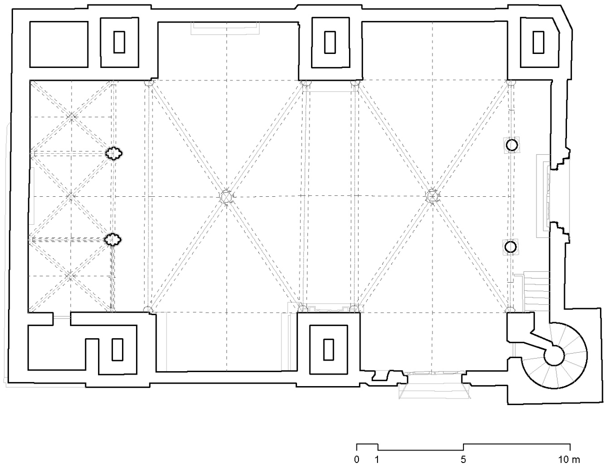


Fig. 7. Longitudinal sectional view of the digital model. Own elaboration.

in a process which Recap helps to do quite automatically. The coordinates of several significant points of the model were noted, and in Photoscan, these coordinates were allocated to the corresponding points in the photogrammetric cloud, obtained from the photographs of the drone. In this way, the photogrammetric model was directed and scaled, to accurately match the information of the laser scanning. Lastly, this point cloud was imported to Recap, along with the others, attaining a perfect overlap.
The advantage of Recap software is that the resulting files are easily integrated into other 3d programmes, for their display, to obtain views and combine with other models. In this case, the AutoCad programme was used to obtain the required views, by applying rectangular cuts to the point cloud.
With previous knowledge on the architectural typography to be analysed, along with its construction system, once the three-dimensional model was obtained, it was decided which traces and dimensions are the ones that define it. This process is of utmost importance, as it enables a comparative analysis to be done between the documented property, the first case of the study and the following ones, which will form part of wider, longer and more ambitious research (fig. 3).
In this case, the accurate documentation of the trace and proportion of the arches that define the structure of the building, were particularly significant, such as the diagonals of the single ribbed vaults, or perpend arches, along with the arch of the pointed barrel vaults of the side chapels.
To obtain the ground floor and the central floor, horizontal cuts were made at different heights, and upper and lower views were generated. To obtain longitudinal sections, vertical cuts were made taking the roof axis as a reference. An oblique vertical cut was also made in the axis, through one of the arches of the ribbed vault of the head, in order to learn the real geometry of this arch. All views were generated at a scale of 1/100 (figs. 4-6).
The sections obtained directly over the three-dimensional model were used as the basis for redrawing them. This method enabled the regulator geometry outlines to be obtained, and to go into more depth on the knowledge of the building, as the drawing, which is an analytical process, enables and requires intense contact with the studied reality (figs. 7-10).

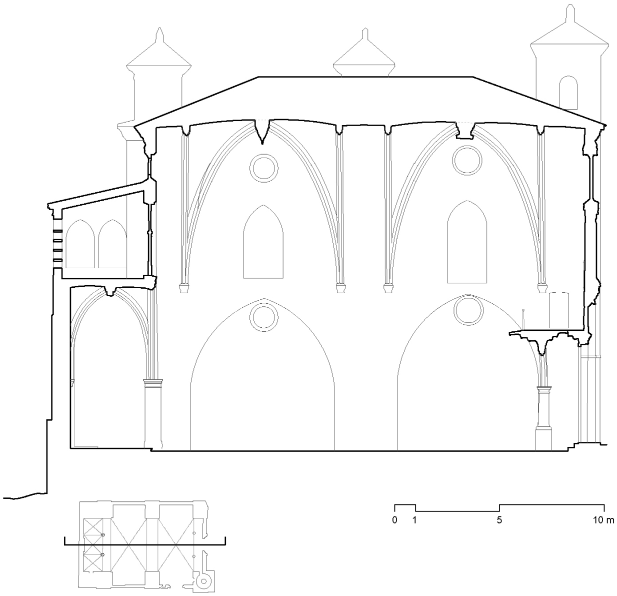


Fig. 8. Plan of the longitudinal section obtained from the digital model. Own elaboration.

Results

As a result of the work and the methodology described, graphic material of a diverse nature was generated. The photography required for the photogrammetric survey is an extremely interesting result in itself, particularly capturing images with a drone, as it is documentation that was not available until now.
The three-dimensional model obtained by combining the data generated by laser scanner technology and photogrammetric processing, contains complete geometric information of the building. Moreover, it records the colour values obtained from photographs used in the process.
Lastly, the graphic analysis made by the selected planimetry delineation, has enabled a large amount of data to be obtained, of which we explain the most significant. The volume of the church is entered in a solid capable of 27,76x 18,67 x 27,84 metres. The maximum height of this volume is determined by the tower located at the foot of the temple, on the Gospel

Fig. 9. View sectioned by the arch of the ribbed vault of the digital model. Own elaboration.

side, and has a floor of 4,44 x 4,42 metres. Inside the temple, the structural system adjusts and provides a space of 24,39 x 16,36 x 15,76 metres, with the height delimited by the position of the keystones of the single ribbed vaults of the central nave. These vaults cover a floor space of 7,30 x 10,87 metres and the crossing arches, that form them, have a rise of 7,86 m and a span of 12,93 m, which means a slenderness ratio of 1/1,64. The perpend arches, which act as a generatrix arch of the pointed barrel vault of the central nave, have the same rise, but cover a span of 10,87 m, hence their slenderness ratio of 1/1.38 , is logically greater. As for the side chapel vaults, covering a space of 2,76 metres in depth, they are defined by a generatrix arch with a rise of 4.20 m and a span of 6.86 m. (slenderness of 1/1.63).
The vaults are simple ribbed shaped, with pointed arches and plane rampant, moulded brick nerves and brick severies as well. The side arches severy encounters the wall assembling an edge instead of a nerve. As said, the vault covers a span of 10.87 m and a bay of 7.30. Accordingly, the floor plan proportion is practically sexquialter (3:2), one of the most frequent in Gothic Style (Palacios 2009 pp. 86-87). The cross rampant, slightly curved and sloped, has a difference of 55 cm high (straight slope =10,7%), while the rampant spine, with the same formal definition, has a difference of 23.4 cm high (straight slope = 7,4%). The side arch is very cambered with a centre 2.68 m far from the impost line, in contrast to the diagonal nerves and the Perpignan-arches, with the centres emplaced very close although always under it, with the diagonal a little bit farther (33.9 cm), and with one curved practically similar. All the nerve curvatures are circumference segments have been traced with a maximum tolerance of 2.1 cm in the middle points.

Conclusions

The various graphic materials generated in the research- the photographic information, the three-dimensional virtual model and the later delineated and graphic analysis- complement each other to obtain the correct formal characterization, defining the geometry, but also the associated color values that determine the true image of the monument.

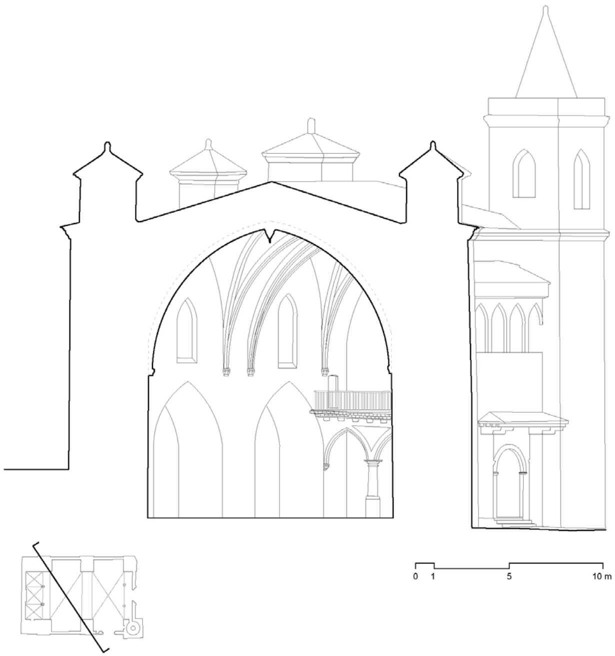


Fig. 10. Plane of the longitudinal section of the cruciate arch obtained from the digital model. Own elaboration.

As a consequence of the methodology used. it was possible to corroborate the importance of a detailed planning of the different stages, for which a previous knowledge of the heritage object is necessary. This is the only way to avoid duplication of efforts in data collection, or the use of improper data, among other errors that could be crucial to the results obtained. In addition, the comparison between the plans and drawings generated by us and those previously made by others revealed an important difference in the geometries represented. The precision obtained with the method used is therefore of great interest in characterizing the shape, especially the curvature of the arches, the plements and other non-rectilinear elements.
Finally, in order to generate a comparable database, which allows for further analysis, it is necessary to establish a data standardization, which enables their interoperability. Those conditions proved to be essential for a valid methodology for the formal characterization not only of a church, but also of the typology itself.

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Reference List

Borrás Gualis, G.M. (2006). Estructuras Mudéjares aragonesas. In Lacarra Ducay, Mª del C. (ed.). In *Arte mudéjar en Aragón, León, Castilla, Extremadura y Andalucía*. Zaragoza: Institución «Fernando El Católico» (CSIC) Excma. Diputación de Zaragoza, pp. 297-313.

Borrás Gualis, G.M. (2011). La iglesia mudéjar de San Félix de Torralba de Ribota. In Yagüe Guirles, Á.F. et al. *Torralba de Ribota. Remanso del mudéjar*. Zaragoza: Institución «Fernando el Católico» (CSIC), Excma. Diputación de Zaragoza, pp. 64-104.

Gil, A. (2016). Digital reconstructions – a methodology for the study, preservation and dissemination of architectural heritage. In *ARQUEOLÓGICA 2.0* – Proceedings of the 8th International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation. Valencia: Editorial Universitat Politècnica de València, pp. 44-55.

Hernández Martínez, A. (2012). Fernando Chueca Goitia y el arte mudéjar aragonés: arquitectura, historia y restauración. La intervención en la iglesia de San Félix de Torralba de Ribota (1953-1972). In *Revista electrónica de patrimonio histórico*: <http://www.revistadepatrimonio.es/revistas/numero10/intervencion/estudios2/articulo.php> (accessed 2012, October 1).

Ibáñez Fernández, J. (2008). La arquitectura en el reino de Aragón entre el Gótico y el Renacimiento: inercias, novedades y soluciones propias. In *Artigrama*. No. 23, pp. 39-95.

Lacarra Ducay, Mª del C. (2011). Arte mueble, medieval y moderno, en la iglesia parroquial de San Félix. In Yagüe Guirles, Á.F. et al. *Torralba de Ribota. Remanso del mudéjar*. Zaragoza: Institución «Fernando el Católico» (CSIC), Excma. Diputación de Zaragoza, pp. 105-162: <https://ifc.dpz.es/recursos/publicaciones/31/27/_ebook.pdf> (accessed 2012, October 1).

Lafuente, M. (2009). *La guerra de los dos Pedros en Aragón (1356-1366). Impacto y trascendencia de un conflicto bajomedieval*. Tesis Doctoral. Departamento de Historia Medieval, Ciencias y Técnicas Historiográficas y Estudios Árabes e Islámicos, Universidad de Zaragoza.

López Landa, J. M. (1923). Iglesias góticomudéjares del arcedianado de Calatayud. In *Arquitectura*. No. 49, 1923, pp. 125-135.

Palacios Gonzalo, J.C. (2009). *La cantería medieval: la construcción de la bóveda gótica española*. Madrid: Munilla-Leria.

Willis, R. (2012). *La construcción de las bóvedas en la Edad Media*. Madrid: Instituto Juan de Herrera. Escuela Técnica Superior de Arquitectura de Madrid.