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Constructive analysis of the rammed earth walls in the Petrés Castle (Valencia, Spain)

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ABSTRACT: The Castle of the Aguiló family is a fifteenth-century fortress located in the municipality of Petrés, Valencia. The castle, built with strong rammed earth walls, was well conserved until the mid-twentieth century, when it was abandoned and partly demolished by its owners. Although currently in very poor condition, the strong construction of its rammed earth walls and other valuable elements of constructive interest, including the earthen vaults in the galleries of the lower part of the building, are worthy of detailed case study. This article presents the constructive and architectural features of the castle, following the lines of earlier studies by a multidisciplinary group of researchers aiming to assess its condition and establish guidelines for possible restoration.

1 CASE STUDY

1.1 *Geographical and historical context*

Dating back to the late fourteenth and early fifteenth century, the Castle of the Aguiló family in Petrés was constructed with strong rammed earth walls and a layout characteristic of the late middle ages. The purely defensive function of Reconquest fortresses was lessened, and more residential elements were incorporated into the castle, evolving toward a typology similar to Gothic castle-palaces (López González 2015).

The castle, made up of two volumes with a rectangular floorplan, is located on a small promontory overlooking the town of Petrés (Fig. 1). This site approximately 30 km North of Valencia was probably originated as a Moorish rural settlement belonging to the city of Sagunto, and its designation as a municipality in the mid-fourteenth century is closely linked to the construction of Aguiló Castle (Corresa 2016).

Diverse graphic and documentary sources quoted in the literature (Iborra 2016, Corresa 2016) show that the castle was well conserved until the mid-twentieth century, when it was abandoned, partly demolished by its owners, and left in very poor condition. As a result, there is currently a broad range of degradation and structural damage issues urgently requiring consolidation work.

1.2 *Architectural approach*

The castle in Petrés is made up of two very different volumes, yet both were built mainly using earthen formwork elements (Fig. 1).

Figure 1. General view of the Castle of Aguiló in Petrés, Valencia (P. Rodríguez Navarro).

The upper part of the construction is a volume of almost square proportions (21 × 19 m) consisting of five rooms organized around an inner courtyard measuring 8 × 9 m (Fig. 2). Until the mid-twentieth century it had two floors, now missing, which were accessed by an ashlar staircase on rampant arches in this central space.

Below this there is a second more massive volume. Its roof forms a terrace which is accessed through an ashlar gate on the south façade of the upper volume, presumably the original main entrance to the castle. The accessible spaces in this volume are an *aljibe* (Moorish water cistern) and three vaulted galleries running parallel to the castle facades (Fig. 2). The area without perforations when superimposing the voids in the galleries on the built volume is almost certainly the result of the slope on which the upper volume was built.

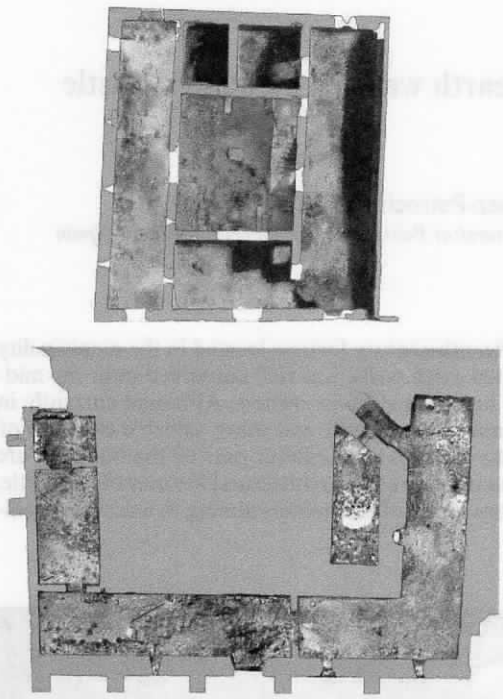

Figure 2. Graphic survey of the castle floorplans (P. Rodríguez Navarro & A. Pérez Vila).

2 METHODOLOGY

The results of the constructive analysis of Petrés Castle presented in this article were obtained through the preliminary studies carried out by a multidisciplinary group of researchers from the Universitat Politècnica de València. This team aims to establish the current conditions of the castle, as well as intervention criteria geared towards its eventual restoration.

Numerous analyses from many angles favored the development of a global view and better understanding of the castle's history and current condition:

- A complete 3D survey following a comprehensive methodology that included techniques ranging from the traditional direct survey to an indirect survey using active and passive systems (photogrammetry, topography and 3D laser scanner).
- Exhaustive data collection and historic and documentary study.
- Military study to identify possible design criteria associated with defensive functions.
- Complete study of constructive materials and techniques with cataloged fiches and plans.
- Study and diagnosis of material pathologies establishing the main lesions present and their possible causes using cataloged fiches and plans.
- Analysis of the structure and fissures of the building, identifying and recording cracks on the outer part of the building, studying their origin, and determining the main elements of the castle which appear unstable.
- Stratigraphic study, identifying the different units in the construction and the relationships between them to establish the construction periods for this study.

3 CONSTRUCTIVE ANALYSIS OF THE FORMWORK ELEMENTS OF THE CASTLE

3.1 *Study of materials and measurements*

Petrés Castle is a highly heterogeneous building given that different techniques were used in the execution of its different spaces, even when completing similar elements within a single body. However, the use of a poured mass of earth, lime, and stone as a basic material is a constant in the construction of most of the elements (Fig. 3).

The imprints left by the auxiliary devices on the castle walls during construction suggest something akin to rammed earth construction (See 3.2 *Constructive techniques*). However, the number of large pebbles on the walls must have hindered the manual tamping of the material poured in, and as can be seen from the marks on the walls, the layers applied were thicker than those usually seen in rammed earth construction: 18 cm instead of the 10 cm considered suitable for compacting (López Martínez 1999).

Figure 3. Detail of the north facade of the upper volume (Authors).

In this case, the cohesion needed to ensure a resistant mass is largely obtained through the lime setting in the mix, rather than through the compacting processes used in most rammed earth walls. Therefore, it is not unreasonable to surmise that the castle walls and vaults were executed using lime and earth concrete. Analyses carried out on similar walls from the late middle ages, for example Bofilla Islamic Tower in Bétera, Valencia, have shown a bonding agent content between 10% and 25% in the lime and earth mix (between 5% and 14% in cases where the lime was applied hot). Therefore, although the castle cannot be examined strictly as a rammed earth construction, it should be considered as a construction executed mainly using earth.

In the different constructive elements in the building, the lime and earth concrete in the walls is often complemented with other materials, using more complex mixed constructive techniques.

In the walls of the upper volume of the castle, both the outer corners and openings from the first construction period of the building were built using an ashlar construction of *pedra blava de Morvedre* which became part of the lime and earth concrete formwork at the pouring stage (Fig. 4).

The corners in ashlar are made up of two stone sheets 30 cm thick, and the outer sheet is of better quality than the inner one. A lime and large pebble mix similar to Roman concrete was poured between these two layers. The openings in the ashlar at times appear combined with brick arches, laid out as lost formwork for the rammed earth wall. This change in the material for the execution of the openings may have been due to the reuse of pieces from another construction (Iborra 2016) or to the need to cut building costs.

Figure 4. Meeting of two external perimeter walls of the castle, finished off with ashlar of *pedra blava de Morvedre* on the corner (Authors).

This volume is six rammed earth modules high. The first two, which correspond to the base under the rooms, slope lightly outwards. In the four upper sections the walls of the outer perimeter are 90 cm high on average, and the inner walls approximately 70 cm thick.

The lower volume of the castle is made up of three facades using three different constructive systems. The west elevation presents similar characteristics to the walls of the upper volume, although it was executed using different auxiliary devices. This could originally have been part of the wall around the castle vegetable garden, and archeological evidence has confirmed its presence, suggested by historians (Corresa 2016).

The east wall at this point is executed using formwork to build a coffered masonry wall, with a greater concentration of stone on the outer part of the wall.

In addition, in the south wall of the construction, the lime and earth concrete that can be observed from inside was poured against an outer sheet of masonry that served as lost formwork and is only one rammed earth module high. This is the springing point for the lime and earth concrete vaults over the interior galleries of this volume, adding to the impression that this mass has been dug out.

3.2 *Constructive techniques*

The walls for the upper body were built using a single constructive technique, using continuous rammed earth walls approximately one meter high and putlogs set 1.50 m apart. The constructive system used can still be observed from the imprints left on the walls by the stiffbacks and bonding strips of the formwork. The large distance between the putlog holes is striking, as is the extensive cross-section of wooden putlogs still remaining.

Although the openings left by the putlogs do not go right through the wall there are also stone slabs which acted as lintels after each section was completed, making it easier to retrieve putlogs. The large putlog holes, apparently too big for the size of the rammed earth wall sections, may in fact be as well the imprints for the supports of the scaffolding used during the construction of the wall, having been reused at different stages of the construction process.

The original openings are the result of two techniques combined: the use of ashlar elements

against which lime concrete was poured and the use of brick arches as lost formwork.

The constructive technique used to execute the west facade of the lower volume is similar to that used in the upper walls. However, in this case the size of the rammed earth modulation and the distance between the putlog holes is much smaller. Equally, the putlogs are smaller and the size of the holes does not suggest that these were used to put up scaffolding.

The system used for the construction of the barrel vaults over the lower volumes (Fig. 5) is especially interesting. A complex centering system using various pieces of semicircular falsework was used to define the cross-section of the vault. These elements were joined to create a resistant wooden framework of boards parallel to the generatrix of the vault, and reed was placed on top to avoid leakage of poured material. The imprint of the reeds used can still be seen on most of the surface of the vaults.

The survey carried out showed that the curvature radius for the circular tracing on the vault cross section is 2.10 m both in the galleries and the aljibe. Therefore, in the narrower space of the aljibe the barrel vaults may have been replaced with gentler curves, reusing the falsework for the outer rooms.

The U-shaped space defined by the three galleries of the lower volume is divided at several points by partition elements in formwork or stonework. Among these elements, poorly manufactured and of little interest, it is worth noting the north wall of the west gallery (Fig. 1) built in close relation to the constructive sequence of the vaulted spaces.

The entire height of this wall was executed with coffered masonry. This could not have been done in a confined space as the formwork couldn't have reached the upper part of the wall, leaving a free space to pour the material from above. Lately, that space would have been filled with common masonry. However, this element is not important enough to have affected the subsequent outline of the vaults. In addition, the partition wall rests vertically on the gallery wall all the way up until it separates to define the curve of the vault. This fact, along with the presence of imprints from reeds passing through the wall for the vault formwork makes it probable that this partition was built against the centering used to execute the vault, and was itself used as a support for the boards and reeds that were to shape the formwork in the vault.

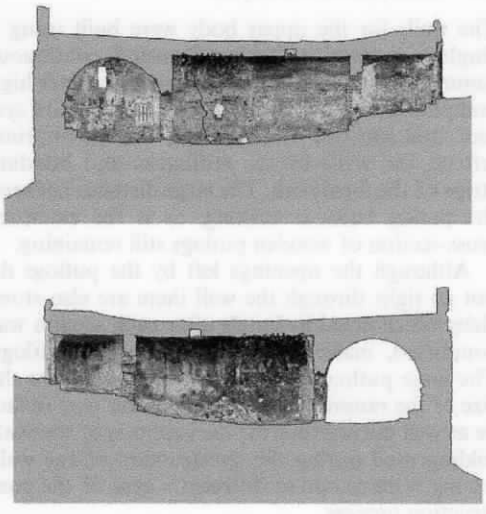

Figure 5. West gallery of the lower volume of the castle (P. Rodríguez Navarro & A. Pérez Vila).

3.3 *Stratigraphic analysis and hypothesis of constructive stages*

According to the results of the study of materials and the stratigraphic analysis of the constructive elements of the Petrés Castle a probable date was proposed for the different periods of construction (Fig. 6).

The original construction, coinciding with the first floor of the upper volume of the castle could correspond to the establishment of the Domain of Petrés in 1389 (Corresa 2016, Iborra 2016) with two different construction phases within the same architectural project.

The perimeter structure would have been executed in the first stage, while the interior walls could have been erected in a second phase. These inner partitions rest against the exterior planes without interlocking as are thick enough in themselves to be stable. Based on the way some walls rest against others it can be deduced that they were built in the following order:

1. Perimeter walls
2. Interior walls in North-South direction
3. Interior walls in East-West direction

In addition to the way the walls of the upper volume rest against each other, the manner in which the flat tile vaults covering these spaces rest on the different walls supporting them suggest that they belong to two phases within the same construction period. As can be observed in the points where even the tiles from the springings of the vaults have been lost, these rested on the inner walls of the castle thanks to the support grooves created with listels inside the formwork before building the wall.

In contrast, on the outer walls they rest on grooves made in the previously existing walls, suggesting that the decision to use tile vaults in the castle rooms was made by the builders at some point between the execution of the outer walls and that of the inner partition walls.

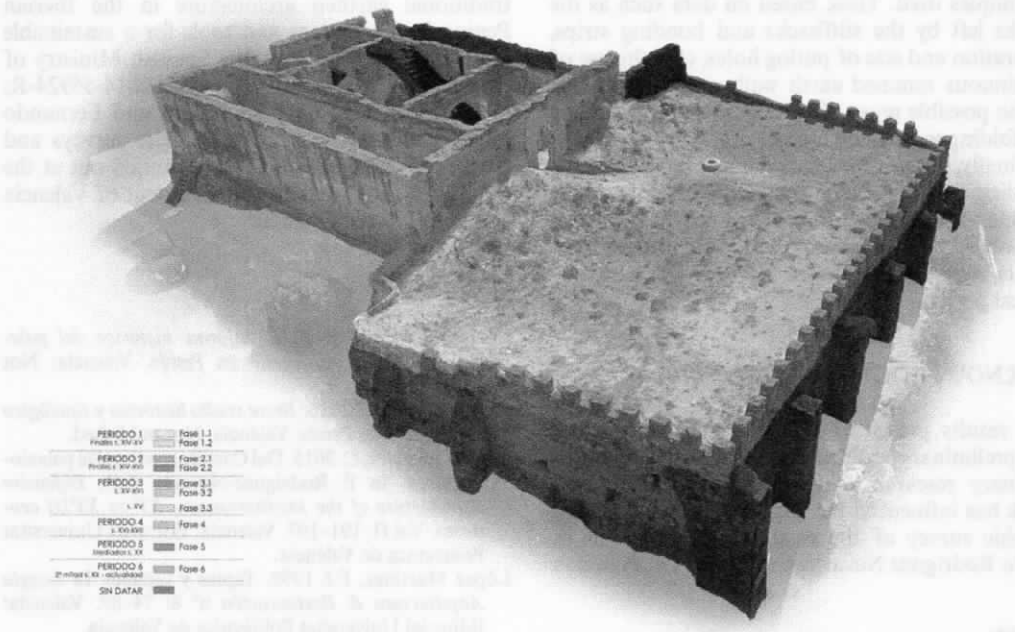

Figure 6. Hypothesis for construction phases of Petrés castle (C. Mileto, F. J. Gómez Patrocinio & A. Hueto Escobar).

According to I. Corresa, it was during this stage, or very shortly afterwards, that a perimeter wall in rammed earth was built around the castle vegetable garden and various traces of this have been found around the castle. From their materials and position in relation to the castle and the surrounding remains it is likely that the western facade of the lower volume was originally part of this enclosure.

The remaining part of the lower volume could have been executed in a second stage, also thought to have been carried out in two construction phases. The south facade of the volume, the south end of the west facade and the tower on the southeast corner, of which only the springing remains, could all have been executed in the first phase. The interior vaults and the east facade could have been executed in the second phase.

The upper volume would have been expanded after the construction of the galleries in the lower volume. Two levels of rammed earth and lime mortar sections faced with brick were added to this volume. These were demolished in the mid-twentieth century and at present all that remains of these are two courses of brick. The battlements crowning the lower volume, adding to its appearance of fortification, also date from a later stage in the construction. The chamfered southeast corner of the parapet shows that this was executed after the collapse of the tower which finished off the construction at this point.

4 CONCLUSIONS

A rigorous prior study is essential when tackling the intervention of a historic building, given that it is the only way to guarantee a comprehensive understanding required for well-documented decision-making at the design phase.

Before carrying out this study, it is essential to carry out a high-precision graphic survey to support the exhaustive processes of data collection and analysis for the job. Even though these examinations have been carried out by different professionals from different fields, the various tasks which constitute a prior study are a succession of approaches to the same set of elements and causes, and are all closely linked.

The results from each individual task help to shed light on, confirm, or refute the conclusions obtained in the other studies so that it is essential for the different specialists to collaborate closely.

The results of the constructive analysis of the rammed earth walls and vaults of Petrés Castle showed how during its construction the rammed earth technique was employed to assemble elements using similar materials with different treatments and varying resistance.

The imprints left by the auxiliary devices during the construction of the castle allowed extensive information to be extracted on the constructive

techniques used. Thus, based on data such as the marks left by the stiffbacks and bonding strips, separation and size of putlog holes, etc., the use of continuous rammed earth walls and half-putlogs or the possible reuse of putlog holes for installing scaffolding were all deduced.

Finally, based on a detailed interpretation of the building and a study of the graphic survey of the outline of the spaces, the reuse of auxiliary devices was observed in the construction of different elements, allowing them to be linked to the same historical period.

ACKNOWLEDGMENTS

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NOTE

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REFERENCES

Corresa i Marín, I. 2016. *Informe histórico del palacio-castillo de los Aguiló en Petrés*. Valencia: Not published.

Iborra Bernad, F. 2016. *Breve studio histórico y tipológico del Castillo de Petrés*. Valencia: Not published.

López González, C. 2015. Del Castillo medieval al palacio-fortaleza. In P. Rodríguez-Navarro (ed), *Defensive Architecture of the Mediterranean. XV to XVIII centuries*. Vol II: 191–197. Valencia: Editorial Universitat Politècnica de València.

López Martínez, F.J. 1999. Tapias y tapiales. In *Loggia Arquitectura & Restauración* nº 8: 74–89. Valencia: Editorial Universitat Politècnica de València.

Vegas, F. et al. 2014. La tapia en la Península Ibérica. In C. Mileto & F. Vegas, *La restauración de la tapia en la Península Ibérica. Criterios, técnicas, resultados y perspectiva.* Lisboa: Argumentum Ediçoes. Valencia: TC Cuadernos.