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Rogério Amoêda
Sérgio Lira
Cristina Pinheiro
ABSTRACT: From the late seventeenth to early nineteenth centuries, many religious temples have been built in the province of Alicante (south east of Spain) with brick domes as their main characteristic feature. Often, the limited data available about these remarkable constructions make rehabilitation interventions become into real research projects, with a high value for their historic conservation over time. The aim of this paper is to show a detailed refurbishment analysis of a religious temple built in 1778, showing the need of preservation of historic buildings as a part of the architectural heritage by establishing a common pattern of materials, geometry and constructive systems, specifically in their domes. In most cases, there was not an architectural project for the construction, that is why the analysis of any documentary and archival sources available is essential to find different ways to proceed on the use and maintenance of these religious buildings.

1 INTRODUCTION

From the late seventeenth to early nineteenth centuries, many religious temples have been built in the province of Alicante (south east of Spain) with the presence of brick domes as their main characteristic feature.

The use of brick vaults in the Spanish Levant was well known, specifically in the area of the province of Alicante, as many religious temples were built mainly during the eighteenth century with different elements performed with vaulted bricks and gypsum. From these brick elements, the dome located at the transept became a common and most characteristic element in all temples between 17th and 19th century.

Despite finding different ways to proceed in the construction of domes, there are common characteristics to all them (recurrent materials, geometry and construction systems) by using different combinations and testing a variety of solutions for brick vaults. But often there is limited data available about these remarkable constructions, which makes refurbishment interventions become into real research projects. That is why this research can present a high value for the historic conservation of these religious buildings over time.
2 OBJECTIVES

The aim of this paper is to show a detailed constructive analysis of a religious temple built in 1778, showing the need of preservation of this kind of historic buildings as a part of the architectural heritage in the area by establishing common patterns in materials or geometry widely repeated, specifically in their domes. In most cases, there was not an architectural project for the construction, that is why the analysis of any documentary and archival sources available is essential to find different ways to proceed on the use and maintenance of these religious buildings.

Within the wide range of constructive elements of the temples, this study is delimited in their coverage and it is particularized in the dome, its main architectural feature. Specifically, this paper studies the dome of the transept in the church of San Juan Bautista in Cox looking for constructive and architectural patterns by analyzing its elements, shape and construction procedures. Outside, this element is really integrated on the landscape, becoming a common symbol for small towns; inside, the dome displays its greatness as a result of a really interesting way of construction with a very tight budget.

3 METHODOLOGY

The temporal and physical scope of the research is focused on the Mediterranean coast (Spain), particularly in the province of Alicante, from the late seventeenth century to the early nineteenth century.

For the selection of domes, this study is based on the inventory made by García Jara about 159 religious temples in the province. Our own selection was performed according to different criteria such as the use of bricks, the temporal scope (from the late seventeenth century to the early nineteenth) and the spatial domain (Alicante). Domes corresponding to churches or cathedrals in crossing elements are chosen, not including small chapels and other religious buildings. Given these considerations, the present study makes a final selection of 38 crossing domes belonging to temples located in 35 towns in the province of Alicante (Fig. 1).

![Figure 1. Left image. Location of the province of Alicante (Drawing of the authors). Central image. Location of Cox, one of the 38 religious temples analyzed in 35 municipalities in the province of Alicante (Drawing of the authors). Right image. Dome of the Church of San Juan Bautista (Cox). (Photograph of the authors.)](image)

This methodology focuses first on a research on specific documentation of each analyzed temple (using in situ data collection or review of documentary sources); a second part of comparative analysis of individual data obtained with similar studies; and finally, establishing general conclusions for the construction of brick domes in the temples of the province of Alicante.
3.1 In situ data

For the in situ data collection in the temples, an orderly and rigorous method has been followed to guarantee the outcomes. Thus, each building has been carefully examined, making countless drawings (plans, sections and details) and distance measurements by Leica DISTO laser distance meter (Fig. 2). This task was essential for the study and involves the generation of new invaluable documentation as, although some temples have certain graphical information, in many cases the existent material does not conform to reality or does not have rigor enough to be studied in detail.

![Figure 2. Floor plan and Section of the Church of San Juan Bautista (Cox). Drawing of the authors.]

The geometric variables measured have been complemented with additional documents for each temple analyzed as interior and exterior digital pictures, thermographies of all domes (Fig. 3), sampling of materials involved in the construction process (such as bricks and roofing tiles), plans, sections and 3D constructive details.

![Figure 3. Thermography of the crossing dome in the Church of San Juan Bautista (Cox). Photograph of the authors.]

3.2 Documentary Sources

In parallel to the in situ data collection, all documentary information of each temple was compiled, both general and specific. Regarding the general documents, there has been a deep bibliographic study with many written sources but limited historical details dealing with the
construction of vaulted elements. On the other hand, regarding the specific documentation, parish archives were also visited (many destroyed during the civil war), municipal archives (with restoration projects and photographs of the process) (Fig. 4) and other archives of associations, reporters, photographers, architects or construction companies that have been interested or involved in the conservation and restoration of the temples.

In conclusion, the proposed methodology was developed as follows: first, establish a study population of 38 temples located in the province of Alicante; second, identify and compare all the geometric and constructive features of these buildings to be used in future refurbishment projects and usual maintenance of this kind of religious constructions, and third, analyze the Church of San Juan Bautista in Cox (1778) as a detailed example of the restoration process of this kind of buildings in the region.


4 RESULTS

The temple under study is located in the town of Cox, in the south of the province of Alicante (region of Vega Baja del Segura) near the towns of Callosa de Segura and Orihuela, known for their monumental importance.

The church has a Baroque-Neoclassical style. It was built between 1774 and 1778, designed by architect Miguel Francia, who participated in the construction and renovation of many temples in the area, being the diocese architect for a long period. His main interventions in temples of the region are in Albatera, Catral, San Felipe Neri, Dolores, San Fulgencio and Callosa de Segura. The floor of this church has a Latin cross nave with side chapels communicated to each other (Fig. 5). The Virgin chapel is located in the transept. Both chapels are crowned with beautiful domes, following special patterns repeated in every temple of that time.
The dome of the transept was completed in 1778, using brick construction as in other temples designed by Miguel Francia. Built with circle tambour and crowned with a lantern, its solid construction has permitted to last over time, enduring even different earthquake shakes in 1829. After these seisms, it was slightly damaged, being finally restored in 1989.

4.1 Analysis of support elements

Both the dome and its sustaining elements are constructed of brick and gypsum. The advantages of the use of brick were based in lower cost, discarding the use of stonework in domes (only used in specific cases). Regarding the gypsum, its quick setting facilitates construction of domes with the use of bricks, reducing the need of centring, which also involved a lower final cost and a great construction speed.

Some samples were taken in each temple to be analyzed. Despite the dimensional range of the samples obtained in all temples, two types of bricks are mainly used: one larger (30x16x4 cm) and another smaller (25x12x4 cm) with variable weight. Depending on the dimensions of the building elements, one type of these bricks is employed: bigger bricks are used in the construction of the dome while the small ones are used in the lantern and the upper finish.

The thrust of the arches are compensated by the arrangement of walls on the transept in two directions, setting up the square where the circle of the dome is inscribed. Its thickness of 1.20m and its length of 3.80m on the shorter side ensures that compensation, with a ratio of L/2 between the span of the main arch and the length of the stirrup.

The floor plan shape of the columns in the cruise is not casual, and they have a chamfer transition, facilitating the change from the square to the circle that serves as a starting point of the lantern. Once walls, stirrups and columns are built, the construction of arches is made with a midpoint shape, constructed with a bond of brick and gypsum. For its construction, it was necessary to use wooden formwork, rising symmetrically on both sides of the arch to distribute the weight and avoid collapsing deformations during implementation.

Since the construction of arches was prior to the construction of the ring, it was necessary to ensure that both remain attached when constructed. In the photographs about the restoration of the temple, it can be seen that while the arches of the central space have a thickness of a brick and a half, the other are two bricks thick, with a width somewhat higher than the drum dome (Fig. 6). This is because they bear the load of the ring, the drum, the dome and the lantern. Also,
in this case the width of the main arches is somewhat greater than the thickness of the ring, having a clearance of 7.66m between the crossing pilasters.

Once the arches were built, pendentives were executed somewhat set back with respect to the edges of the main arches, ensuring the transmission of thrusts and facilitating their assembly. For its construction, a string attached to the centre of the sphere was needed, placing successive string courses of brick to match the top of the arches. Like any other vault, it was finally filled in its batter and loaded on main arches.

The construction of pendentives was solved by horizontal layers, tied with the main arches during its construction. This way of constructing pendentives in string courses is the most used in all temples due to its simplicity, as the intersection between the pendant and the ring is easier to solve because both elements are in the same horizontal plane. Afterwards, once the vault was formed, the triangular space between the pendant and the main arches was filled with mortar and rubble. On the main arches, a ring of brick was constructed as a binding element, with a circular shape and a slightly larger thickness than the drum. The ring was made by bricks placed in a bond course, without paying much attention to connecting different courses.

The floor plan of the drum is also circular and, as the ring, it is solved with brickwork. There are 8 opening lights oriented following the distribution of the crossing both for interior lighting and also for reducing its weight. About its dimensions, the drum has a total height of 8.64m, an inside diameter of 4.31m and a thickness of 0.85m in walls. With these dimensions, the relation between the diameter and height of the drum is D/2. Regarding the thickness of the drum and its diameter, a ratio of approximately D/10 is obtained.

4.2 Analysis of the dome

Regarding the geometry, there is a dome crowned with a lantern. The relation between the height and the diameter of the dome defines a value of 0.58 (Fig. 7). The thickness at the top of the dome is about 0.15m, what is a ratio of 1/40 of the radius of curvature.

The lower areas are in tension and that is why there is a higher thickness to compensate the thrusts of the dome. This considerably reduce the weight on the main arches while it also serves as counterweight. The stirrup normally yields outwards so that the dome tends to form meridian cracks to accommodate the movement. In this case, as there is a lantern in the dome, the cracks reached almost its start, as it can be seen in the pre-restoration photographs (Fig. 7).
The construction of the dome was solved with running bond brickwork, placed with gypsum as mortar, allowing its construction without or very light formwork. Courses were placed so that the joints between each other remain perfectly locked. The start of the dome coincides with the final of the drum. From here, courses of brick and gypsum are laid with the help of light trusses. Each course is completely closed before starting the next (Fig. 8).

If in the construction it was used a very light formwork, it served as guide and support, especially in the upper area where the bricks’ inclination from the horizontal was high. This inclination made a variation in the size of the brick joint between inside and outside.

Specifically in this church, the start of the dome was solved with bricks in a bond course in the first five rows, increasing the thickness of the dome at its base just where it is most needed for counteracting thrusts. This constructive solution has been used in other domes in the province such as the in the church of Santos Juanes in Catral, also from Miguel Francia.
4.3 Analysis of the dome cover

Together with the physical appearance of the dome outside, an specific outline is also characteristic in the province, forming a reverse when reaching the drum which allows the evacuation of water. Furthermore, the shape of the eaves and the number of ridge beams are also characteristic features throughout.

Once the brickwork of the dome was built, or parallel to its construction, the back was filled with several centimetres of lime mortar. Over this mortar, 8 ridge beams were marked in the cover of the dome, dividing it in different sections. As it has circular eaves, ridge beams are located coinciding with the midpoint between the windows of the drum (Fig. 9). Afterwards, roofing tiles were laid down from bottom to top and from the centre to the sideways. Courses were completed, first placing the pantiles and then the ridge tiles. It was important to make the setting-out stake of the first course, establishing the location of other courses.

To achieve vertical alignment of different tiles, once the first course was placed, they were laid out parallel to the line that previously had been performed at the midpoint of the deck. In this way, courses were completed with roofing tiles and lime mortar, paying attention to the connection with the underlay due to their excessive roof pitch by using nails to keep the overlap on the cover roofing tiles.

Since the lower part of the dome had a higher curvature, the overlapping between roofing tiles in this area should be increased to achieve a smoother transition towards the top, right where the curvature changed from concave to convex. This transition ensured the removal of water (Fig. 9), where the overlap could be lower since the curvature was softer.

![Figure 9. Left image. Cement mortar on the brickwork (Parish Archive of San Juan Bautista, Cox 1990). Central image. Outside view of the dome before restoration (Parish Archive of San Juan Bautista, Cox 1990). Right image. Flat roofing tile used as pantile (Parish Archive of San Juan Bautista, Cox 1990).](image)

5 CONCLUSIONS

The design and construction of the domes in religious temples in the province of Alicante (Spain) from the late seventeenth to the early nineteenth century are the result of changes in testing materials and state of the art for years. In this evolution, eventually, brick was chosen as the main material, finding a perfect ally in gypsum.

After the analysis of domes in the province, it can be concluded that their construction was performed following the rules of well planned buildings and the dimensional recommendation in historical archives, as the geometry and dimensions of Fornes i Gurrea.

The choice of solid bricks as main building material in domes became widespread during the eighteenth century in the province. There are many benefits that can be attributed to the use of brick and gypsum as construction materials of domes as, for example, their economy, adaptability, lower weight, lower thrust, no need of trusses and high speed of building performance.

In the studied example, the dome is built with running bond of bricks rows, except the first ones, in which the brick is placed in a bond course to favour thrust counteracting during its
construction and give stability to the assembly. This approach has been used in other temples in the area, also from the architect Miguel Francia.

The thickness of the dome is about 15cm, which is 1/40 of the radius of curvature. From the data used in various restorations, it follows that this is the most widespread constructive way to build domes in the province.

The outline of the dome is also a main characteristic, although in this case is blurred due to the big size brick lantern, with an structure that has remained largely unchanged over the years showing the good quality and theoretical basis of these construction techniques.

In conclusion, religious constructions have been part of the architectural heritage from many centuries ago, so it seems necessary to comprehend their formal and material characteristics to obtain new proposals applicable to current refurbishment designs, without neglecting the technical advances at our disposal nowadays.

It should be clarified that brick domes in the temples of the province became widespread for their economy and their easy adaptation to any shape. This material allowed to considerably reduce thickness of walls, leading to the disuse of trusses for commissioning work (with a cheaper and faster construction) and generating certain implications regarding how to work and the resulting construction types. Data non-existent so far and necessary to establish criteria for the use and conservation, and also to facilitate future refurbishment interventions in these religious constructions.

REFERENCES