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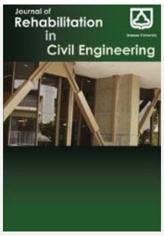

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Historical and Structural Analysis of the Lintel Fracture Over the Monastery of El Escorial Main Door

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ABSTRACT

Lintels are typical horizontal elements of the oldest buildings, especially in Egypt and Greece. Their presence has been constant throughout the centuries in countless buildings and constructions. When the lintels are masonry, they have many limitations due to their low flexural strength, which can cause their fracture. Here we analyze a very relevant case in a very significant monument. This article conducts a historical analysis to diagnose the moment in which the fracture of the lintel of the main door of the Monastery of El Escorial occurred and a structural analysis to diagnose the causes and danger of this fracture. Analyzing the fractured lintel on the main entrance door of the Monastery of El Escorial is important for several reasons related to its historical, architectural, and conservation significance. A fractured lintel could indicate broader structural issues that, if not addressed, could compromise the building's stability, or simply be a logical consequence of the normal functioning of this structural element.

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1. Introduction

The Monastery of San Lorenzo de El Escorial was designated a World Heritage Site on November 2, 1984 [1]. Built during the second half of the 16th century under the direction of King Philip II of Spain, the Monastery was created to fulfill two main objectives: to honor a promise made in gratitude for victory in the Battle of San Quentin, fought on August 10, 1557, Saint Lawrence's feast day, and to serve as a royal mausoleum for his parents, Charles I of Spain and Isabella of Portugal [1,2].

Construction commenced in 1563 [1] and was completed in 1584 [2]. The original architect, Juan Bautista de Toledo, initiated the project but passed away in 1567 before its completion. Juan de Herrera took over the project and introduced adjustments to the initial design to accommodate emerging requirements for the Monastery [2,3].

Philip II was deeply involved in the construction process, actively reviewing plans and visiting the site frequently to monitor progress [2].

The resulting structure is an immense rectangular complex measuring 207 meters by 161 meters, covering a total area of 33,327 square meters. Situated on the slopes of the Sierra de Guadarrama near Madrid, the building features a tower at each corner, each standing 55 meters tall and topped with a slate spire, a metal sphere, a weather vane, and a cross (Fig. 1). Although the structure's layout is broadly rectangular, its floor plan forms a grid pattern, symbolizing the gridiron used in the martyrdom of Saint Lawrence, to whom the Monastery is dedicated. A statue of the saint is prominently displayed above the main entrance (Fig. 2).

The lintel that we study in this article is located above the main door, on the west facade (Fig. 3). This is the main entrance leading to the Patio de Los Reyes.

Fig. 1. Southern facade of the Monastery of San Lorenzo de El Escorial (photograph by the author).

Fig. 2. Primary entrance to the Monastery of El Escorial, located on its western facade (photograph by the author).

Fig. 3. Principal entrance to the Monastery of El Escorial on its western facade, where the lintel discussed in this article is situated (photograph by the author).

2. Materials and methods

By the main facade of the Monastery of El Escorial we mean the west facade. If we analyze the floor plan of the Monastery (Fig. 4), we can see that we are talking about the back part of the San Lorenzo gridiron. As we will analyze later, this was one of the last parts of the building to begin construction [2–4].

In the center of the main facade is the main entrance (Fig. 2). It is not the only door to the Monastery, but it is the most used because it allows direct access to the Basilica. The visitor only has to cross a small arcade (room 49, Fig. 4) to immediately enter the Patio de Los Reyes (48, Fig. 4), which is the forecourt of the Basilica.

This single-span entrance is possible thanks to two one-piece lintels, arranged one above the other, with a small cornice above them (Fig. 3). We do not need to get very close to notice striking fractures in these two elements. Here we are going to try to explain these fractures and assess whether they present any cause for concern.

To carry out this work, the first thing we did was a complete geometric characterization of the door (Fig. 5) using a tape measure and a laser measure [5]. With them, we determined the dimensions of the single-span entrance (3.38 m x 6.72 m), the first lintel, and the lateral stone supports.

To obtain a better geometric definition and estimate its structural behavior, a three-dimensional representation of the lintel was also made (Fig. 6). The geometric measurement also allowed us to quantify the deflection in the middle of the monolithic stone lintel, which was 6 mm.

Afterwards we carried out a visual inspection of the elements. Given the location of the element to be analyzed and the difficulty of approaching it, to carry out a more detailed inspection we used drones (Fig. 7). The effectiveness of drones has already been demonstrated in this type of inspections [6,7]. We made two inspection flights with different drones:

- The first inspection used a drone with fisheye camera (Fig. 7, above), model Parrot Beebop 2. This inspection was carried out during May 2021.
- The second inspection was with a drone with a 4K camera (Fig. 7, bottom), Parrot Anafi model. This inspection was carried out during September 2023.

With the photographic material obtained in both inspections, we made up an exhaustive photographic report. This report allowed us to conduct a very detailed lesion mapping (Fig. 8 and Fig. 9). We were not only able to locate and analyze all the fractures produced in the lintel, but also verify that attempts had already been made to disguise these fractures. However, these attempts were in vain, and the fractures are still clearly visible on the lintels today.

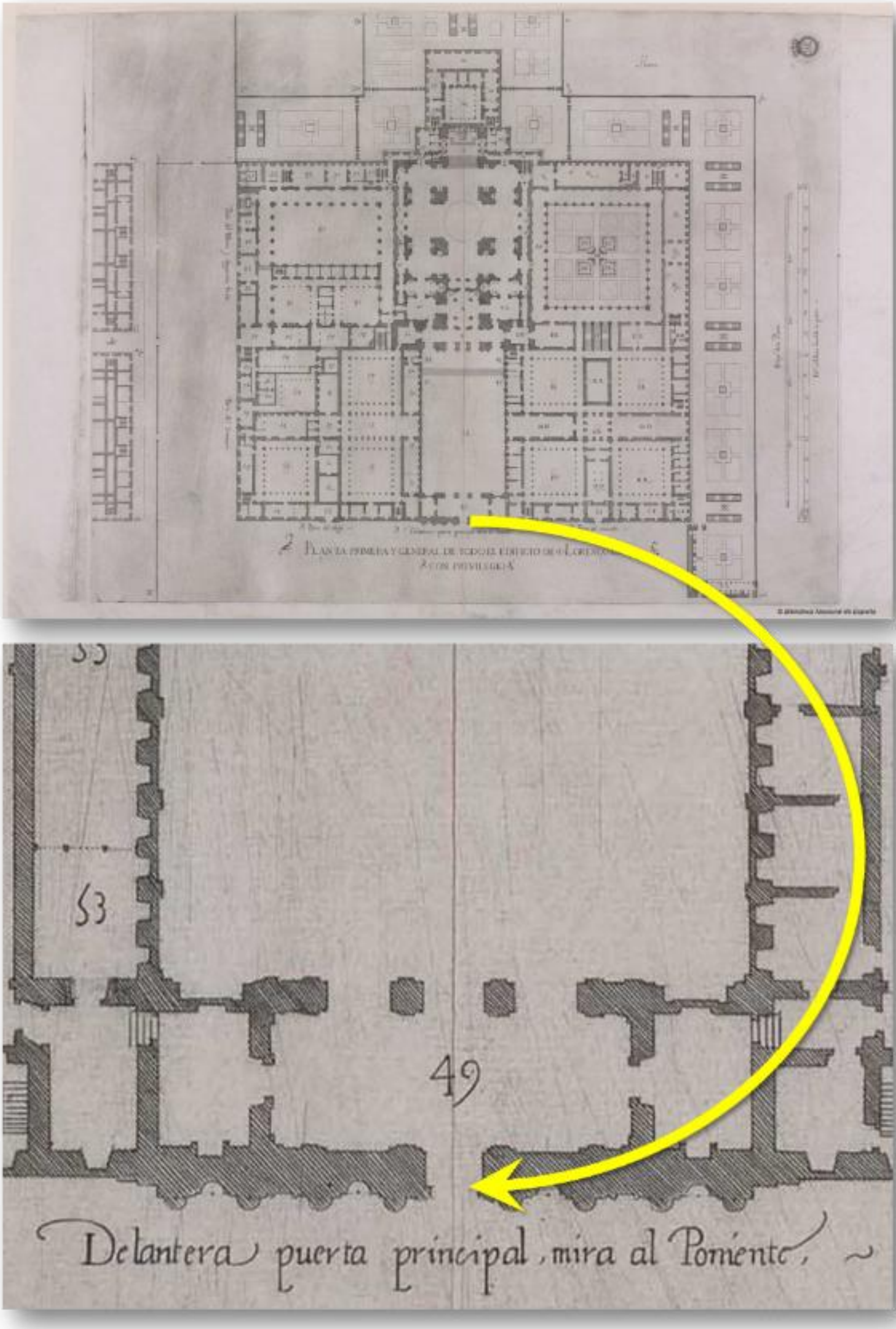

Fig. 4. Ground-level floor plan of the Basilica, showing the location of the main entrance. The door provides access to room (49), which opens onto the Patio de los Reyes (graphic created by the author based on a plan by Juan de Herrera [8]).

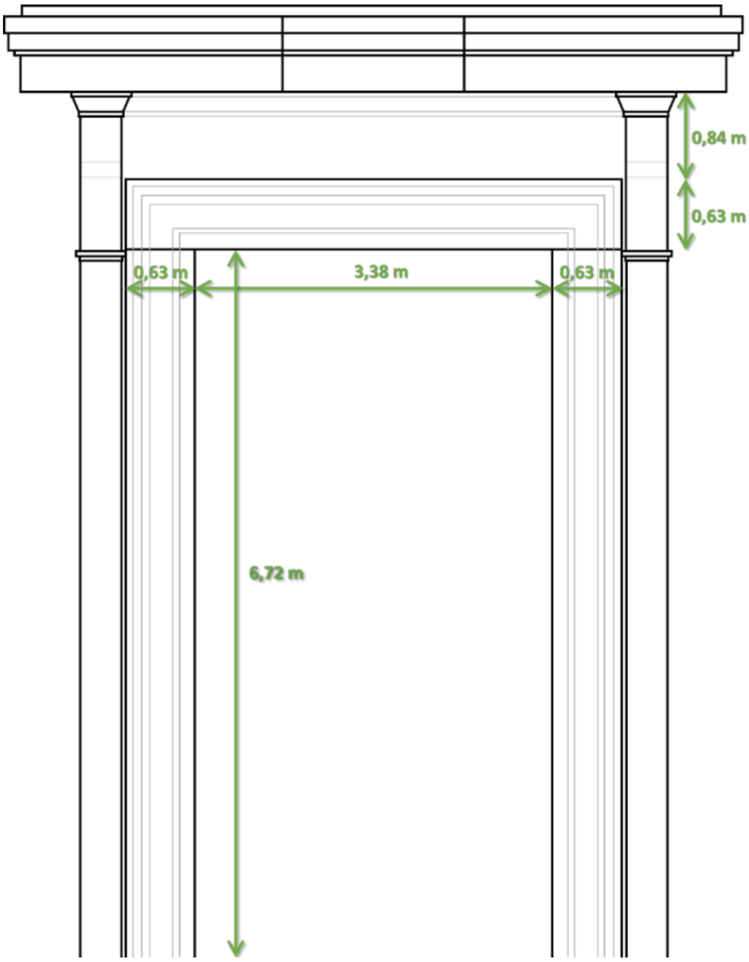

Fig. 5. Geometric definition of the entrance door on which the lintel analyzed in this article is located (graphic by the author).

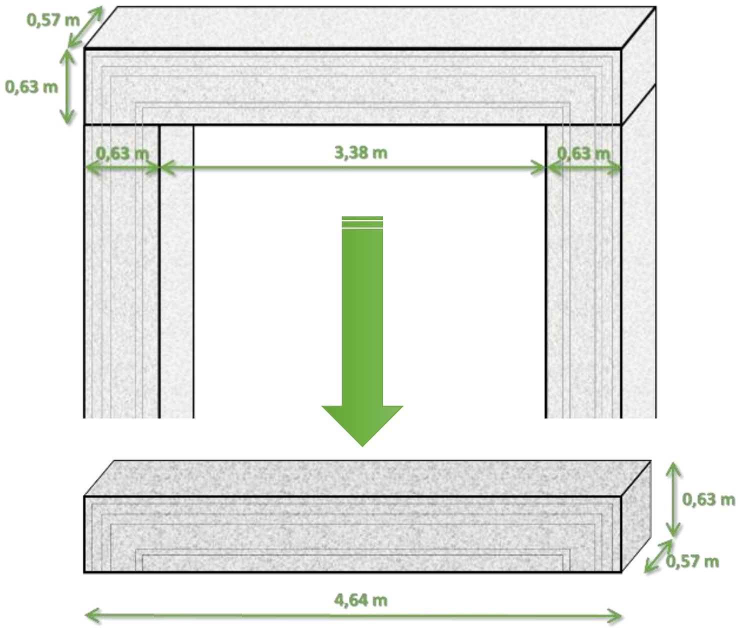

Fig. 6. Three-dimensional representation of the monolithic stone lintel and its two supports (above) and representation of the isolated monolithic stone lintel (below) with its dimensions (graphics by the author).

Fig. 7. Drones used in separate reconnaissance operations of the lintel analyzed in this article: the first flight (top) was carried out with a drone equipped with a camera and the second flight (above) with a drone equipped with a thermal imaging camera (photographs by the author).

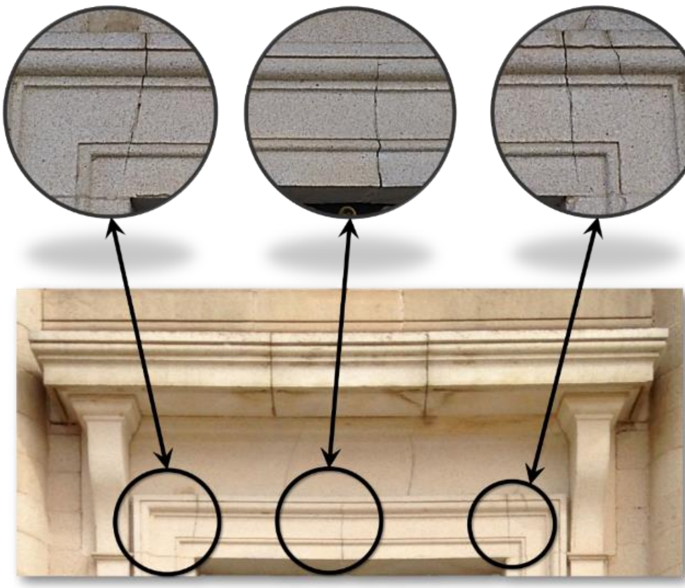

Fig. 8. Details of the main fractures visible in the lintel above the door, in photographs captured by drone. In addition to the cracks, we can observe remains of materials used in unsuccessful restoration operations (photographs and graphic by the author).

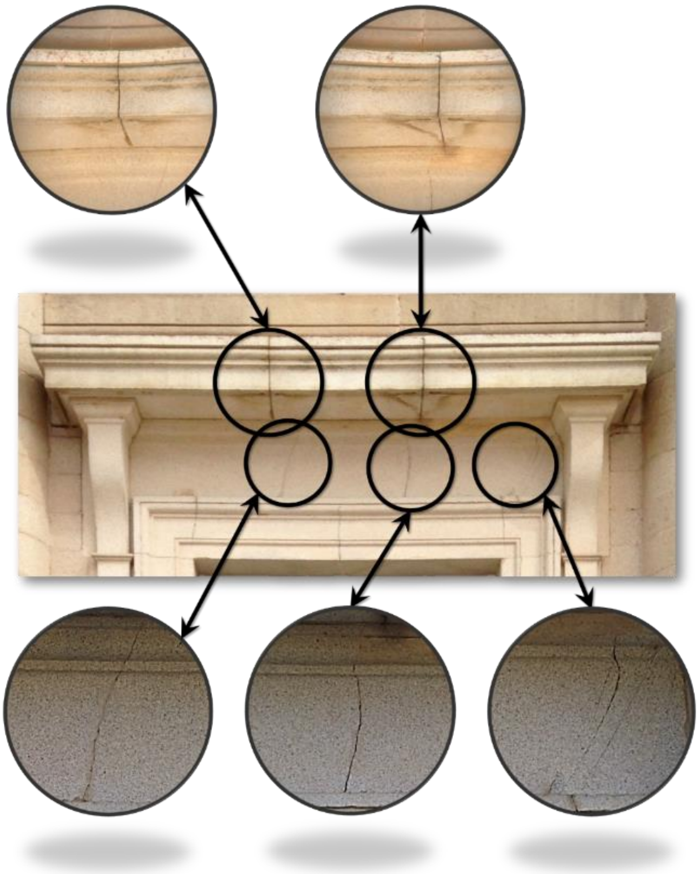

Fig. 9. Details of the main fractures visible in the over-lintel, which rests on the element in Fig. 8. , in photographs also captured by drone. In addition to the cracks, we can also observe remains of materials used in unsuccessful restoration operations and water marks from runoff on the cornice (photographs and graphic by the author).

To check whether these fractures affected the durability of the structure, we examined the elements using thermography, taking advantage of the characteristics of this technology [9–11]. To do this, we used a simple Flir thermal imaging camera (150 mK thermal sensitivity), which resulted in various frames and thermograms (Figure 10). The characteristic parameters of this thermographic capture were the following:

- Emissivity: 0.95
- Distance: 1m
- Reflected temperature 22℃
- Relative humidity: 50%
- Atmospheric Temperature 20℃
- Atmospheric transmission 0.99
- External optical temperature 25℃
- External optical transmission 1

The construction element we analyzed is located 6.85 m above the ground (6.72 m of span + 0.13 m entrance step). Given the height of the author of this article (1.85 m), the focus angle of the thermal imaging camera was unsatisfactory, so the information provided by terrestrial thermography had to be corroborated using aerial thermography: a drone with a thermal imaging camera could be located in the optimal focusing position [12]. For this reason, the drone we used on the second flight (Fig. 7, bottom) had a built-in thermal imaging camera. With it, we were able to obtain new frames (Fig. 11) that allowed us to verify that the information provided by terrestrial thermography was adequate. To capture it, the drone was positioned at the same distance from the wall as the terrestrial thermal imaging camera that captured the thermogram of the Fig. 10: 1.00 m. Thus, both thermograms could be perfectly compared.

With the material we obtained in these reconnaissance operations, and complete bibliographic research, we were in a position to analyze the lintels and their fractures.

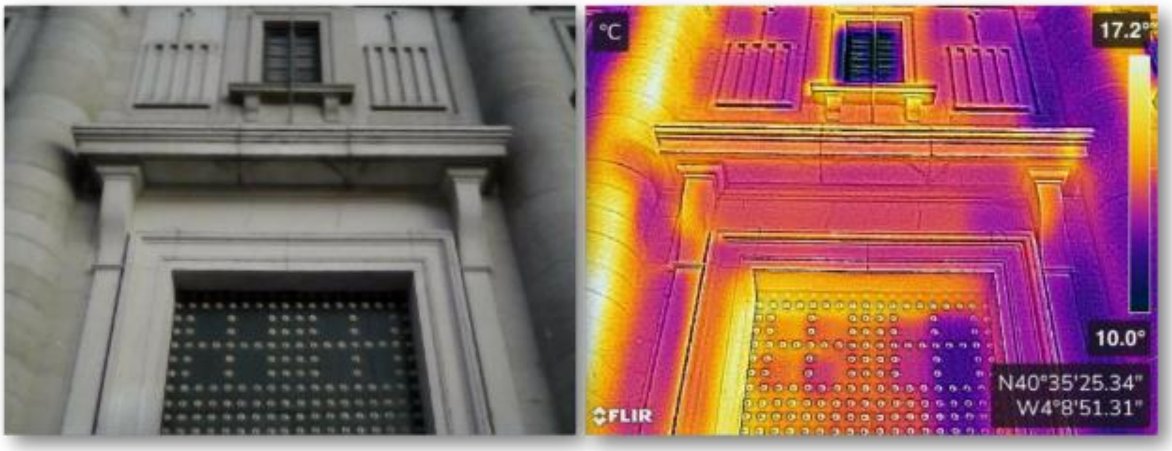

Fig. 10. Photogram (left) and thermogram (right) of the monument area analyzed in this article, in images captured by terrestrial thermography, with a thermographic camera (photographs by the author).

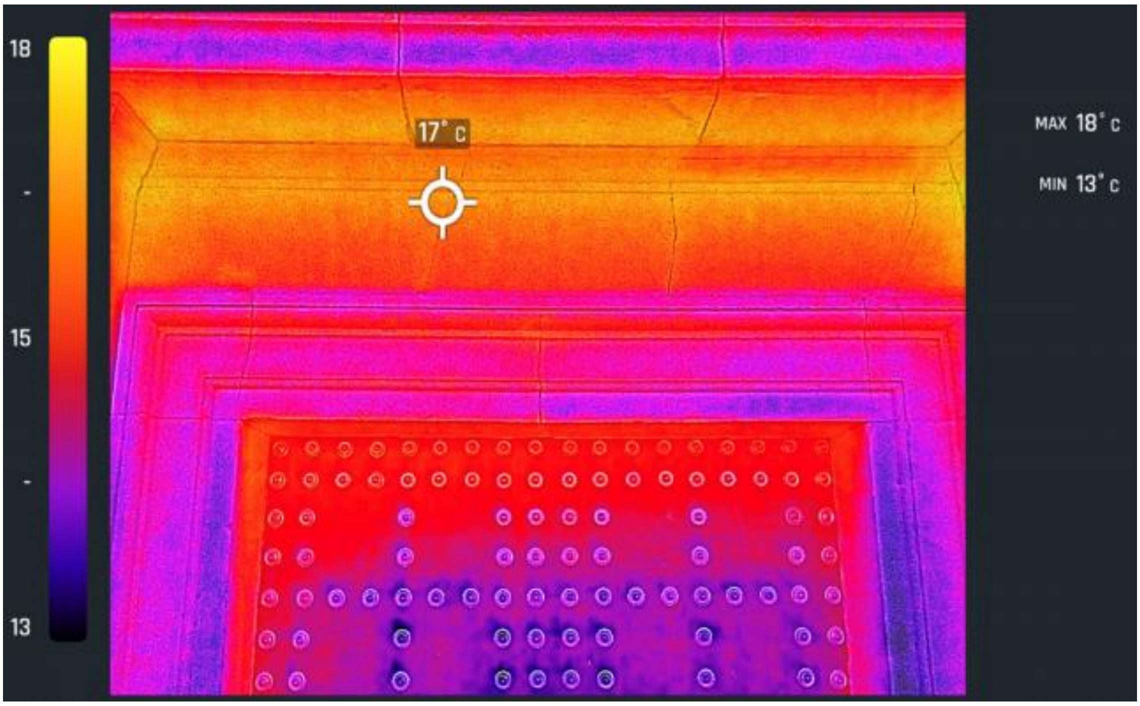

Fig. 11. Thermogram captured by aerial thermography, using the drone seen in Fig. 7, in the lower photograph (photo by the author).

3. Results

The first element that we are going to use for our analysis is a drawing made in 1576 and attributed to Fabrizio Castello, kept at Hatfield House (Fig. 12). In addition to reflecting the importance of the construction of the Monastery of El Escorial in its time, it offers extensive information about the construction procedures of the period [13,14]. The drawing is an aerial perspective of the monastery taken from the east [15], which is the rear part of the monastery (facade opposite the main entrance facade).

This drawing is very interesting because it perfectly describes the dynamics of the construction work, its organization and the work that was being carried out at the time when the execution of the basilica began (central area of Fig. 12). In the picture we can see the location of the cranes and the distribution of the different tasks by areas and equipment [16]. The drawing was made according to construction plans and hand notes [13–15]. The plan defines the axis of the Basilica and the palace areas. Human figures appear out of scale [14].

When Juan de Herrera took over as the chief architect, the number of Hieronymite monks expected to inhabit the monastery increased significantly, doubling from the original plan [2,3]. This expansion of the monastic community required a shift in the project's direction and led to numerous modifications to the original plans. One of these variations on the original solution was the construction of one more floor on the main facade. At the time Castello drew his work, the central area of the main facade had not yet begun to be built (Fig. 12).

Fig. 12. Drawing of the construction of the Monastery of San Lorenzo de El Escorial, by Fabrizio Castello, in 1576. Hatfield House (British Library [17]).

Fray José de Sigüenza, a close advisor to Philip II and the librarian of the Monastery of El Escorial, spent his final years living within its walls. He witnessed the monastery's construction from its inception and greatly appreciated the architectural significance of this monumental project. In his work, Historia Primitiva y Exacta del Monasterio del Escorial, Sigüenza pointed out several interesting things [2]:

1. The front door is 12 feet wide and twice as high, 24 feet.
2. The lintel and over-lintel are whole stone pieces. Both were cut from the same rock.

3. Because of their size, a cart pulled by forty oxen was needed to bring these elements from the quarry to the construction site, one at a time.
4. Due to the large size of the gap, the lintel broke in half when it had already been placed.
5. The weight of the over-lintel did not cause the previous fracture: the lintel split under its dead weight.
6. The fracture caused was barely visible and it was not feared that it implied a lack of solidity or firmness in the element.

This provides us with information of great value: the damage that we now observe is not recent; some of these fractures, at least the central one, occurred practically during the execution. Sigüenza also pointed out that, according to Vitruvius, this was within the foreseeable [2]. Indeed, in his work De Architectura (Ten Books on Architecture), in the third chapter of the third book [18], Vitruvius established that every lintel supported on two columns must have “intercolumniations of three diameters” (“cum trium columnarum crassitudinem intercolumnio interponere possumus” [18]).

As the first section above points out, the span of the door measured 12 x 24 feet. Fray José de Sigüenza, in another section of his book [2], explains that the Castilian foot is one third of the Castilian vara, which has four palms, and each palm four fingers, and each finger four grains of barley crab, which is the last resolution and the indivisible to which the measure of quantity is reduced. The friar adds that the Castilian foot is the unit of measurement in which the designs of the monument are made and the building constructed.

If we accept that the Castilian foot is equivalent to 0.278635 meters [19], we would have the span to measure exactly: 3.34362 x 6.68724 m, which is close enough to the measurement made in situ to write this article (Fig. 5). We can see that, in both measurements, we have a few centimeters more distance, probably the result of the wear of the material over the four centuries that have passed. In this case, it was evident that this relationship of values was violated:

- Measured column width (Fig. 5) = 0.63 m.
- Span according to Vitruvius = 3 x 0.63 m = 1.89 m.
- Measured span = 3.38 m, which is 50% more than the span postulated by Vitruvius.

When it was not fulfilled, Vitruvius warned: “haec dispositio hanc habet difficultatem quod epistylia propter intervallorum magnitudeinem franguntur” (“the inconvenience of this species is, that the architraves over the columns frequently fail, from their bearings being too long” [18]). Therefore, the architects and builders of the Renaissance (such as Juan de Herrera), who knew Vitruvius's work well, should not have been surprised that a monolithic stone lintel over a span greater than that established by Vitruvius would fracture.

It is true that this comparison with the relation proposed by Vitruvius seems inappropriate, because the width of the column is compared with the width of the jamb, as next to the jamb there is masonry and not a void. However, the characteristics of this lintel construction and the importance of Vitruvius at the time of its construction justify this comparison.

Therefore, Fray José de Sigüenza was aware of at least the central fracture of the lintel, dating it securely before his death in 1606 [2]. Likewise, thanks to Sigüenza we know that the cracking was downplayed. This information is very important: despite how unsightly and apparently dangerous the fractures are (Fig. 13), they seem to have been there from the beginning, and never to have been a cause for alarm. Juan de Herrera, a great expert on lintel construction [20], accepted these fractures without concern [21]. Similarly, since the over-lintel cracks are closely related to the lintel cracks (Fig. 14), we can also accept that they occurred practically simultaneously.

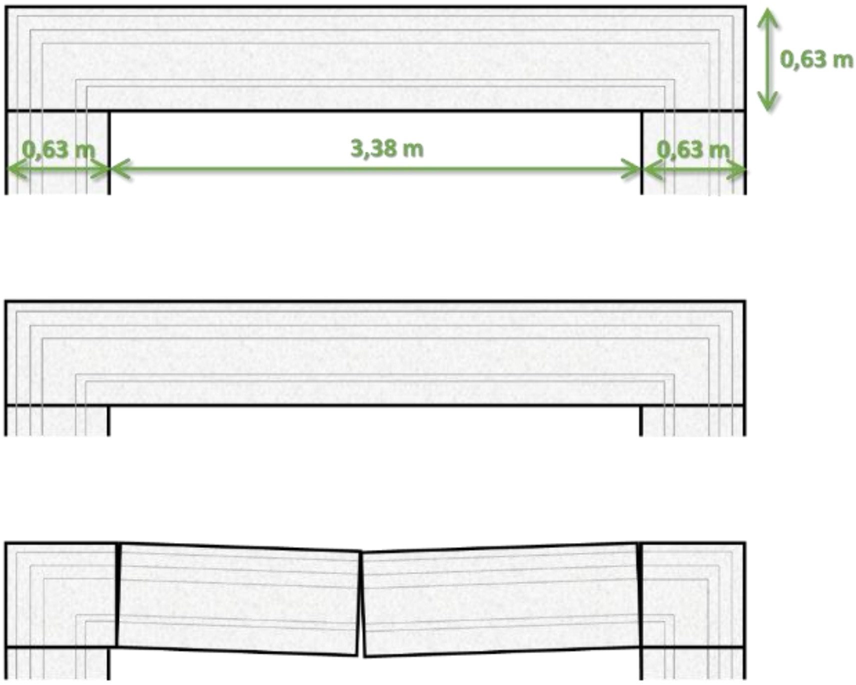

Fig. 13. Geometric definition of the first lintel (above), with representation of its ideal state of conservation (center) and exaggerated representation of the fracture processes (below) that we can currently see (graphics by the author).

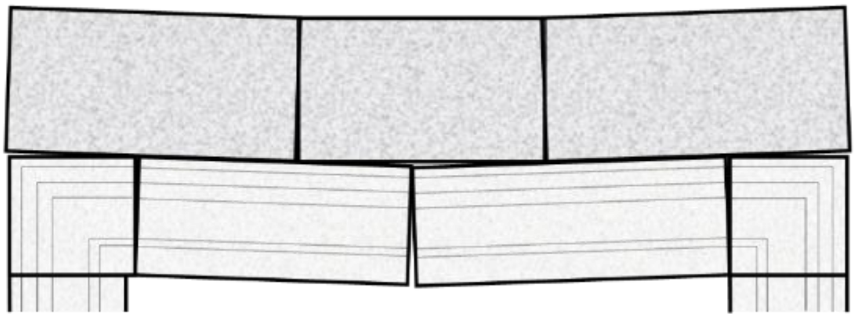

Fig. 14. Exaggerated representation of the fracture processes that we can currently see, including the over-lintel (graphics by the author).

4. Discussion

We could assume, as a starting point, that our lintel (Fig. 13) is a double-embedded beam for the purposes of mechanical operation, recording the corresponding shear stresses and bending moments, considering the entire overlying load as a uniform load (Fig. 15).

To estimate the overlying load, the average height of the facade above the lintel and over-lintel has been taken into account: 27 m. Obviously, this approach entails three considerable errors that we cannot ignore:

1. The height of the facade is not constant nor is it uniform: for example, there is a gabled facade. For this first approximation, the average height in the studied facade area has been considered.
2. The thickness of the facade is neither constant nor uniform. For this first approximation, a thickness similar to the thickness of the lintel has been considered.
3. Facade openings have not been discounted nor have facade irregularities been considered for calculation purposes. For example, above the entrance door there is a window.

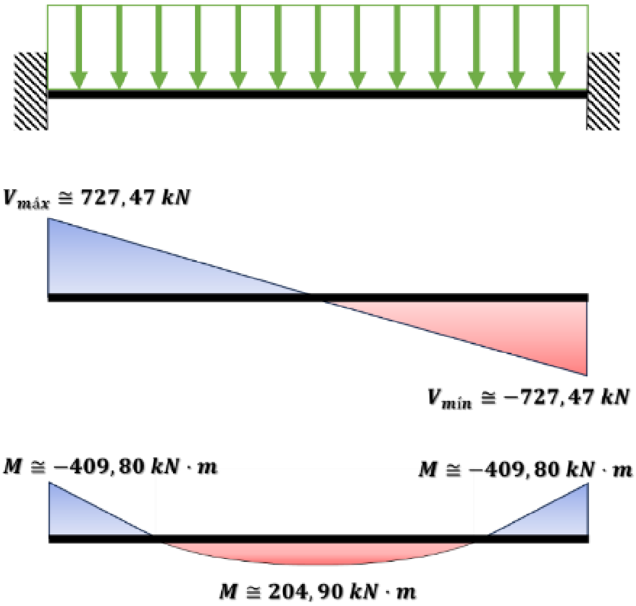

Fig. 15. Synthesized representation of the uniformly distributed load that acts on the double-recessed lintel beam (upper diagram), resulting shear force (middle diagram) and moment (lower diagram) (diagrams by the author).

These three reasons show that the uniformly distributed load represented in Figure 13 is not correct: it does not correspond to reality, because the load supported by the lintel is not uniform. Therefore, we cannot assume the resulting values.

Therefore, initially we could not accept such values. However, the complete analysis of the data, omitting the three previous conditions, would give us a stress diagram similar to that in Figure 16, with the resulting shear force and moment. Note that the values obtained do not differ significantly from the previous ones.

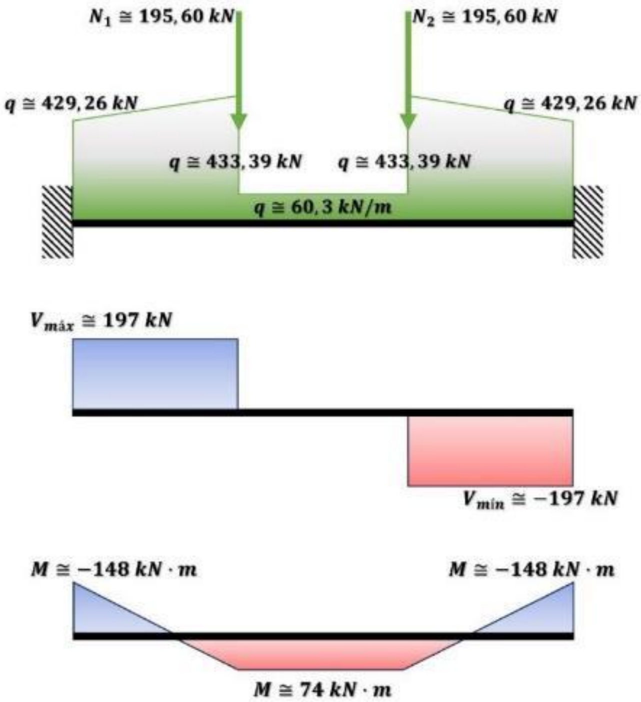

Fig. 16. Synthesized representation of the real load distribution that acts on the double-recessed lintel beam (upper diagram), resulting shear force (middle diagram) and moment (lower diagram) (diagrams by the author).

However, we cannot validate this hypothesis. The consideration of the embedment before rupture is correct, but to the extent that its moment is double at its ends than in the middle of the span of the structural lintel. The design simulation in (Figure 15 and Figure 16) has nothing to do with the actual structural reality defined Figure 13. The limit analysis referred to in this article must be performed on Figure 13 and the joints created therein. Since the stress diagrams do not clarify this process, we must justify how the process of its rupture and the current stability process was carried out.

Most surviving ancient structures are masonry structures, aggregates of stone materials. In some cases, specific contributions of wood were added. Stone materials are brittle, with very low tensile strength. Therefore, we can only take advantage of their compressive strength.

In masonry elements, breaks appear without steps of deformation, because in these structures there is hardly any elastic deformation. Therefore, conducting a stress-strain analysis is not appropriate for this type of structure.

The masonry beams (and the monolithic stone lintel, of course) are almost completely deflectionless (the low tensile strength confers low bending deformability), meaning the maximum ordinate of the deformed lintel between the two support points. As we said in the previous paragraph, masonry beams do not experience elastic deformation. Masonry beams can have displacements, they can have shifts, or they can have translations, but they can never have deflection.

This aspect is fundamental to understand that masonry structures have to be in equilibrium. However, due to their character as an aggregate of independent elements, with no link between them, their structural behavior raises a multitude of hyperstatic unknowns. For this reason, we cannot analyze masonry structures from the theories of elasticity and resistance of materials. Many traditional errors in the analysis of masonry structures have occurred by assuming elastic behavior that these elements cannot have.

In masonry structures, resistance is not the problem in compression because the section of the structural element is always overabundant. The granite lintel of the Monastery's facade is an example of this: its section is 0.63 x 0.53 m. However, in the analyzed lintel the crack occurs due to reaching the (very low) tensile strength and only after this happens, the described later thrusting mechanism develops.

In masonry structures, rigidity is not the problem either, because the materials support little stress in relation to their breaking stress. However, masonry structures are very sensitive to changes in stability. In other words, masonry structures are very sensitive to load modifications that can cause changes in shape. As masonry materials are rigid and compressive materials and do not have tensile strength, they can crack or modify their shape and, thus, alter their balance. This is the central question of the analysis of masonry structures, at least in relation to the lintel of El Escorial.

We may think that a masonry structure, in theory, can hardly tolerate changes in load position for a given shape. However, the self-weight of the masonry elements is the main effort and is highly conditioned by the shape of the element. Thus, accidental overloads are significantly lighter than the structure’s own weight. These overloads are assumed by slight modifications of the pressure line that are unimportant.

The origin of pressure in any masonry structure begins in the transmission of the weight of one element to two adjacent lower elements. This transmission must be carried out at all points of the masonry structure. Thus, what begins as a vertical load to the ground is immediately transformed into a weight plus a horizontal load that must be resisted at all points.

This requires the carving of the ashlars to favor this transfer of horizontal load, especially on the edges where there is no counterbalance. For this reason, the lintel has clamped support: it is mechanically responsible for guaranteeing the fixed position. In other words, it ensures stability.

We cannot forget Jacques Heyman's three postulates about the stone skeleton [22]:

1. Masonry structures have no tensile strength. As we said before, the materials used in the construction of masonry structures have a negligible tensile strength. Therefore, we can do without it.
2. The stresses supported are low enough not to allow crushing of the material. Therefore, we can consider the compressive strength unlimited.
3. Sliding failure is impossible. Friction between masonry elements is high enough to suppose that they cannot slide over one another. Furthermore, the shear forces are very low.

A masonry structure supports loads due to its geometrical form. If this varies due to external or internal causes, flexures will appear that cannot be resisted by fragile compressive materials. We accept, therefore, something evident due to its non-deformability: a masonry structure does not modify its shape in the analysis, and this is carried out for a given shape since not all shapes are stable.

The arch and its derived elements (the vault and the dome) are the tools that allowed masonry structures to overcome their main deficiency: zero tensile strength. In ancient Egypt and ancient Greece, whose constructions were lintel-based, these construction elements were unknown [23–25]. However, when the Monastery of El Escorial was built, they were well-known, as evidenced by the presence of various vaults and domes inside the building [2–4,16,21].

At this point, we can turn to an article by Jacques Heyman which questions the traditional division between lintel construction and vaulted construction [24]. Heyman considers that, as in El Escorial, there are single-span lintels that end up functioning as an arch. In this case, balance is possible if there are abutments capable of causing the precise horizontal reaction.

According to Heyman, all structures function as an arch [24] and it is very important to discover the arch lodged inside. On the one hand, depending on whether its geometric shape corresponds to an anti-funicular load, the structure will function under compression. But on the other hand, the more its geometric shape differs from this anti-funicular load, the more auxiliary bending mechanisms the structure will use. In other words, and in accordance with Heyman's approach, we could say that a lintel is a poorly designed arch because it transfers the loads received through bending.

In Figure 17 we can see an example. In this case we have a brick voussoir lintel over the garage door of a residential building located in Madrid (Spain). Heyman's approach that all structures function as an arch is also applicable to voussoir lintels. The fractures that we observe reflect the departure of the geometrical form of the lintel from the anti-funicular curve.

To try to better understand the phenomenon of the lintel of the Monastery of El Escorial, we are going to resort to the strut and tie method, which can represent the field strength against external loads in a masonry structure [26–28]. According to this method we have prepared Figure 18. If we follow Heyman's theory, this lintel initially behaved as a piece embedded at its ends (Figure 15 above). This lintel was fundamentally subject to two external actions:

- The dead weight of the lintel
- The vertical load of the overlying elements (Figure 15 above).

These loads induced the appearance of bending moments in the critical sections (clamped support and center of the span, according to the diagram in Figure 15 below) greater than the cracking moments. Fractures are the visible manifestation of this (Figure 8 and Figure 13).

If we stick to the classic concepts of strength of materials for linear elements lacking reinforcement, it would be impossible to ensure the balance of this element.

Fig. 17. Cracks on a masonry voussoir lintel (a brick plante-bande made of ceramic brick and cement mortar) that show the pressure line now inscribed on the lintel (photographs and graphic by the author).

However, the testimony of Fray José de Sigüenza reveals that at least the fractures are more than four hundred years old. Over so many years the balance has been maintained. This has been made possible by the formation of a pair of inclined compression struts. These struts transmit compression from the upper compressed zone of the center of the span to the lower part of the support points. The abutments are infinitely rigid. They are able to provide horizontal counteracting forces that balance the horizontal components.

The reaction on the clamped support (green arrow in Figure 18) is a counter reaction. It is essential to ensure the structural equilibrium of the lintel.

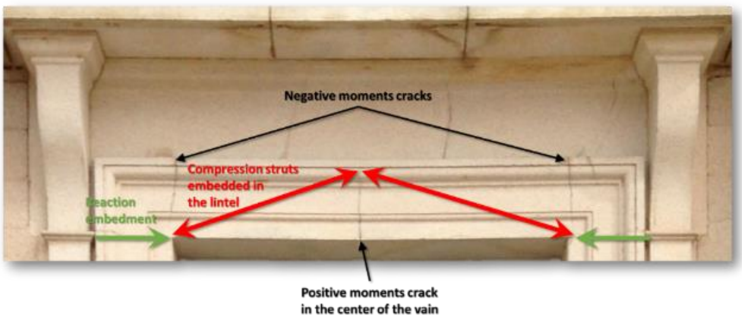

Fig. 18. Strut and tie method applied to the lintel analyzed in this article, to justify its current structural equilibrium state (photo and graphic by the author).

This would demonstrate that the lintel experienced a predictable logical and technical reaction. It is a monolithic stone lintel which, before breaking, work in bending as a beam and do not thrust. Indeed, despite being a lintel (linear element, not curved), it ended up becoming an arch. For a structure to collapse or destabilize, it must be able to execute the degree of freedom that determines it. Even if there have been multiple previous breaks that indicate this, if the fractured element cannot move because it lacks this degree of freedom, it will hardly be able to collapse.

Finally, we must add that the thermographic analysis carried out on the lintel (Figure 10 and Figure 11) corroborated the absence of damage in the different fractures. Not capturing chromatic variations in the thermograms obtained with thermographic cameras (Figure 10 and Figure 11) means that this type of phenomenon is not occurring: there are no deterioration processes related to the presence of humidity (possible frost inside the fractures), related with thermal expansion (or contraction) or related to a possible attack by salts (crypto-efflorescence). Therefore, these fractures do not represent a durability problem for the granite that makes up the lintel.

Following the analysis of Viollet Le Duc [25], Heyman began his reasoning for the conversion of every lintel into an arch in the constructions of ancient Greece [24]. Figure 19 shows one of the oldest examples, pointed out by Heyman in his article: the Temple of Zeus in Athens. Heyman himself pointed out that, in this case, the architrave has sagged slightly to reveal a wedge-shaped crack at the center of the span.

Figure 20 shows various examples of lintels over doors and windows in the Monastery of El Escorial. While they are less representative elements than the lintel that we analyze here, they all demonstrate that the fracture of the entrance lintel was not an anomalous event in the construction of El Escorial.

Fig. 19. Photograph of the Temple of Olympian Zeus in Athens showing a detail of the Corinthian capitals. The green arrow marks a fracture on the lintel in the center of the span (photo by Wikipedia [29]).

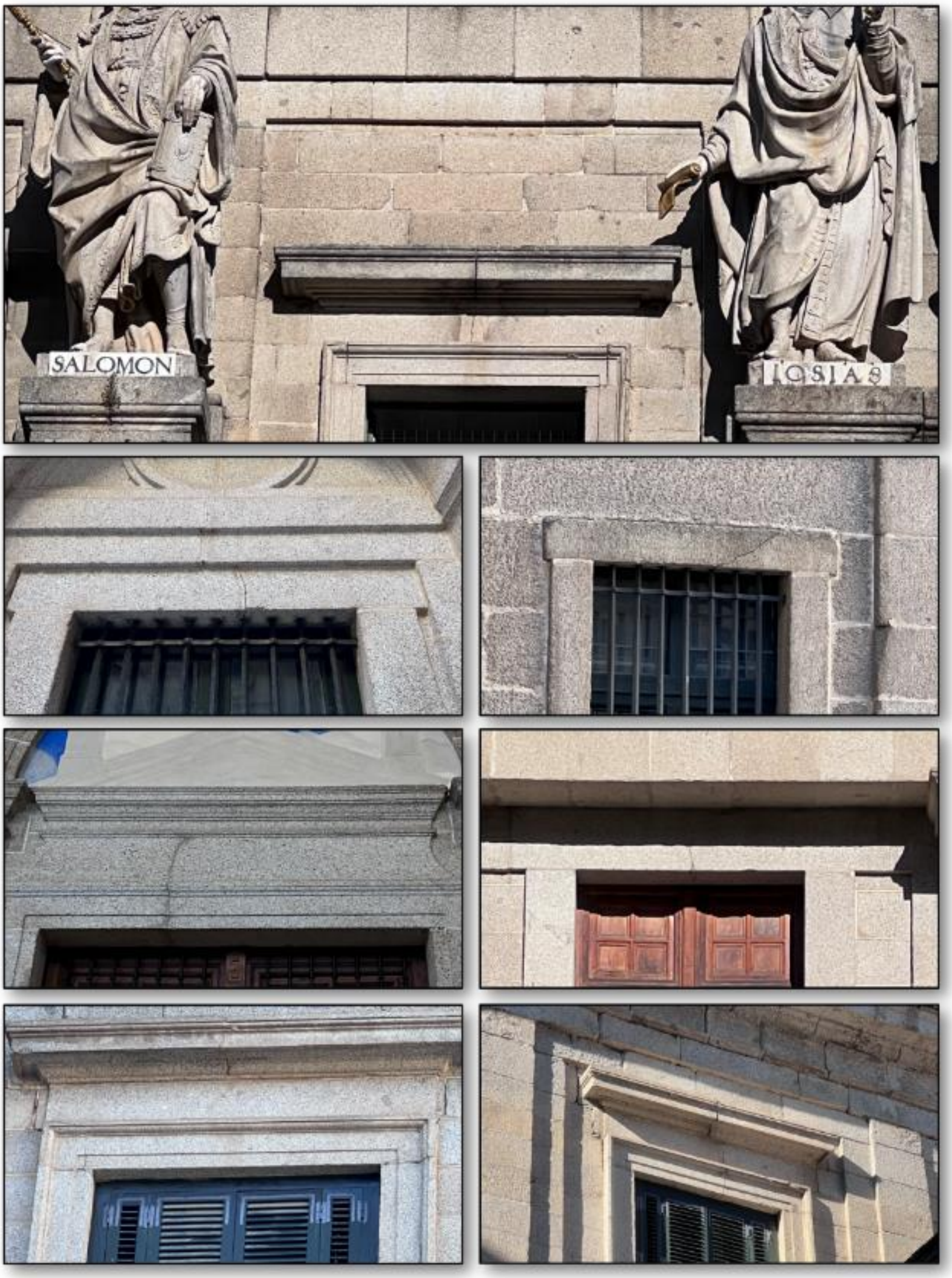

Fig. 20. Various examples of lintels over doors and windows in the Monastery of El Escorial (photographs by the author).

Among all the fractures discovered on the lintels in the Monastery in this investigation, the most interesting was the one we discovered in the lintel of the entrance of the Real Colegio de Alfonso XII (Figure 21), a Catholic school located inside the Monastery and run by the friars. The entrance to the school is also located on the west facade of the Monastery (room 63 of the plan in Figure 4). This means that this lintel is located on the same facade as the main door lintel. If we look at Castello's drawing (Figure 12), we can see that this part of the facade was made before the central part of the facade, where the lintel that we analyze in this article was located.

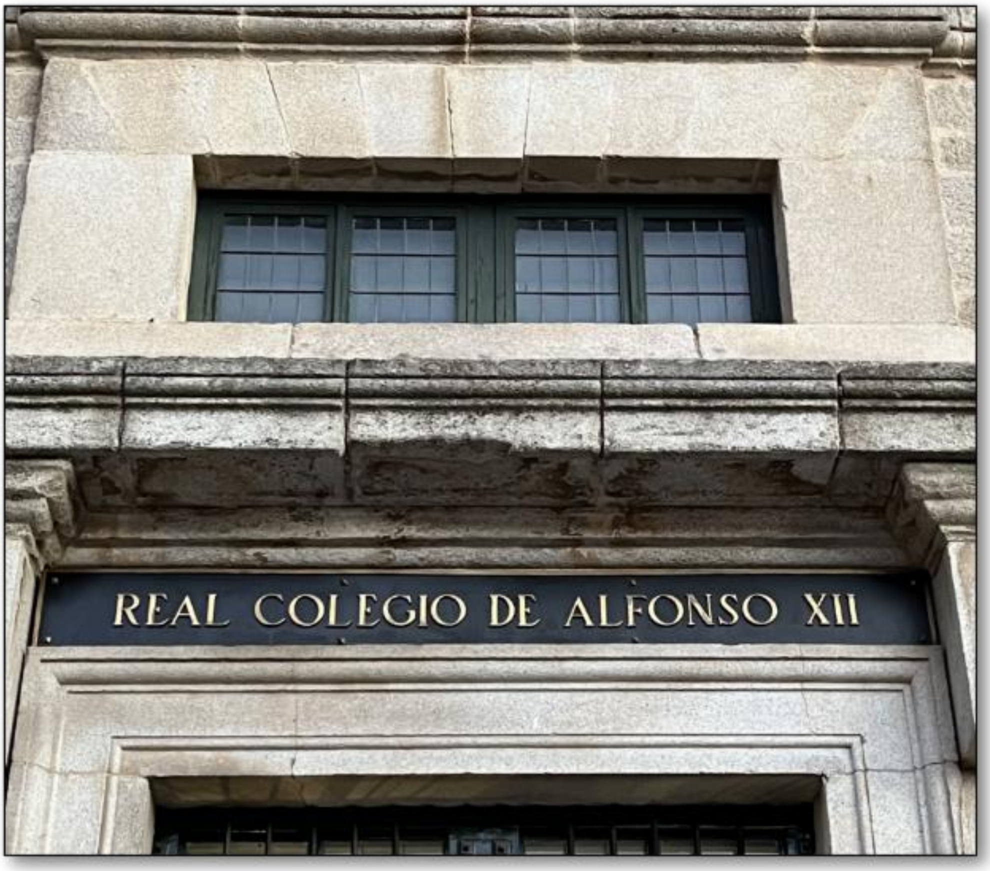

Fig. 21. Lintel over the main door of the Real Colegio de Alfonso XII, also located on the west facade of the Monastery of El Escorial, incorporating a voussoir lintel over the upper window (photo by the author).

Here we can see another difference with respect to the main door of the Monastery. There is a window above the lintel of the school door. The span of this window is formed by a fitted plate-band lintel with granite voussoirs. We must not forget that Heyman also considered voussoir lintels in his analysis, since according to him they also end up functioning as an arch [24]. In this case, structural equilibrium is also possible if we have abutments capable of causing the required horizontal reaction. If we analyze the upper lintel (Figure 21), we can observe the lack of alignment of the voussoirs, this being especially noticeable in the central voussoir. The phenomenon has been the same: the voussoirs have moved until they reached a stable position for an imperfectly fitted plate-band [24]. In other words, since it is not a monolithic lintel, the voussoirs do not break. Before a voussoir fractures, the complete lintel produces a hinge and seeks stability through the formation of a pair of articulated struts.

Outside the Monastery of El Escorial, it is common to find lintel masonry structures in which the lintels have suffered similar damage.

5. Conclusions

The lintel and the over-lintel arranged on the main doorway of the Escorial facade are both single-piece granite elements. The lintel has an open fracture downwards in the center and two fractures upwards on the sides.

At first, these fractures could be worrying. At first glance, we might think that these fractures may pose risks to both the structural integrity of the building and the safety of visitors.

Despite the above, we have been able to confirm that these injuries are not recent. From testimonies of the time, today we know that this fracture occurred during or shortly after the construction of the Monastery. We also know that this fracture, so striking and unsightly, was not regarded as important at the time it occurred.

The fractures are consistent with the nature of the lintel: it is a monolithic stone lintel, which, before breaking, work in bending as a beam and do not thrust. The lintel became an arch, because all masonry structures function as an arch. Fractures, therefore, are not a symbol of ruin; the fractures allowed the fictitious arch to adapt to the induced movement. The small displacements suffered by the lintel did not disorganize the structure. Therefore, the variations in the shape of the fictitious arch did not modify its balance.

The analysis carried out concludes that there is no reason to worry about visible cracks from a structural point of view. Similarly, thermography has shown that these cracks do not constitute an entry route for dangerous external agents, so we do not have to be afraid from a durability point of view. Thus, in accordance with the minimum intervention principle, it is not appropriate to carry out any type of intervention on these monolithic stone lintels, although they should be monitored periodically to locate any damage that may occur in the future.

This article therefore serves to demonstrate that fractures, despite being unsightly, are not always structurally worrying. A thorough technical inspection is recommended to determine the causes and extent of the damage, and to implement repair or conservation measures that ensure the safety and preservation of the affected monument or the affected construction.

The passage of time has shown that Juan de Herrera was perfectly aware of how the lintel worked: the fracture occurred almost immediately after the lintel was placed. However, Herrera considered it logical and not a cause for concern. More than four hundred years later, the lintel is still there, above the main door of the Monastery of El Escorial.

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Conflicts of interest

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