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Masonry Walls Restoration and Urban Regeneration in the Clock Tower of Monóvar (Alicante, Spain)

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Abstract

The paper presents the historical restoration and musealization of Monóvar's clock tower. This isolated 18th-century tower was initially built to house the public clock, marking one of the earliest known examples in the Comunitat Valenciana of a secular timekeeping structure. Unlike most towers of the time, which were part of religious buildings, this project was driven by the local civil government to assert municipal control over timekeeping. The tower was constructed using a mix of stone masonry techniques, with varying material qualities, including well-cut ashlar, irregular stonework, and poor-quality rubble masonry. Stress tests revealed low tensile strength values, and due to construction deficiencies, the upper section developed a slight tilt, which has remained stable since its original construction. Over the years, several interventions were carried out the most intensive intervention occurred between the 1960s and 1970s, involving widespread use of cement, modifications to the façades, and the replacement of original materials with prefabricated elements, also masonry walls were added to visually correct the tilt. Following the recent demolition of a nearby building, which led to a landslide, concerns emerged about the tower's foundation and overall stability. However, analysis confirmed that the tilt has remained stable since its construction. Due to the masonry's poor quality, reinforcement was necessary and was implemented using lime injections. The landslide also exposed a previously undocumented Muslim cemetery, where thirteen burials were discovered and carefully excavated, adding an important layer to Monóvar's historical narrative. This archaeological site has been integrated into the urban project through a musealization, which includes a new walkway that encircles the tower, the cemetery, and two viewing platforms. These interventions enhance the site's cultural and historical significance by giving visitors a deeper understanding of Monóvar's past, from its medieval Islamic period to its 18th-century civic developments. This project preserves and reinterprets the architectural heritage, fostering a stronger connection between the historic fabric and the contemporary urban landscape.

Keywords: *clock tower; masonry wall; muslim cementery; landslide; Monovar*

1. Introduction

Monóvar, a town in the Vinalopó Valley, has had a defined urban structure since the 12th century (Azuar, 2016). It is built on the southern slopes of a series of hills, the highest of which was the site of a medieval castle. In the early 18th century, the town council constructed a clock tower separate from the church to reclaim the control of time from religious institutions, a move aligned with Enlightenment ideals promoting the separation of church and state (Fig. 1). Unlike most towns, which added a clock to existing buildings, Monóvar was unique in constructing a dedicated, standalone tower for this purpose (Vidal, 2000). At that time, the bell marked the rhythm of the daily life, scheduling the routine for religious and lay matters (García, 2016).

On April 27, 1734, the council held a public auction for the tower's construction. The contract was awarded to Tomás Querol, a master stonemason from Alicante, for 308 pounds. Querol, at that time working on the parish church of Aspe, completed the tower within six months, finishing on October 18 of the same year. The tower was built on a hill called the "zamoha" near Monóvar's urban borders. The bells were added in 1798, though it remains uncertain whether a clock was installed then.

The tower's design borrowed from religious bell towers, utilizing counterbalancing techniques developed in the 17th and 18th centuries to achieve stability and visual lightness (Fig. 2), like the vertical trims on the tower's main body.

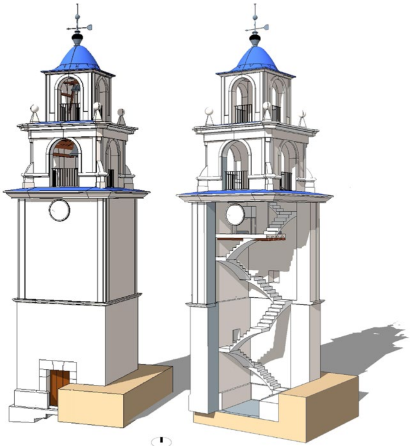

Fig. 2 – *Recreation of the tower's original image.*

The structure consists of a masonry base with varying quality materials. The lower sections use well-cut ashlar, transitioning to irregular masonry and eventually rubble masonry of poor quality bound with low-quality lime mortar (Fig. 3). Cornices and decorative elements were made of soft, easily eroded sandstone. Inside, a tabicated vaulted staircase spirals around the perimeter in a traditional castellana style. As usual, the walls diminish in size as the tower gets higher. A traditional vault system (*revoltó i bigueta*) was used to build the slabs on the two bell's body floors.

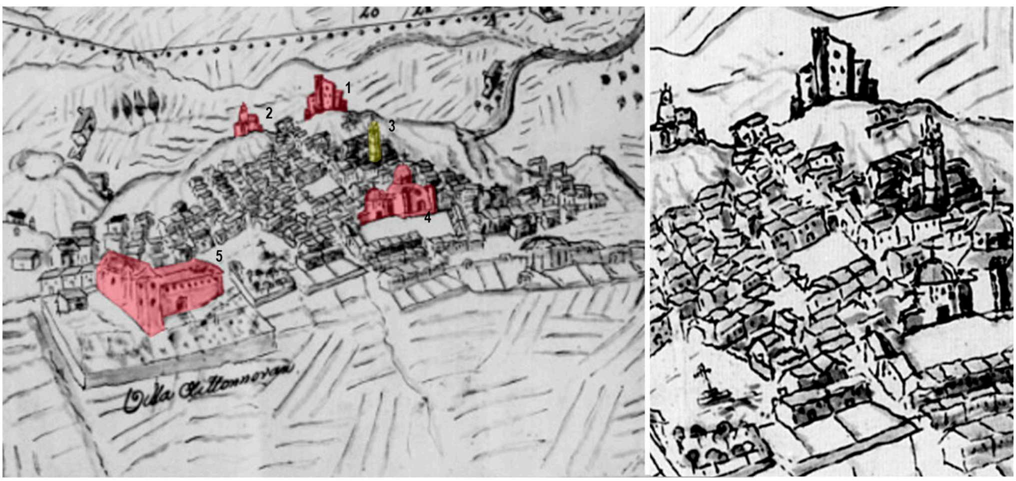

Fig. 1 – *Demarcation plan from Elda's county archive (1748).*

Fig. 3 – *Masonry wall's composition.*

The bell chamber was intended to be topped with a dome on pendentives, but only the pendentives were completed, and a simple vaulted ceiling was installed instead. Two wooden structures support the bells, distributing their weight to the tower's corners, one on each floor.

Over the centuries, several modifications altered the original structure. When the mechanical clock system was added, it was necessary to demolish the original stairs and build the one visible today. It also seems that this affected several windows, closing them (Fig. 4).

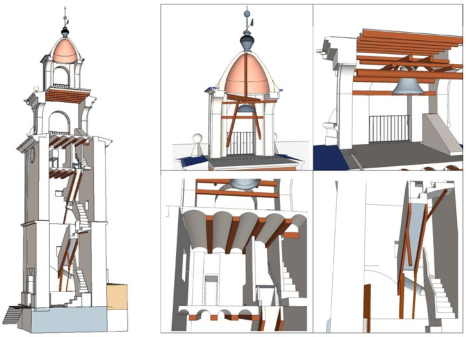

Fig. 4 – *Current stairs and interior of the clock tower.*

A significant intervention in the early 20th century added masonry reinforcements to the northern and eastern facades to counteract the tower's inclination in the lower body.

In the 1960s, the tower underwent extensive modifications: cement replaced the original lime plaster, sandstone moldings were substituted with concrete elements, the northern and eastern facades were clad in brick to mask the inclination, and the bell chamber floor was resurfaced. The tower's original whitewashed appearance was also replaced with a yellow finish more in line with mid-20th-century historicist trends.

The archaeological intervention was necessary due to the designation of the Clock Tower as a Local Heritage Asset (Bien de Relevancia Local - BRL), which mandates a prior study before any work can be undertaken on the tower or its surroundings (Ley 4/1998, art. 62). The historical graffiti inside the tower were documented, along with an analysis of the construction system and any possible remodeling visible during the restoration process.

A 2022 report identified human remains within the site of the tower, which were at risk of being lost due to erosion and the ongoing construction work. This led to the excavation, aimed at recovering the remains and documenting any additional cultural evidence that might have been preserved in the areas impacted by the construction activities on the site.

This paper presents the restoration of Monóvar's 18th-century clock tower. After outlining the tower's historical context, the methodology used in its structural and archaeological assessment, and the technical solutions implemented is presented. The intervention is framed within broader heritage preservation practices, emphasizing minimal intervention, material authenticity, and the integration of cultural heritage into urban space.

2. Methodology

2.1. Intervention goals

The project's main goal is to stabilize the tower, stabilize the nearby terrain, and create a new urban space around the tower.

To meet these goals, a procedural methodology has been followed for the data collection. First, the tower was visually inspected to determine its current preservation state, and data from historical sources were collected. Second, a series of tests have been performed to obtain data from different sources.

2.2. Pathologies

At a visual glance, several pathologies were detected on the tower. The tower presented an inclination of 13 cm to its southeast side. The façade presented different damage. There were humidity stains under the ledge, vertical cracks along the southern façade, and general cracking on the mortar. The wooden structure for the bell presented damage from an olden xylophage attack and rot.

The most crucial damage was on the terrain. Two nearby houses were demolished recently and provoked a major landslide. During the landslide, a human bone was unearthed. The extent of the slide covered several meters and raised concerns about potential impacts on the tower's foundations and stability.

2.3. Data collection campaign

After the inspection, a campaign test was developed to obtain data and evaluate the tower's structural performance. A specific campaign test was explicitly defined to obtain the relevant data. It was fractioned into two parts: tests on the tower and tests on the terrain.

The tests were performed on the tower to obtain descriptive information about the preservation state of different materials, their structural capabilities, and their composition. Simple and double flat jack test were performed on the other walls, accompanied by several archaeological borings to ensure its composition. Degradation and structural resistance tests were performed on the wooden structure using seismographic systems from AIDIMME.

The data from the terrain was critical to ensure the tower's stability, and due to this difficult access, some tests were hard to perform. A topographical representation of the site was developed to obtain accurate geometrical data on the terrain and the tower. One SPT was performed to learn about the layers on the terrain. Its information was contrasted and completed with two electrical tomography profiles and a granulometric test on the slide, as it was impossible to perform more tests.

2.4. Archaeological site

The tower structure was monitored during the removal of the cement and the opening of the original windows, documenting the process photographically. Graffiti was identified, cleaned, and documented using digital photography and photogrammetry (Valente and Barazzetti, 2020), noting their typology, technique, and condition.

In the archaeological excavation of the site, strata, structures and materials were documented, with samples taken for possible future analysis. The information was recorded in files, photographs and photogrammetric models. Materials were cleaned, catalogued, and deposited at the Archaeological Museum of Alicante (MARQ).

3. Results

3.1. Structural stability of the tower

The tower is composed of two prisms with a square base. The first body has a size of 4.80 x 4.80 m at its base, and it is reduced to 4.30 x 4.30 on its second body. While the first body is mainly straight, the second is tilted towards the southwest (Table 1).

Table 1 – *Inclination measurements per corner.*

Façade	Inclination	Downfall
Façade N	0.84º	0.164 m
Façade W	1.77º	0.345 m
Façade S	1.86º	0.362 m
Façade E	0.81º	0.158 m
Center	0.66º	0.130 m

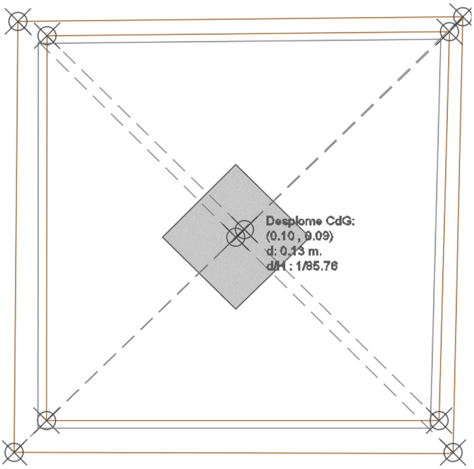

Fig. 5 – *Relative displacement of reference points.*

Because of the downfall, the center of gravity from both bodies is not aligned. There is 13 cm from one center of gravity to the other with a d/Z ratio of 1/86.7 (Fig. 5).

Despite this displacement and the inclination of the tower both centres of gravity are entirely inside the central core of the tower's section. So, the tower is perfectly stable as the gravitational forces upon it do not create any tensile efforts on its base.

During the execution it was discovered that the northern and western façades were covered with a non-structural brick masonry of variable depth. This wall was built in the last intervention in 1960s to correct the tower's inclination visually. These brick walls were demolished during the execution, recovering the original shape and volume of the clock tower.

3.2. Masonry walls description

The quality of the masonry walls was deemed as "LOW," with a Masonry Quality Index (MQI) ranging from 1.12-2.13. The stone and lime mortar wall were not well consolidated and presented several gaps with a size equivalent to that of the used stone.

Table 2 – *Flat-jack test results.*

Wall	Tensile strength (MPa)
East	0.49
West	0.43

The flat-jack test results (Table 2) are coherent with the MQI and the rest of the data. High air volume and low horizontal continuity are critical to the wall's cohesion. The results indicate that the building experiences a significant load for its capacity, using 43.95% of it, contrary to the usual 10% capacity usage in other masonry structures.

A lime mortar of a liquid consistency was injected to reinforce the walls. A grid of 50 x 50 cm was drilled in every façade with a hole of 20 mm. By using a low-pressure pump working at 2 atm. of pressure or lower, the mortar was injected from the bottom to the top. The injection continued until the mortar reached out in the wall, either by another drill or a cavity. Several mortar compositions were tried to adjust the mixture to the ideal consistency, adjusting sand granulometry and fluidizing additive. At the end, the mortar used was *Morcem® Cal Inyección Consolidante* from *Grupo Puma*, as it was not possible to use nearby sands.

After performing the injection, the façades have been covered with coloured lime mortar. The mortar has been applied with a layer of continuous thickness despite the irregularities in the masonry. The decorations have been reproduced with the measurements from the previous intervention, and the colour scheme has been chosen based upon typological studies on similar buildings on the zone.

3.3. Wooden structure and bell restoration

The degradation test on the different wooden structural elements of the bells and the stairs showed damage in all the elements. There were elements that had suffered an attack from xylophages but were no longer active. There were also rotten parts due to atmospheric exposure.

Every element was treated based on its necessities based on this criterion: the rotten wood was chiseled and sanded, and missing parts were reconstructed using epoxy resin and glass-fiber rebars to reinforce them. No element was replaced, and they were all treated to prevent further xylophage attacks.

3.4 Graffiti on the walls

The study of the graffiti on the tower walls has focused on their cataloguing and analysis, carried out in collaboration with Irene Agües, expert in historical graffiti. Nearly 200 samples have been recorded, with dates ranging from the 1910s to the present day. These markings consist primarily of names and dates, though several figurative examples also stand out, including a depiction of a bell tower with a weathervane (Fig. 6), a boat, and several human figures.

Fig. 6 – *Figurative charcoal graffito representing the dome of a bell tower with a weather vane.*

The graffiti were created using a range of techniques, including charcoal, incisions made with sharp instruments, paint, and markings on fresh plaster. This record is especially valuable as it captures the interactions of various individuals with the building, showcasing a diverse array of techniques, styles, and messages (Lozano 2023).

3.5 Terrain stabilization

The slide near the tower was caused by the collapse of two nearby houses on Sacristan Street, 23 and 25. The landslide created a 7.5-meter-high terrain scarp. Due to its steep slope and soil composition, the slide is considered unstable (Fig. 7). The security factor is 1.7 in normal conditions, and it is reduced to 1.4 in seismic conditions.

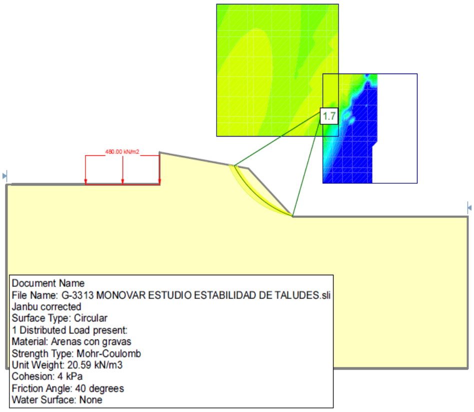

Fig. 7 – *Security factor of the slide.*

The slide does not currently affect the tower's foundation as the loads under them do not collide with it. Despite this, its instability and atmospheric erosion will affect it in the future. During the time gap between the studies and the execution (11 months), the slide top had neared around 50 cm toward the tower's base.

The terrain stabilization has been solved by combining two methods, cutting the height in two and diminishing the structural needs (Fig. 8). The lower part sustains the terrain using a concrete brick wall. The concrete bricks are filled with reinforced concrete. The wall impedes the slope to advance and takes advantage of the natural ground friction angle to improve its performance.

In contrast, the upper section was adapted to the existing slope and reinforced by applying shotcrete directly onto the terrain.

Fig. 8 – *Terrain stabilization solutions.*

The tomography and penetration analysis provided insights into the terrain's profile. It was used to determine the state of the tower's foundations. The admissible soil tension is 0.25 MPa, while the tower max pressure is 0.19 MPa. The test also showed a layer of debris 1.2 to 2m deep and temporary humidity deposits.

3.6 Excavation and the *maqbara*

Two distinct periods of use were identified on the tower site. The earliest corresponds to a place of burial from the Islamic medieval period, a *maqbara* or cemetery (Echevarria 2020, 83). A total of 12 tombs were discovered, though their preservation is generally poor. Later constructions, debris deposits, and natural erosion have caused many of the tombs to be only partially preserved. Furthermore, the presence of insects and plants has also contributed to the deterioration of the human remains.

Despite conservation issues, such as insect activity, erosion (Fig. 9) and subsequent uses of the site, two types of tombs have been identified. Excavated directly in the ground, simple graves and graves with a lateral steps/rim can be observed. These graves feature a lateral rim where adobe blocks or stone slabs are placed, adopting a form similar to a shed roof. The orientation of the tombs aligned NE-SW, and the positioning of the bodies—on their right side with their faces directed towards the S-SE—suggest that these burial sites date to the Islamic period, a pattern also observed in nearby *maqâbir* (Jover et al., 2005; Lopez Segui et al., 2005; Olcina et al., 2008). Additionally, no grave goods have been found within the tombs in keeping with Islamic burial practices.

Fig. 9 – *View of tomb 1 showing how erosion has made part of the tomb disappear, the tibia and fibula of the buried individual are suspended in the section of the ground.*

The study of the skeletal remains is still in its preliminary stages, but it has already provided valuable insights. It has revealed individuals from all age groups: 2 infants, 1 adolescent, and 9 adults. In terms of biological sex, 1 female, 2 probable females, and 3 probable males have been identified, while the sex of the remaining individuals remains undetermined.

The second phase of use identified is linked to the construction of the Clock Tower in 1734 or possibly to later remodeling efforts. A stone carving area was uncovered, revealing splinters and fragments of partially carved stone. Additionally, two structures built with stone and lime mortar were documented, likely used to support a platform or crane. These structures were later covered with building materials, ceramics, plastics, and other debris, which accumulated in the refuse dump that occupied the tower site until the commencement of the restoration work.

3.7 Urban Intervention

The surroundings of the tower are now a new urban area. A walking area around the tower with two agora-like meeting points for the people to observe Monovar's main monuments and historical center. The walk crosses the musealized *maqbara*, showing the remains of their ancestors. A new and unique place in town to understand where they come from and the importance of History.

4. Conclusions

The archaeological interventions have made it possible to identify and preserve parts of Monóvar's cultural heritage at risk of disappearing. They have also made it possible to locate the town's first urban archaeological site and integrate it into its surroundings, thus enriching its cultural offer for residents and visitors.

Data collection has proven necessary for the heritage preservation of this building. Historical data and the tests performed before the intervention have been critical to its success as they have demonstrated the tower's stability after all these years.

The suitability of the solutions is essential for heritage preservation, and only with profound knowledge can it be achieved.

Ongoing studies based on these findings are expected to enrich not only the historical and cultural understanding of Monóvar but also to contribute to broader discussions on heritage preservation practices, aligning with international approaches that emphasize contextual research, minimal intervention, and the integration of archaeological evidence into urban regeneration.

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