

Article

Proposal of a Sensorization Methodology for Obtaining a Digital Model: A Case Study on the Dome of the Church of the Pious Schools of Valencia

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Abstract: The Church of the Pious Schools of Valencia (18th century) has the largest Valencian dome ever constructed, with its 24.5 m span, and it is included among the prestigious great European domes, inspired by the Pantheon and belonging to neoclassicism. Currently, this monument is undergoing a thorough study and restoration process to improve its management, especially to halt its deterioration due to moisture and cracks. An initial study included in the Master Plan (1995) determined that these cracks were caused by thermal effects, but recently, other studies have suggested that these failures originated from the walls. Additionally, environmental impacts and thermal behavior are among the causes, as excessive humidity due to high interior occupancy can cause damage to the dome, which has historic coatings. As a result of this study process, we propose sensorizing the dome of the church in order to enable comprehensive control of the temperature, humidity, and CO₂, as well as installing accelerometers to monitor the movements of the structure. With this, after the restoration of the dome, the potential effects of temperature, humidity, and CO₂ on the dome's surfaces will be controlled, in addition to verifying if there is any correlation between the cracks and the temperature.

Keywords: heritage; study; crack



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1. Introduction

Within architectural heritage, there are elements that, due to their scale and aesthetic beauty, form a unique entity; there is no person who does not marvel when entering through the portico of the Pantheon and observing the largest masonry dome in history with its nearly two millennia of existence and its 43.3 m span [1]. In this context, the spaces created and their structures form heritage that must be preserved, and thanks to current technology, we can access resources that ensure their maintenance and intervention.

It could be stated that pathology in historical constructions is defined by two main aspects: the presence of cracks and the presence of moisture. Both pathological lesions directly interfere with the useful life of the materials and the building itself, with preventive conservation being one of the ways to minimize future costly interventions, in addition to being an example of sustainability. Currently, the problem of CO₂ generation is the focus of the famous 2030 Agenda of the United Nations (UN) [2], with architectural restoration being a way to preserve buildings in such a way that environmental impacts are minimized and resource efficiency is maximized [3]. A sustainable approach to restoration includes preventive maintenance plans that ensure the longevity of structures [4].

The Church of the Escuelas Pías in Valencia (Spain) (Figure 1), built in 1771, is undergoing a comprehensive study with critical perspectives as its dome is currently being restored, funded by the Ministry of Transport and Sustainable Mobility (Government of Spain). This dome is the largest in the Valencian territory, with a span of 24.50 m [5], and is

included among the great European domes, as well as being notable for its exemplarity within neoclassical architecture [6]. Its pathology is primarily due to the presence of four large cracks, each approximately 6 m long, in four of the ten sectors that compose the dome, in addition to moisture problems inside due to damage to its covering, which was made using the traditional masonry technique with blue glazed ceramic tiles.



Figure 1. Aerial view of the dome of Escuelas Pías.

Some authors, such as Soler and Benlloch [7], define the pathology of the dome as being due to thermal and rheological actions in a monument whose construction systems are made of brick and lime masonry. These authors base their findings on current research in other similar monuments, omitting the different construction materials, such as the major domes of Santa Maria del Fiore in Florence or the Pantheon of Agrippa in Rome. In the case of Santa Maria, Fanelli [8] conducted an exhaustive study of its cracks after having installed a monitoring system in 1987, concluding that the cracks extend from the base of the pillar to the top of the dome, dividing the structure into four substructures subjected to the action of their own weight and to eventual mutual reactions, i.e., reactions of compression. On the other hand, in the case of the Pantheon of Agrippa, Masi [9] concludes that meridional cracks may have been produced in the early stage of the dome's life by the action of concrete shrinkage and gravity.

Recently, with the increase in HBIM technology, we are seeing a rise in the monitoring of monuments for their management [10], especially for the control of wall surfaces and to prevent damage in areas where there are elements of interest, particularly paintings [11]. This has led to the creation of virtual twins to manage their maintenance and conservation [12]. However, when it comes to heritage, it is essential to consider that the overall stability of a structure is perhaps the most important aspect in the maintenance of the monument, as it can be the source of many issues and potential heritage loss [13]

For the study of cracks and dampness, as well as their causes, there currently exists a wide range of methodologies and tests, which can be either destructive or non-destructive. In the application of destructive tests, it is necessary to sacrifice part of the wall surface in order to test its resistance or physical and mechanical characteristics such as its composition and strength [14]. This category includes methods that use core samples, although some may be reversible. Conversely, there is a broad spectrum of non-destructive tests that also serve to determine certain aspects without the need to remove a piece from the structure for analysis [15]. These non-destructive methods include the application of ground-penetrating radar, ultrasound, thermography, tomography, etc. All of these testing methods are compatible with the parameterization and introduction of the obtained data

into a repository following the HBIM methodology, representing the virtual DNA of the monument.

The main objective of this article is to establish, through case studies, a methodology for monitoring monuments, focusing on the most important heritage element of the Escuelas Pías Church in Valencia: its dome (Figure 2), which is within a small and prestigious group worldwide, as noted by Guastavino in 1893 [16]. Additionally, the proposed method aims to control the indoor air quality and improve the energy efficiency of the church, given its continuous use as the largest space in the school, filled with students almost every day. The first level houses a museum space that receives daily visits, and religious events are also held after school hours. This case serves as an example of knowledge transfer to society. Through innovative techniques applied experimentally in monument conservation, made possible by greater economic resources and the necessity of technology in monuments, these methods can later be exported to other existing or future buildings, thus serving as an example of sustainability.



Figure 2. Inside view of the church.

2. Study Object

The school and Church of the Pious Schools are located in the historic Velluters neighborhood in Valencia (Spain), occupying almost the entire rectangular block, excluding the eastern corner on Santa Teresa Street. The school building has a rectangular layout, with the church positioned at its eastern end. The church is bordered by the main facade

with the bell tower to the south, two wings of the school cloister to the west, an alley to the north, and houses with a courtyard to the east. Architecturally, the church features a notable dome with a 24.5 m interior span and a total area of 1000 square meters, divided into ten sectors. This design is reminiscent of the Temple of Minerva Medica, though its architectural inspiration comes from the Pantheon of Agrippa [6].

Saint Joseph Calasanz founded the first public school in 1597 in Rome (Italy), naming it “Escuela Pía”; only the wealthy social classes had access to education [17]. The religious order, known as the Piarists or Escolapios, arrived in Valencia in 1737, where they initiated the construction of the school in 1739, finishing it in 1747 [18]. In 1767, construction of the church began according to the plans outlined by the master builder Josef Puchol. Archbishop Andrés Mayoral, the driving force behind the project, desired a church that would stand out from the Valencian architectural tradition, sending the architect to visit the church of the Bernardine Nuns in Alcalá (Madrid) [19].

The church’s initial design and supervision were undertaken by José Puchol until he was replaced by Antonio Gilabert in 1768, who made further adjustments to the project. Construction was halted in 1769 due to Archbishop Mayoral’s death and financial constraints. Despite these challenges, the church was eventually completed in January 1771 and consecrated in 1773. Puchol’s original plan included a third section of greater height, but this was reduced in size for economic reasons [20].

The compositional scheme of the floor plan is similar to that of the Temple of Minerva Medica and derives from a circular plan. The first level of the temple’s interior consists of ten radial spaces situated between the piers. Eight of these spaces are configured as exedras with concave back walls, while the remaining two have straight walls, designated for the atrium and the main chapel of the temple. The wall surface is structured with intercolumns flanked by fluted Corinthian pilasters. The intercolumns forming the fronts of the chapels are organized according to the well-known Palladian motif, which was highly innovative in Valencian architecture at the time, particularly for its serial application in the interior elevation of a temple. Seven of these spaces are intended for chapels and feature altars formed by two Corinthian columns on pedestals with alternating circular or triangular pediments. The remaining three spaces configured between the piers of the church are designated for entrances: one from the school cloister, one for access from the street, and one for access to the main altar. The main altar, located opposite the entrance, is larger than the others and connects the first level with the second.

The second level, lower in height than the first and encircled by an iron railing resting on a narrow walkway, accommodates galleries between the spaces left by the piers, all interconnected by narrow passages open within them. The vertical rhythm imposed in the first level by paired Corinthian pilasters is maintained in the second level, but there is a radical change in the composition of its intercolumns. The previous articulated elements give way to rigid lintel compositions here. This curved in antis composition employed in the Escuelas Pías serves as a columnar screen corresponding with the almost cubic framework of the galleries, but not with their lowered vaulting, as the straight entablature conceals the curvature of their covering.

The third level, formed above the upper cornice at 21 m, continues to maintain proportions and a distribution similar to that of the Pantheon. Enclosed by a metal railing and a narrow walkway, its surface is organized with ten rectangular windows above the galleries of the lower floor, niches in the piers, and decorative panels in the intermediate spaces. Statues of ten apostles are placed in the niches. From the cornice of the uppermost level rises the hemispherical dome, marked on its intrados by twenty paired ribs. Above the upper ring of the dome stands the lantern, divided into ten segments with windows.

3. Background: Previously Conducted Studies

More than a century has passed since Guastavino [16] studied the church of the Escuelas Pías, without alerting to any pathology in the dome. The Escuelas Pías was declared a National Artistic Historic Monument in 1982 after two hundred years of history,

and due to the pathological damage of the dome, Rafael Soler's firm was commissioned to develop the Master Plan in 1993 [21] by analyzing the complex and focusing on the cracks of the dome (Figure 3) and their possible causes.



Figure 3. View of the dome and the cracks in four different sectors.

Since then, various reports and studies have been conducted to determine the cause of the cracks in the dome, while establishing a construction hypothesis for this masonry dome of approximately 48 cm in thickness. Initially, these studies focused only on the dome and attributed the origin to tension issues caused by thermal inertia, indicating that the thermal fluctuation stresses were not supported by the structure due to its material properties [21].

Various studies mention the behavior of the iron chains in the dome, especially Rodríguez and Gil [22], who suggested the possibility of spalling in a pattern parallel to the dome because of the oxidation of metal rings, initially mentioned by Zacarés [20]. They also conducted a planimetric survey with laser scanning (TLS), as well as preparing images and adjusting their color balance in order to observe the degradation and damages.

Marín [23] establishes an architectural comparison of the Escuelas Pías rotunda with other models, proposing a hypothesis of a trace analogous to that established by Carlo Fontana for the dome, while also highlighting that the cracks could have been caused by the settling of the masonry during the construction process due to the use of lime mortar. Similarly, he discusses the metal rings mentioned by Zacarés, and concludes, like the study by Alonso and Martínez [13], by suggesting that metal reinforcements are unnecessary once the dome is finished.

Other studies, both historical and structural, provide us with extensive knowledge about structural behavior throughout history. López [24] examines technical reports and studies conducted on masonry domes in the 18th century, highlighting how building masters applied principles of mechanics and material behavior. This connection links the study of domes (three-dimensional structures) with the theory of arches and vaults (two-dimensional structures). Huerta [25] studies and analyzes cases from different historical periods to conclude that the stability of arches, vaults, and domes relies on traditional calculations supported by geometry. He also correlates supported structures with load-bearing elements such as walls and buttresses.

Many historical and contemporary studies have predominantly focused on analyzing the behavior of cracks in domes, often overlooking investigations into the walls and foundations. However, when the ground or foundation settles, resulting in subsidence, cracks may manifest at the base of the walls, subsequently affecting the integrity of both the masonry and the dome. Instances such as that observed in the dome of St. Peter's Basilica in the Vatican, where cracks were evident at the level of the drum and dome [26], underscore the necessity of thoroughly examining the wall structure and foundation to comprehensively address structural concerns.

3.1. Sensorization between 1996 and 2003

Between 1996 and 2003, architect Rafael Soler's study carried out the sensorization of the dome in order to obtain the relationship between temperature and the movement (opening/closing) of the cracks, similar to what was carried out in the dome of Santa Maria del Fiore [27]. An analysis of the extensive documentation collected, along with the interpretation of the results that recorded the movements of the probes over the analyzed time period, confirmed the inverse correlation between temperature variation and crack opening: as the temperature increases, the crack distance decreases, and vice versa (Figure 4). It is worth noting that in the analysis of these data, a drift was observed, meaning that the crack openings increased over time due to thermal variations.

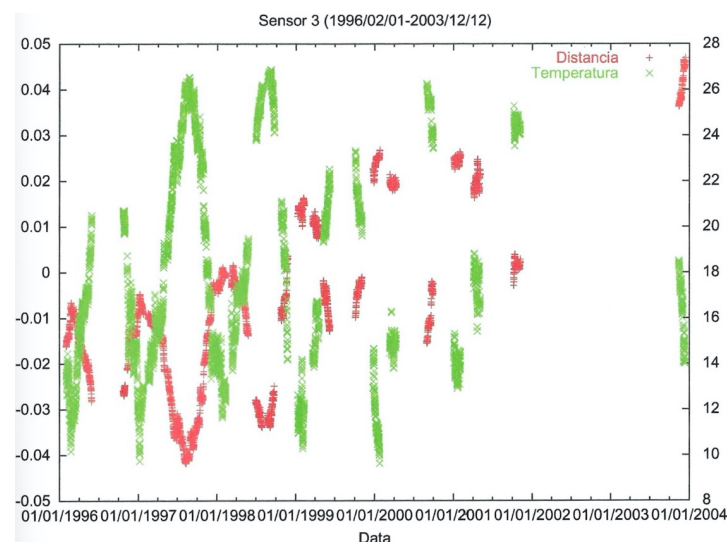


Figure 4. Scheme of the relationship between temperature and crack movement, with red representing movement and green representing temperature; 1996–2003.

3.2. Virtual Theoretical Study of the Dome

Alonso and Martínez [13] conducted a virtual theoretical study of thermal behavior due to temperature variations on the dome, concluding that the combination of thermal and gravitational loads leads to tensile stresses that greatly surpass the structural capacity of the material. However, they established that the damages observed in the model did not correspond to the actual state of fissures documented in the Master Plan [21]. In this

study, they only analyzed the dome, without taking into account the supporting walls. However, Soler and Benlloch [7] stated that gravitational actions were not the cause of the injuries, given that neither their location in elements of very different sections nor the various studies conducted using graphic statics or finite elements indicated as such. They also established that seismic action did not seem to be the main cause of the damages, but perhaps it could have been, at some point in the past, a contributing factor to the fissures in two of the sectors, which are not the ones with the most damage.

Clearly, the cracks that exist in four out of the ten sectors of the drum, with lintels and jambs of the openings being split and the cracks extending to the upper ring and prior to the start of the dome (Figure 5), as well as the displacement of two ribs in two of the ten sectors, indicate some movement of the materials, and it can be affirmed that the cracks in the dome were not solely caused by thermal inertia. Following these findings, Cortés and Alonso [28] carried out a complete parameterization of the dome and walls to analyze the behavior due to settlements, using the finite-element method (Angle software 2021), and obtained results similar to those existing in the monument, providing an explanation for the cracks (Figure 6).



(a)



(b)

Figure 5. Cracks in the drum and the ring before the dome: (a) cracks in one lintel and vault of one of the four damaged sectors; (b) crack in the ring before the dome in sector G.

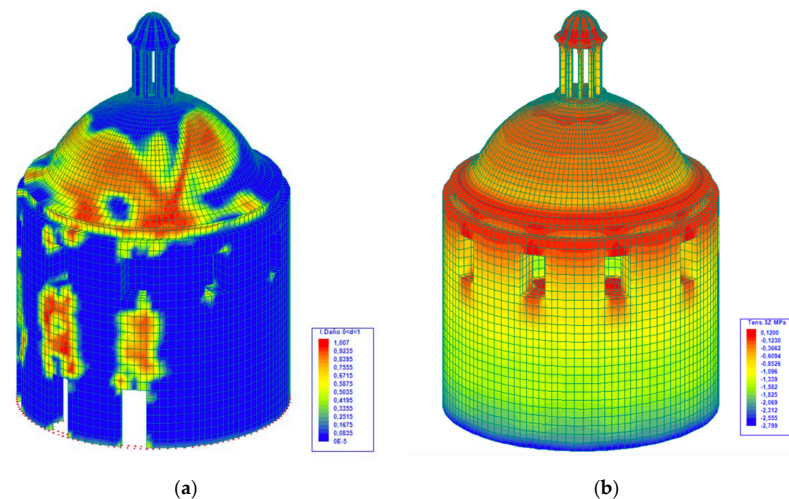


Figure 6. Cracks in the drum and the ring before the dome: (a) fissure pattern with the hypothesis of a settlement of the vertical wall; (b) stress state of the dome showing tension at the base of the dome.

3.3. Study of the Pathology

Both the interior and exterior pathology have been analyzed and documented in graphic and written reports, with special attention being given to the cracks as they represent the main problem of the building. The structural component is one of the fundamental aspects of architecture established by Vitruvius: *venustas* (beauty), *firmitas* (stability), and *utilitas* (utility).

Prior to the restoration, the dome exhibited four large cracks in the calotte that extended from the interior to the exterior, as well as in the drum. Additionally, there was a displacement of two roof tiles, allowing water to leak into the interior. The tile covering was in a very poor state of conservation, with water infiltration causing dampness, salt deposits, and loss of plaster, among other issues. The exterior showed numerous broken tiles, vegetation, missing tiles, and tiles with enamel loss. Furthermore, the lantern had had its openings blocked with a honeycomb brick infill and red waterproof paint.

Currently, the interior of the dome is undergoing restoration. As an initial step, the cracks in both the interior and exterior of the dome and its drum have been repaired. These cracks followed the meridian direction and were centrally located, extending from the base of the dome to approximately 3/5 of the length of the calotte, about 10.74 m, in four of the ten sectors of the dome (Figure 7). Associated with these cracks, there are numerous other fissures that exclusively pertain to the cracking of the coating.

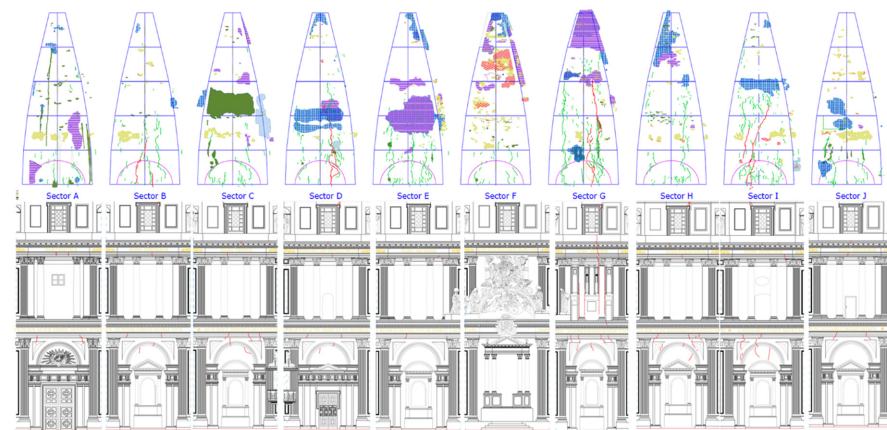


Figure 7. Study of the pathology of the interior, with the observation of damage in the dome derived from moisture and cracks.

3.4. Study of the Tilt

In light of the previously discussed condition of the dome and the drum, a more recent study was conducted to analyze tilts and settlements using orthoimages to establish a quantitative evaluation. This study took into account everything from the foundation to the highest part of the lantern.

The study began with a methodology that involved active sensor surveys, performing an exhaustive survey with laser scanning (TLS). For this 3D survey, the phase shift measurement system, which is faster and more precise, was used. A Leica scanner was utilized, conducting a total of 60 scans: 12 for the exterior and 48 for the interior space. In the subsequent office processing, the point clouds were downloaded and processed using Leica Cyclone Register360 software to generate a unified model, achieving a minimum precision of 1 mm for the exterior and 2 mm for the interior [22].

This study determined that the origin of the issues was the tilt of the drum, which consequently affected four sectors of the dome as it readjusted to its new state [28]. Additionally, the poor condition of the roof covering did not prevent water infiltration during rain, which affected the interior coating of the dome. This resulted in the appearance of dampness, salt, mold, and a partial detachment of the coating, impacting both the aesthetics and the healthiness of the building.

3.5. Geophysical Study

Zacarés [20] mentioned the existence of stone blocks in the dome where iron rings were fitted during the construction of the Escuelas Pías dome, specifying a weight of 613 @ (arroba), approximately 7790 kg. After two campaigns with ground-penetrating radar (GPR) technology, the existence of some metal rings was confirmed [29], similarly to what Guastavino [16] described as a “brick dome with iron rings”, understanding that the depicted figure represents the dome of the Escuelas Pías de Valencia.

The objective of this geophysical study (Figure 8) was to search for metallic elements and locate rings and bars in the masonry dome (Figure 9) using a GSSI SIR3000 (Nashua, NH, USA) ground-penetrating radar system. Due to the range of thicknesses in the different sections that were to be studied in the dome, two antennas with central frequencies of 900 MHz and 400 MHz were selected for the location and detection of metallic elements up to approximately 2 m in depth:

- The 900 MHz antenna was used for location and detection up to 1 m in depth;
- The 400 MHz antenna was used for location and detection up to approximately 2 m in depth.

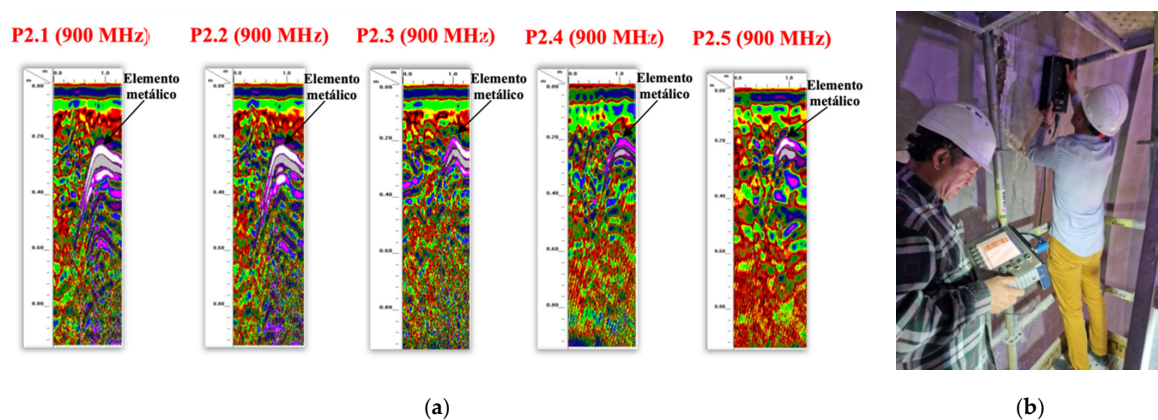


Figure 8. Results of the geophysical study using ground-penetrating radar to detect “anomalies” in the dome and an image depicting the progress of the study within the dome: (a) radargrams where anomalies in the waves can be observed; (b) image showing the execution of the geophysical study.

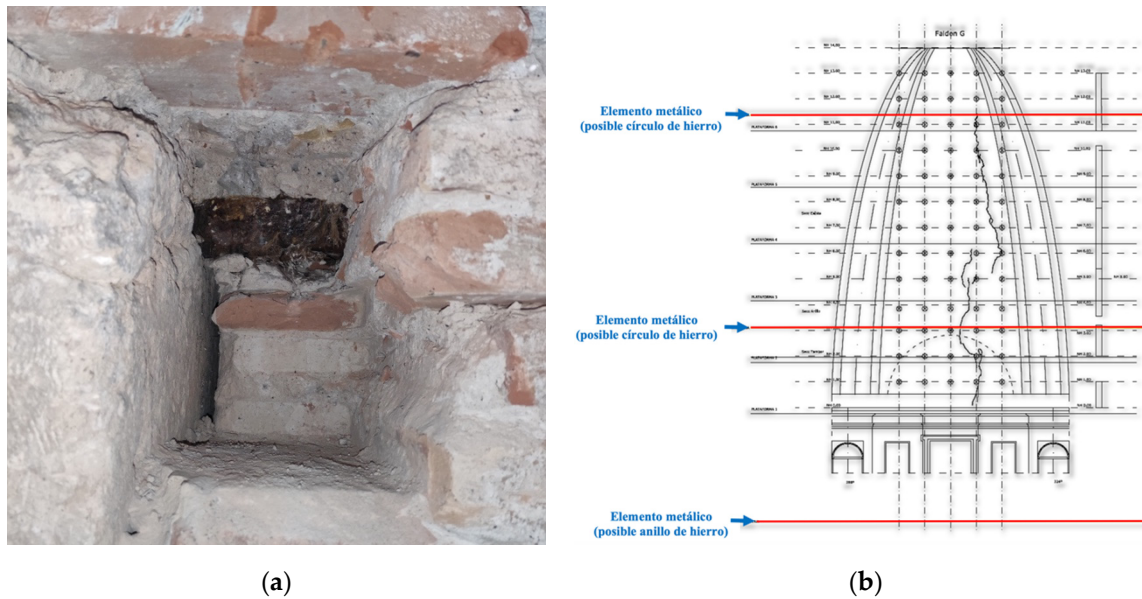


Figure 9. With the geophysical study, it became possible to find the iron rings: (a) archaeological window with an iron ring; (b) representation of the grid with the red lines representing iron rings.

Two campaigns were carried out, conducting profiles both on the extrados and the intrados. On the extrados, a complete profile was conducted, finding metal elements at 11.20 m and 16.50 m, measured from the inner start of the dome. Internally, based on the platforms of the available scaffolding system and the accessibility to the dome elements, geophysical radar profiles were projected to search for and locate metallic elements in three sectors:

1. In sector G of the dome, 28 geophysical radar profiles were projected in 6 levels, corresponding to the 6 platforms of the available scaffolding. The 900 MHz antenna was used in all profiles, and the 400 MHz antenna was also used in the profiles between platform 1 and platform 2. These geophysical radar profiles were arranged longitudinally and parallel to each other, spaced 1 m apart.
2. Likewise, on platform 2 of sector I of the dome, two geophysical radar profiles were projected with the 900 MHz antenna to corroborate the results of the profiles on platform 2 of sector G.
3. In an area of the lintel above the columns of the second body, one geophysical radar profile was projected to detect a possible iron ring using the 900 MHz antenna (Figure 10).

In these three sectors of the dome, a total of 31 2D geophysical radar profiles were conducted, and an archaeological window was opened to observe the mentioned ring. This consisted of a 5 cm × 5 cm iron bar covered with braided esparto, embedded in stone blocks approximately every 5 m.

Study of Thermal Behavior

Given the importance of the thermal behavior of the dome due to its mass, with a perimeter of 77 m and approximate volume of 4500 m³, a study of the thermal behavior of the dome has been conducted using Therm 8 software (Figure 11b) and sample collection with a thermal camera (Figure 11a) to enable its constructive parameterization. Various data captures have been made with the thermal camera, a Flir T530 camera, with the most satisfactory results occurring in winter due to the greater thermal contrast between the interior and exterior.

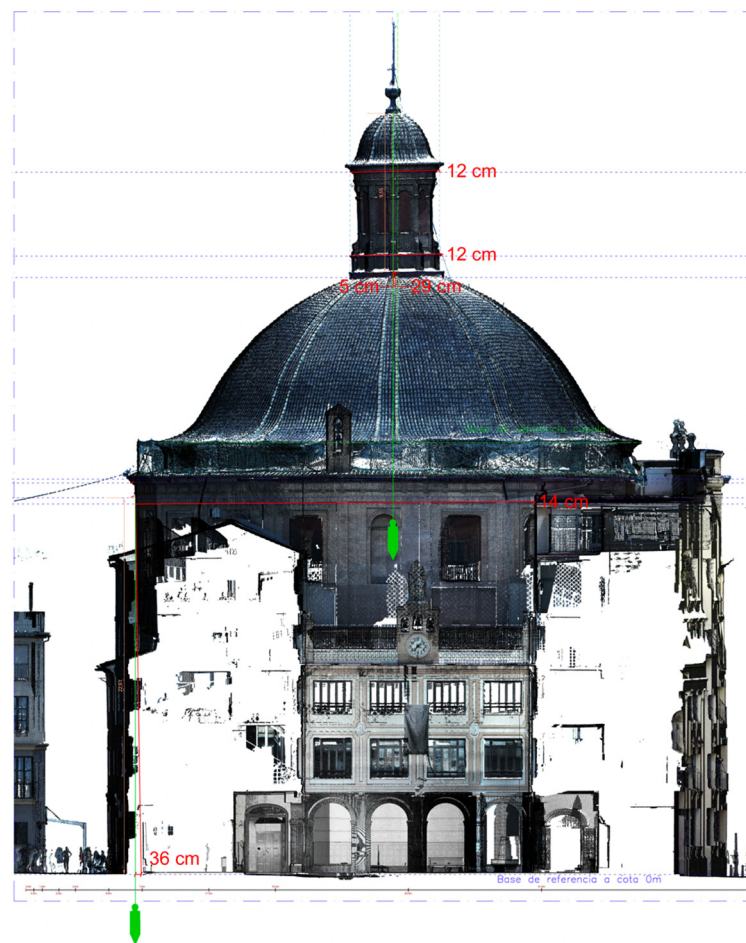


Figure 10. Study of the tilts using orthoimages obtained from 3D laser scanning (TLS).

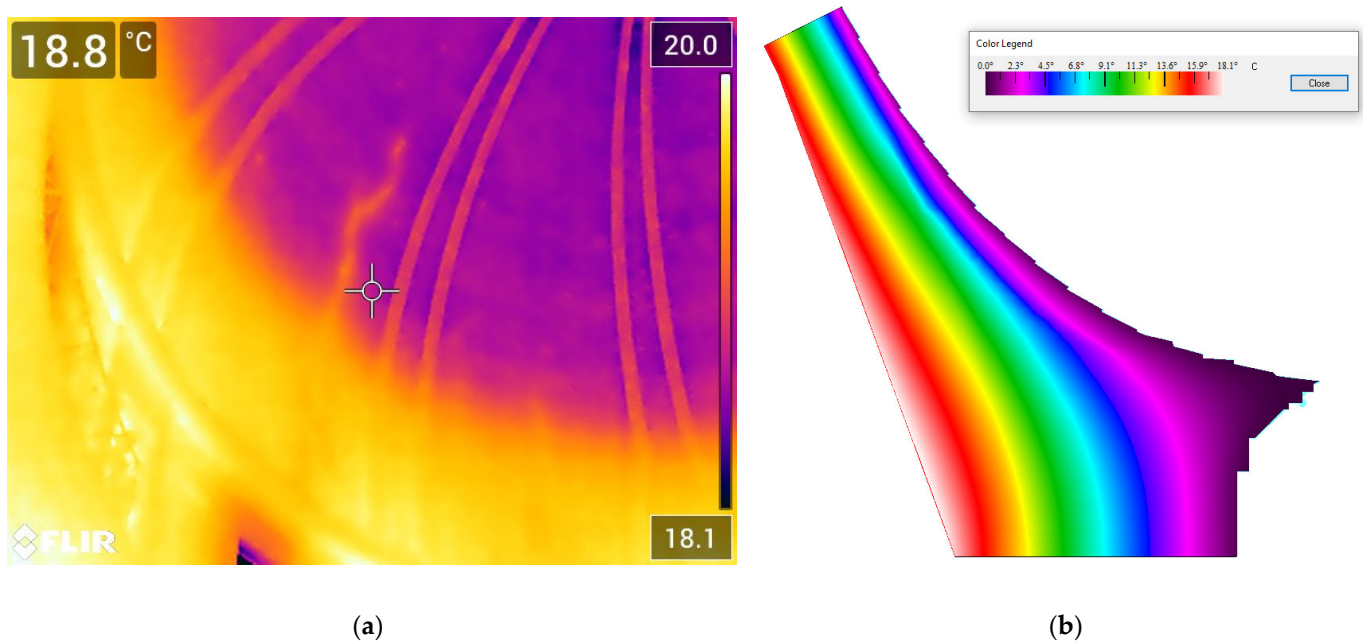


Figure 11. Thermal behavior: (a) image from the thermal camera, where the crack shows a thermal bridge; (b) parameterization of thermal behavior in the Therm 8 software, with an external temperature of 0 °C and an internal temperature of 20 °C.

From the observations with the thermal camera, it was noted that across the dome, from the intrados starting from the drum, the ribs increase their thermal inertia, highlighting thermal bridges caused by the cracks, which have since been repaired and sealed.

The construction materials exhibit high conductivity, with no thermal insulation present, leading to rapid heat transmission. The thermal insulation of the church is determined by the thickness of the construction solution rather than the properties of the materials.

A verification of the limitation of interstitial and surface condensations of the dome (main thermal envelope and most delicate construction and structural elements) has been carried out using the eCondensa2 program according to the Technical Building Code (Spanish national regulations), document DA DB-HE/2 [30]. This verification established an indoor temperature of 20 °C and a relative humidity of 55%, and for the outdoor conditions, a temperature of 10.4 °C and a relative humidity of 63%, resulting in a thermal resistance of 0.532 m²·K/W and a thermal transmittance of 1.881 W/m²·K.

The verification of surface condensation limitation was based on a comparison of the surface temperature factor for the interior surface (fR_{si}) and the minimum surface temperature factor for interior surfaces (fR_{si,min}) for the corresponding indoor and outdoor conditions in January for the city of Valencia.

Thanks to its construction arrangement, including a 2 cm thick inner layer of plaster, a 45 cm thick solid brick dome, a layer of lime mortar, and glazed ceramic tiles, a more than satisfactory result was obtained. This is because the saturation pressure is much higher than the vapor pressure, and no condensation occurs or accumulates. The graph shows two parallel lines (Figure 12), indicating the absence of condensation accumulation.

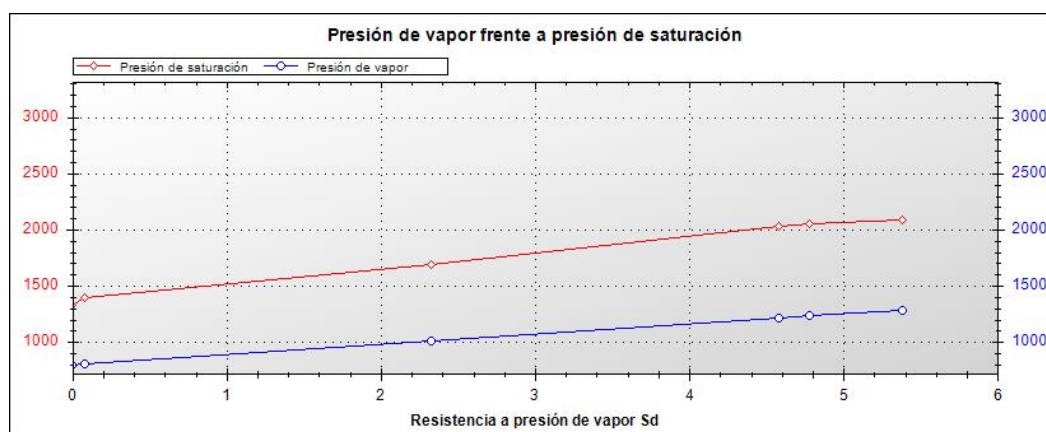


Figure 12. Study of the verification of interstitial and surface condensations of the dome.

4. Results and Discussion

These studies conducted to obtain a comprehensive understanding of the dome's construction are fundamental for addressing any other type of study, whether it be energy-related or related to structural behavior. Within this research, a new methodology must be established, which could include a thorough planimetric survey, a structural analysis, a pathological study, a study of collapses, and/or a geophysical study.

From the study of collapses, we know that the drum has a deviation of 36 cm from its base, and the horizontal planes in the dome bodies have rotated 14 cm. This study helps us address the disparity in opinions from all previous structural studies and explains the dome's cracks: as the drum deforms and there is a deviation, the ring cracks, and the dome readapts to the new stresses, resulting in cracks in the dome.

The pathological study provides all of the data needed to shape a project and make an architectural proposal, whether it involves repair, restoration, or consolidation. However, with the construction study and the complementary geophysical study, we can determine

anomalies—in our case, the chains mentioned in the 19th century—without having to carry out costly destructive testing.

The thermal study serves to confirm what experience has granted over time, which is that the dome is a simple enclosure without thermal insulation, built with highly conductive materials, and with insulation provided by the thickness of the dome, which is 50 cm.

One of the results of this research is that it is unknown whether the walls follow a pattern of movement or remain fixed over time. Witnesses to the work conducted on the dome have confirmed that the cracks have not opened, but it is unknown if there are any possible movements of the building. Therefore, the following methodological proposal is made for the sensorization of the dome to obtain real-time data and obtain a digital twin, following the HBIM methodology [31].

Measuring CO₂ levels is a key indicator to assess indoor air quality [32]. Thanks to energy efficiency standards, improvements in insulation, and materials, energy efficiency conditions have substantially improved. However, this can lead to a dramatic worsening of indoor air quality conditions. On the other hand, in a heritage architectural context, an excessive concentration of CO₂ can affect artistic elements such as fresco paintings or coatings like plaster or stucco, detracting from the monument's appearance and leading to its heritage degradation. Therefore, active ventilation is necessary to maintain a healthy environment and ensure the proper preservation of artistic assets. Additionally, with the use of CO₂ sensors, it is possible to generate alerts if levels are excessive to ensure a healthy and safe environment for users. It is through these sensors that the concentration of CO₂ in the air can be measured.

It is important to know the temperature and humidity levels of materials because they reveal the technical behavior of the materials in normal conditions, under extreme temperatures, or during sudden changes in temperature or humidity. With these sensors, ambient humidity and temperature are also obtained.

The church facade that faces the alley is leaning because there is no building to buttress it against horizontal forces. The value of this slant is 36 cm over the height of slightly more than twenty-four meters. Simultaneously, the entablature of the first ring of the drum has a vertical tilt towards the aforementioned alley of 14 cm, 2 cm more than that of the base and the top of the lantern. Additionally, the lantern is displaced from its ideal axis. By using an inclinometer, it will be possible to determine whether the building is stable or if movements of the building and/or the terrain persist. In the case of this being affirmative, the appropriate stabilization or foundation reinforcement tasks will be carried out.

5. Conclusions

In light of all of the studies and tests conducted on this dome (Figure 13), and with the aim of adapting to the 21st century and the new requirements that must be imposed for the conservation of architectural heritage, it is necessary to sensorize the dome to obtain a virtual model and to understand the behavior of the dome in real time by obtaining its virtual twin.

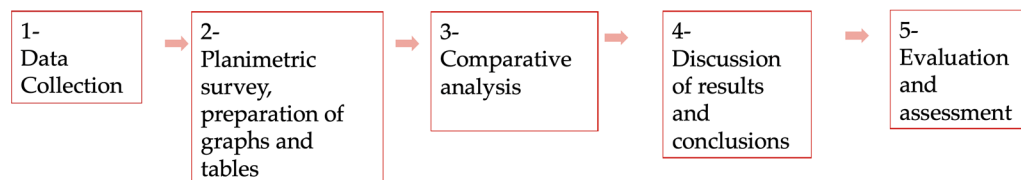


Figure 13. Phase chart.

From the records of the sensors in different orientations, it will be possible to evaluate the hygrothermal conditions of the enclosure. Different parameters of interest inside and outside the building, such as ambient temperature and relative humidity, will be obtained remotely, in real time, and continuously. Additionally, surface temperature and humidity sensors will also be installed to obtain a thermal profile. On the other hand, the analysis

of data during one or several annual cycles will allow us to evaluate the moments when there is a higher risk of condensation, if the existing ventilation is adequate, or the thermal inertia of the dome.

Through the monitoring of the dome of the Church of the Pious Schools of Valencia, the continuous evaluation of the dome's condition and indoor health is intended to improve its heritage management. This church is in continuous use, as it is the meeting space for the school, houses a museum space, and also maintains daily liturgical use. With digital tools and computer applications, minute-by-minute information on its temperature, humidity, and CO₂ levels will be obtained, facilitating user-access management of the interior, improving the building's energy efficiency, and, above all, minimizing the environmental impact on the monument and its coatings.

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