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Preliminary studies for intervention, interpretation and value enhancement of Tower of Don Fadrique (Albaida, Seville, Spain)

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ABSTRACT: A multi-disciplinary team from the University of Sevilla studied the Tower of Don Fadrique (Albaida, Seville, Spain), carrying out an analysis of its history, materials, construction, and pathologies. The aim was to provide local authorities with information to guide their technicians in assessing the possibilities of an intervention on the tower based on a better understanding of its masonry and an evaluation of its hazards and levels of vulnerability. A synthesis of the preliminary phase of this study is presented below.

1 BACKGROUND

This work provides the first results of the preliminary studies for an intervention on the Tower of Don Fadrique, an interesting medieval guard tower built of rammed earth chained in ashlar masonry con door and window frames on a stone wall, probably built in the early decades of the 13th century. The tower is located in the municipality of Albaida del Aljarafe in Seville and is the main monument there; after the destruction of its upper portion, it became known as the Torre Mocha (the *Topless Tower*). The study was undertaken by a multi-disciplinary team from the University of Seville (Spain) implementing a work methodology established in the framework of project BIA2004-1092 (Graciani et al., 2004).

It was declared an Asset of Cultural Interest in the Monument category, the first legal status of the Tower was as an Artistic Historical Monument by Decree 22/04/1949 for the General Protection of Spanish Castles. Currently it has its own file in the Andalusian Heritage Site Database (Code 410030003), which specifies it as a Defensive Guard Tower and dates it at 1245–54, an early medieval timeframe, an estimate that this study casts considerable doubt upon.

It was strategically built to overlook the floodplain of the Guadiamar River. It lies on land that cannot be built on to the N, E, and W, as classified in 1997. At that time, due to its R2 status (progressive ruin), the tower and its immediate urban surroundings were intervened by the Las Torres School Workshop under the direction of the architect Ricardo Moreno Moratinos, stabilizing part of its structure (uncovered) and enclosing and adapting its public access. Despite this, the current state of the tower makes it advisable to undertake a future intervention to optimize its conservation status and provide a complete analysis regarding its origin and historical evolution in order to provide the local administration with guidelines for their technicians. Consequently, a group of researchers from the Department of Architectonic Construction 2 of the Institute of Technology of Building Engineering at the University of Seville set out a preliminary intervention plan fitting the needs of this building. The preliminary results are presented herein. Specifically, for a better understanding of the tower's masonry and a more complete evaluation of its hazards and vulnerability levels, we undertook multi-disciplinary historical, material, construction, and pathology analyses of the tower in order to address intervention proposals on this Historical Heritage Site.

2 TOWER DESCRIPTION

The preserved remains of the tower correspond to its base and to 5.5 m of the body since the tower's top was demolished at some point, perhaps in the mid-13th century or in the late 15th century. The tower may have been demolished during the reconquest of the village by Pelay Correa (Pelayo Pérez Correa), a Master of the Order of Santiago, or it may have happened at the end of the 15th century, when the Catholic Kings demolished a considerable number of guard towers to limit the power of the local nobility.

The base measures 11.20 × 9.50 × 2.50 m and extends 0.50 m beyond the body's wall. The remains of said tower body correspond to the lower chamber and the first two stretches of the inner staircase. The chamber (2.30 × 2.20 m) is accessed directly from the NW face (facing the Guadiamar lowlands) through an archway (3.25 m above ground level) with a flat arch with a segmental arch on top of it (2.35 × 1.15 m of span covered by a groin vault (redone in 1997).

The W and S walls of the tower both have sections of staircase (of 1 m) leading to the chamber(s). The existence of merlons is logically accepted, but the possible tower height is cast into doubt as is whether the inside had two or three chambers. The upper ones were probably residential and were the reason for its being demolished; this last option seems to be the most widely accepted due to the solid construction of the remains, the proportions of the base, and the existence of local coetaneous parallels (Olivares y Benacazón, Valor 1991).

The vaults restored in 1997 are, in the first stretch of the stairway, two groin vaults, a barrel vault, and another groin vault higher than the one at the landing and lower than the previous one. On the south side, there are two groin vaults and a barrel vault at the landing, both of which are stepped as they are neither splayed nor rampant.

3 CONSTRUCTIVE ANALYSIS

3.1 *Methodological approaches: Wall analysis*

In the tower's architectonic analysis, the researchers applied the stratigraphic model in order to supply new data to unveil the building's evolution by studying its masonry, the types of bonds, and the relations amongst the various parts.

The study, performed according to the methodology of Tabales (2002), is based on a graphic representation of the elevations of the bastion, identifying noteworthy corresponding to periods of its evolution, how they are related to each other (through bonding, abutment, breakage or embedding), and the relation or temporal nuance between them (of coetaneity, antecedence, or subsequence).

The evolutionary sequence parted from the historical study provided by the prior historiography since, due to the diagnostic level, we could not obtain data by other means such as an archaeological dig. The final result has been graphically represented in planimetrics for the four sides of the tower, some stratigraphic (noting the physical relation between the units) and the others evolutionary (defining their timeframe).

The most interesting sides of the tower are the NW (Fig. 1) and the SW face, where appear the main elements contributing to clarify the tower's origin.

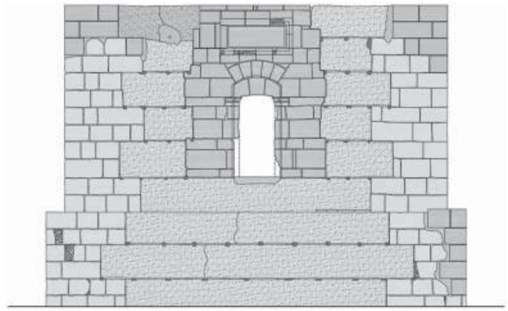

Figure 1. NW face of the tower (L.A. Núñez Arce).

3.2 *Timeframe and constructive stages*

The stratigraphic study allowed us to determine, for the first time, that the tower did not undergo a single construction process. Instead, there was an initial Islamic building (Almohad) that was subject to a Christian intervention over the course of a few decades, led by the Prince Don Fadrique. The existing remains correspond to three different construction processes (Almohad, Christian, and 20th century) that are analyzed below.

3.2.1 *Phase 1 (Almohad), early 13th century*

The original Almohad building was raised at the start of the 13th century. It was attached to a walled recinct of which we have found no remains to date. However, we have traced its existence in the course of our research. In fact, images from the 1930s preserved at the Photography Library of the Art Laboratory of the University of Seville (Fig. 2), allow us to refute previous hypotheses and confirm that the Torre Mocha was not a guard tower or a Fort Tower (Ortiz de Zúñiga 1975) in contrast to the San Antonio Tower, a nearby coeval building.

The tower was built of mixed rammed-earth and stone masonry (Fig. 3). The chain was carried out with coursed ashlars of local stone and some pieces were re-used. The courses have a height ranging between 0.88 to 0.90 m and are separated by a 0.03 m thick layer of lime. It is executed with overlapping formworks creating 6–7 meter sections of continuous rammed earth between the stone chains. Its NW face, towards the plain, must have housed its original entry point, of which there is currently no evidence.

Two arrows slits in the rear of the bastion (SW) flare out into an embrasure inside the chamber, thus also serving to provide light to the upper chambers. Today, these spaces have been altered from their original shape, appearing now as a break in the masonry; they were also partially redone in brickwork in recent interventions.

Figure 2. Image from the 1930s (Photography Library of the Art Laboratory of the University of Seville).

Figure 3. NW wall of the tower (A. Graciani).

Three building characteristics of the rammed-earth wall masonry make it unquestionably Almohad, and even more specifically as from the early 13th century: the use of flat horizontal timbers, continuous rammed-earth walls, and chained stone masonry. These features make their first appearance with the Almohads and show considerable care in their execution and the use of the best materials (Fig. 3). The use of chained stone masonry on the corners, not recorded in Seville until the start of the 13th century in towers (such as the Tower of Gold in Seville), also constrains the building of the Tower of Don Fadrique to this period.

3.2.2 *Phase 2 (Mudejar), middle of the 13th century*

The second phase corresponded to the intervention by Don Fadrique (Fadrique of Burgundy and Swabia, Prince of Castille 1224–1277, son of Ferdinand III the Saint and Beatrice of Swabia) and took place between 1248 and 1260 during the Reconquest of Seville and its fall into disfavor. After this, Alfonso X handed it over to the Church of Seville, to which it belonged until the end of the 15th century. The intervention of Don Fadrique on the tower has been dated at 1253, in which year, with the Apportionment of Seville, the Prince received the farmhouse of Solúcar de Albaydar for having participated in the siege of Seville.

Consequently, the only entry point to the tower, on the NW face overlooking the plain, was altered to incorporate a segmental arch, probably topped with an emblem or coat of arms. Above the doorway was placed a notice in pink marble and uppercase gothic lettering reading “The Prince Don Frederic had this tower built”.

Different construction evidence confirms that the current doorway is not coeval with the rest of the masonry. In fact, the entry point was made by breaking up the original masonry and demolishing the necessary area. This could be undertaken due to the extreme hardness of the lime-rich rammed-earth wall, incorporating headers to make the necessary adjustments to fit the frame size to the new doorway.

The doorway, made of the same local stone as used in the Almohad tower, is made of semi-coursed ashlars, with an evident height difference between the courses of ashlars. Although this is a chained layout in order to adapt to the rammed-earth wall masonry insofar as possible, the lift of the rammed-earth walls and the pattern of these chains do not coincide in height, noticeable in the adjustments that had to be made to admit the opening. The portal shows features typical of Gothic stonework such as the joins of the voussoirs of the entry archway and the moulding of its jambs.

It was probably in this phase that the original arrow slits were expanded, shaping them into brick lancet arches on the SE face at both ends of the second ramp stretch and in the NE face at the start of the third stretch, although only the base remains of this last loop hole.

3.2.3 *Phase 3 (modern), 1997*

During this phase, various interventions were undertaken in the tower’s surrounding to lend it an air of distinction, define it, and provide it with a garden. The curtain wall was removed, a garden was planted, and the perimeter zone was landscaped. Vehicular traffic was detoured from the area to surrounding lots and access was given to the inside of the tower and to its current roof. A semi-circular overlook was also built, with panoramic views, a guardrail along its edge, and a brick bench built into the wall.

In the tower itself, all the horizontal surfaces were waterproofed, including the roof. The rainwater was channeled by water spouts draining to the outside, and a system was established allowing public access to the inside. Some ashlars in poor condition were replaced with ashlars of the same type, and the ashlars, rammed-earth walls, and brick masonry were consolidated and waterproofed. Inside, the chamber and section of hallway that were uncovered were protected from the elements. The chamber, rampant stair, and the arrow slits were restored with materials, textures, and tones similar to the originals. The chamber floor was filled in with cast-in-place concrete. The rampant stairs were rebuilt using permanent formwork with a bridge-on-edge course and filled in with a ramp of cast-in-place concrete. They also substituted lost material in rammed-earth walls, vaults, and arrow slit embrasures using brick masonry and lime bastard mortar.

4 CHARACTERIZATION: MATERIALS AND METHODS

The study carried out in this unique place has consisted of characterizing two samples: two rammed-earth walls. The names assigned to them and the types of materials are REW1 (internal rammed-earth wall) and REW2 (internal rammed-earth wall).

The carbonate content was determined by Bernard's calcimeter according to UNE 103200: 1993, with the aim of approximating the original amounts of lime in the rammed-earth wall since lime becomes calcium carbonate. One must take into account, however, that both soil and the aggregates used in their making might contain natural carbonated fractions, so that the entire carbonate content cannot always be explained by the addition of lime.

Physical and mechanical properties were determined. The water-accessible porosity was calculated through the vacuum method according to UNE-EN-1936 (2007). In order to determine the compressive strength, 10 × 10 × 10 cm cubic test cores were used for the rammed-earth wall samples. Cement mortar with a 1:1 ratio was later used to cap those wall pieces, the samples were broken, using a strength testing machine TCCSL model PCI-30 Tn., according to UNE-EN 1015-11:2000 standard.

4.1 *Results and discussion*

4.1.1 *Carbonate analyses by Bernard's calcimeter*

The carbonate contents determined in both samples are shown in Table 1.

Table 1. Carbonate content (%) of Don Fadrique's tower samples.

Sample	REW1	REW2
$CO_3^=$	10.8	10.9
$CaCO_3$*	18.0	18.2

*$CO_3^=$ expressed as $CaCO_3$.

Both samples have low $CaCO_3$ contents (18.0% and 18.2%). Since the $CaCO_3$ contents from 1:2 and 1:3 reference lime mortars (siliceous sand/lime ratio in weight) are 40% and 31% respectively (Martín-del-Río et al. 2008), our samples seem to be very poor in lime conglomerates. However, it is not certain that all analyzed $CaCO_3$ comes from lime since $CaCO_3$ might also come from the aggregates. Therefore, the percentage of binder could be even lower.

4.1.2 *Physical properties: Porosity accessible to water*

Porosity values constitute a criterion to determine the quality and durability of mortars, concretes, and rammed-earth walls. Results for the wall samples were 21.8% for REW1 and 22.2% for REW2.

The materials used for these rammed-earth walls tend to have high open porosity (30–50%, commonly over 35%), and are consequently classed as very porous materials. This high porosity can probably be accounted for by the presence of a fine fraction of Ø<0.063 mm (lime, calcite, clay minerals, etc.), all of which have a high specific surface with a high capacity for water absorption. Consequently, during batching they demand large amounts of water that, when eliminated by evaporation, leaves high open porosity in the rammed-earth wall structure. It is also a common practice to use large amounts of batching water for greater workability of the slurry during work.

REW1 and REW2 samples have porosity accessible to water values close to 22%, those values are very low. The origin of this low porosity level might be likely justified by the use of low water/lime ratio in order to obtain good workability, good compaction from the rammer, and adequate aggregate grain size.

4.1.3 *Mechanical properties: Compressive strength*

Empirical data obtained from rammed earth wall samples are shown on Table 2.

The compressive strength in REW1 and REW2 samples is similar 20.1 N/mm^2 and 20.3 N/mm^2, most likely due to the low porosity. Compressive strength depends on several factors, but one of the most influential is the material's open porosity (the lower the porosity, the greater the material's strength and vice-versa).

Table 2. Study of compressive strength (N/mm^2) of different rammed-earth walls at various sites in the province of Seville (Spain).

Place	Compressive strength
Fadrique's tower (Albaida)	20.1*
C/ Sol wall (Seville)	13.0
Maria de Pineda wall (Seville)	3.9
S.Antonio's Tower (Olivares)	3.7
San Juan de Aznalfarache's wall (Seville)	3.1
Marchena's wall (Marchena)	3.9
Villaverde`s wall (Villaverde del Río)	7.3

*Average of values from the two samples REW1 and REW2.

In addition, the lime content positively affects mechanical strength. In previous studies on rammed-earth walls (Martín-del-Río et al. 2008), an analysis of mechanical properties revealed the exceptional quality of these rammed-earth walls, with higher values than found in other studies on this material at different sites in the province of Sevilla (Spain).

5 CHARACTERIZATION OF PATHOLOGIES AND HAZARDS

The analysis and diagnosis of the tower's pathologies are based on the analysis methodology proposed by Canivell (2011) for the characterization of damages and hazard assessment in rammed-earth wall masonry.

5.1 *Damage characterization*

The tower is generally well preserved as a result of its recent intervention, although there is some damage (structural, material, and superficial) due no doubt to the minimal regular maintenance. This damage is generally scant or, at the most, of little importance and of low hazard.

Amongst the scarce and less significant damages are the vertical fissures visible in some courses due to the expansion and contraction of the infill due to drying shrinkage during manufacture of the walls.

Material damage is more evident and is due to erosion (especially bad in the topmost courses lacking adequate roofing). The surface loss of mass overall in the walls is significant, with a consequent exposure of the lime mortar layer between courses; however, it can be classified as of slight importance due only to the highly cohesive mortar resulting from the high-quality execution and the high proportion of lime.

The superficial damage is limited to adhered stains (no crust formation) arising from washing by rainwater which, upon filling the exterior network of pores and concavities with particles, slightly darkens the wall's surface and highlights its washed outer face.

5.2 *Hazard assessment*

The tower's hazard assessment has been carried out (applying the methodology proposed by Canivell, 2011) to facilitate the application and management of preventative strategies and actions and of maintenance in the medium and long term. The vulnerability and hazard status can be defined through the appropriate management of hazard factors and the assessment of hydric, physical, and structural hazards.

Three types of hazards have been evaluated: hydric, physical, and structural, corresponding to vulnerability to the action of water, erosion, and structural instability, respectively. Given the tower's small size and the homogeneity of the external hazard factors, we have applied the assessment methodology without distinction amongst the walls since differences are minimal in the global assessment.

The hazard factors associated to water vulnerability are mostly low to very low, with poor values found only in the scarcity of covering and roof, which are compensated for by the high cohesion and hardness of the rammed-earth wall. All this results in a very low hazard level to water and therefore there is no urgent need for applying specific preventative measures.

The structural instability has an even lower hazard level since none of its hazard levels reach high values; consequently, it has a very low hazard level. Therefore, we can assume that the probability of structural damage is low in the short term and, as a result, there is likewise no need for applying preventative measures.

However, there is a certain trend to higher hazard in material damage (erosion), evidenced by a somewhat higher hazard level due to the lack of protec-

Figure 4. NW face of the tower (detail) (A. Graciani).

tion (roof and covering), to the high exposure, and to the lack of regular maintenance. Therefore, it is advisable to apply certain preventative measures in the medium or short term to reduce the hazard of existing erosion progressing. Otherwise, what is currently superficial loss of mass and stains could degenerate with a certain degree of probability into more serious damage.

6 CONCLUSIONS

In addition to reconstructing the building process and phases, this technical-construction study (discussing the technical similarities and differences with other coeval buildings in the area, including the San Antonio de Olivares guard tower) has allowed us to establish construction guidelines to be followed in the tower intervention.

At the same time, based on a stratigraphic study, we have been able to resolve the historiographic doubts concerning its ascription (Islamic or Christian) by demonstrating it is an Islamic building remodeled in the Christian period by Prince Don Fadrique de Castilla (1224–1277).

The quality of the masonry and the material characteristics of the rammed-earth wall have been evidenced by the material characterization study performed based on the determination of carbonate content, the properties of the rammed-earth wall, and its mechanical strength. These characteristics not only confirm the hypotheses of temporal ascription put forth by the authors based on construction arguments, they can also be considered when establishing the features of future interventions.

This analysis of hydric, physical, and structural vulnerability of the masonry and their corresponding hazard levels has evidenced that the tower has no outstanding need for an intervention.

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