

# A Study of Defensive Architecture in the al-Andalus City of Vascos from a Topographic Survey with Laser Scanner

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*In this paper, we present the methods implemented to obtain a general map of the defensive structures of the Al-Andalus city of Vascos. To this end, we have started mapping the structures of the Qasb by conducting a survey with laser scanner and photogrammetry. The mapping products obtained from the survey will be very useful in the study of the archaeological site of Medina Vascos.*

*Keywords:* Defensive Architecture, Laser Scanner, “Mādina Vascos”.

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## 1. Introduction

Ancient Medina Vascos, or City of Vascos, is an important archaeological site located in the municipality of Navalmorelejo, in the province of Toledo, Spain, at about 5 km distance from the town center.

The traditional Islamic urban scheme defines the city as a binomial defensive control point that consists of a Kasbah and a Medina. The Kasbah is the place of residence of the political and administrative authorities of the area. The city, or Medina (in Arabic), is the place occupied by the population under the direct defensive dominance of the Kasbah, both are bounded by a wall that protects them but, at the same time, differentiates them both legally and socially.

After the settlement was abandoned in the twelfth century, the impressive defenses of the city were still standing. Actually, many travelers and catalogs from the sixteenth century onwards refer to them as such. In 1931, the city was declared “*Bien de Interés Cultural*” and catalogued as a special piece of Spanish archaeological cultural heritage, especially for its walls.

This article presents the first results obtained from a laser-scanner topographic survey of the defensive architecture of the al-Andalus city of Vascos. This first approach to the results has taken into account the study of the citadel or Kasbah of this outstanding site, which after its complete excavation has revealed all the structures that composed the Kasbah. Accordingly, a

general survey of the building elements that composed the citadel has been conducted. Upon completion, the conducted survey will allow us to propose a series of studies, analyses and future projects of investigation, conservation and information dissemination.

The digital information generated from the survey will allow for the construction of a digital model of the defensive architecture of the Medina that will be used to perform an archaeological study of the architecture, to improve the general understanding of the fortification process of this important site, and to take full advantage of the experience of the research teams that have used these tools (PERIPIMENO, 2005; DONEUS and NEUBAUER, 2005; FARJAS and GARCÍA, 2008).

## 2. Materials and Methods

The survey was conducted by using topographic equipment and a Trimble GX Advance laser scanner, which was used to obtain a point cloud. A mesh with a resolution of 2 cm in absolute coordinates was generated from the point cloud. Photographs were taken to give a real texture to the mesh, following terrestrial photogrammetry methods as far as the difficulties of the terrain allowed (Fig. 1).

The first phase of the study was a planning phase. During this phase, we studied the optimal location of the laser scanner for the scanning of the wall, taking into account the characteristics of the equipment and the

difficulty of the terrain. A planning phase was absolutely necessary to ensure the complete survey of all the elements, insofar as the citadel was located on a rocky hill of complex terrain, in which rocks projected shadows that hid the wall.



**Figure 1:** Screenshot of the superposition of a photo for the photorealistic representation of data.

The second phase started with data capture in the field. Firstly, a total station was placed at the top of the wall to obtain a geodetic link, which was required to provide absolute coordinates to the zone. Readings were taken from three REGENTE (*REd GEodésica Nacional por Técnicas Espaciales*) geodetic points by GPS techniques using the method of static positioning. To give coordinates to the scanning bases, the bases were measured using GPS techniques, namely the RTK (Real Time Kinematic) method.

Fieldwork continued with the scanning of the wall using the Trimble GX Advance laser scanner. The so-called "Longest Range Scan Mode" scanning method was used. In order to ensure the required 2x2 cm resolution, the mesh was defined at a resolution of 1x1 cm. The placements of the scanner were connected to ensure proper orientation between different point clouds. In this case, a series of Trimble-brand targets were used.

In addition, a series of photographs were taken with a Canon 450D camera with 12 megapixels and the focal fixed at 18 mm. Because high-resolution orthophotos were needed, a high-resolution camera was used. Photos were taken using terrestrial photogrammetry methods



**Figure 2:** Image of points for georeferencing and quality control of photographs used for 3D reconstruction of the citadel. Blue circles show the small paper targets at the corners of the wall. Yellow circles show the reflective targets used as control points of the images.

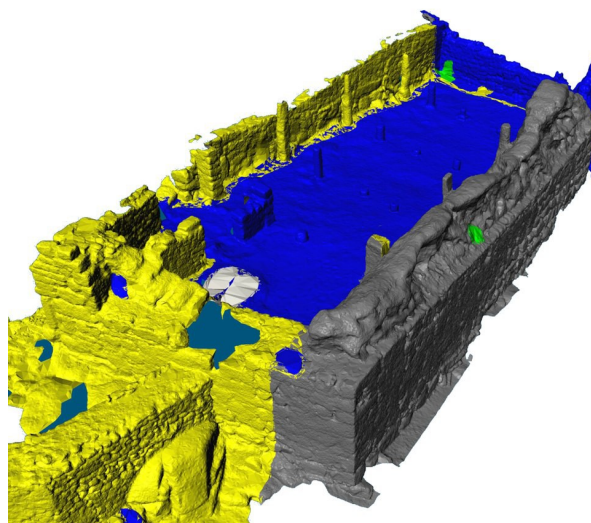
and the following parameters: the distance between the camera and the object was 10 meters and the overlap between photos was 1 meter.

To georeference the photos in the office, small targets of white paper were placed at the corners of the walls before scanning (blue circle in Fig. 2). To control the quality of the georeferencing process and the real texture mapping, some reflective targets were placed along the wall (yellow circle in Fig. 2), such that the real measurements could be compared with measurements made in the final virtual model.

Once the fieldwork was completed, the last phase began. The last phase of the process comprised office work and the production of results. The whole process was carried out using Trimble Real Works 6.32, a software specifically developed for processing data from surveys with laser scanner technology.

Firstly, a process of filtering and cleansing data was required to eliminate noise and vegetation from the model. A filter of 2 cm was applied to obtain a mesh with a resolution of 2 cm. After that, a triangle mesh was created using the 3D mesh method, which generated multiple meshes of the different parts of the wall, as a single mesh was heavy for a PC (Fig. 3).

Following the generation of the triangle mesh, we georeferenced the photographs. The photographs were previously treated interactively with the PhotoShop CS4 software in order to balance the hue, the brightness and the contrast because the light did not reflect the same way on each individual photo, and colour varied from frame to frame. Radiometric colour balancing ensures homogenous representation when all the photos are stitched together and improves the texture of the wall. To georeference the photos in Real Works, the reflective targets (blue circle in Fig. 2) were used to search for matching points between the images and the point cloud, always using more than five points for each image.



**Figure 3:** Screenshot of the three-dimensional reconstruction of the remains of the citadel of the al-Andalus city of Vascos, corresponding to the mosque area.

Finally, the process automatically allocated texture. To achieve this, the georeferenced images were projected from the camera point on the mesh of triangles, which produced the 3D model (Fig. 7) of the Kasbah, plus a series of products for the study and analysis of the city.

### 3. Results

The 3D model and the collected data were used to obtain the first applications for the study of the Kasbah of the City of Vascos. Such applications are presented below.

A series of 16 orthophotos (in .tiff format) of the Kasbah wall have been taken, which can be used to provide extremely precise measurements. The quality of orthophotos is high enough to be digitized with CAD software, with 7800x4360 pix and a resolution of 13ppp (Fig. 4).

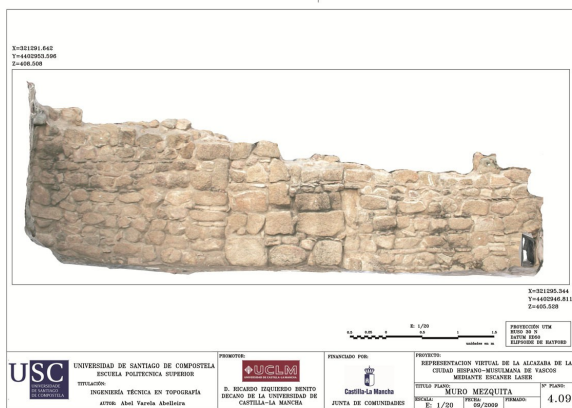


Figure 4: Image of one of the orthophotos of the citadel wall.

In addition, 17 different sections have been done on the three-dimensional model to study the geometry of the citadel wall and to analyze its structural problems and distortions, especially in those areas that have suffered a greater degree of degradation (Fig. 5). The ability to geometrically analyze an element in order to monitor, quantify and study its shape is one of the main reasons that justify the need of a laser scanner.

Sections have been generated from a vertical plane perpendicular to the wall that divides the generated mesh; this section is generalized in straight stretches of 4 cm.

With these products, the first analysis of the structural problems of the walls of the citadel can be undertaken. The study has been carried out on the theoretical verticality of the wall. From among the five areas studied, study zone 1 should be highlighted. Zone 1 is located to the Southeast, near the main gate of the citadel, where curvatures greater than 18 cm in relation to the vertical plane were detected (Fig. 5). As shown in the contour map for zone 1, this zone is convex in the center (Fig. 6).

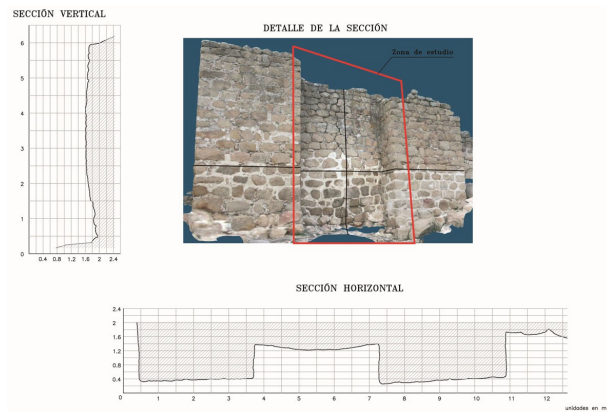


Figure 5: Sections of zone 1 on which a study of distortions has been made. In these sections the wall presents curvatures in relation to the theoretical vertical plane.

Finally, a virtual model with real texture has been created. The generated model can be viewed by anyone using a specific free network browser, Real Works Viewer. In addition, we have generated a "bird's eye view" video across the virtual model. The mesh of the city wall obtained by laser scanner is supported on a digital terrain model generated from a photogrammetric flight. This video can be viewed at the following link:

<http://www.youtube.com/watch?v=uyFGj2LgYPI>  
(Accessed October 2011).

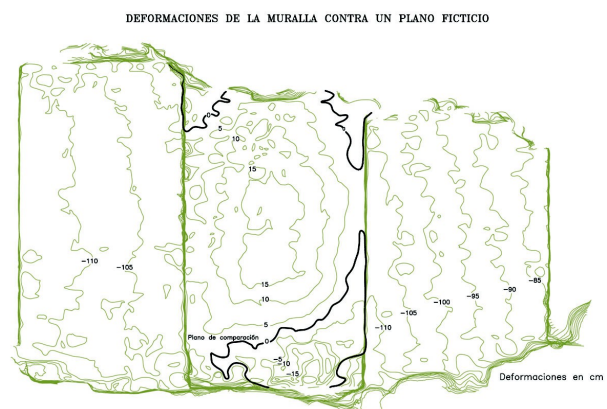


Figure 6: Contour maps for zone 1, which was the object of a study of distortions.

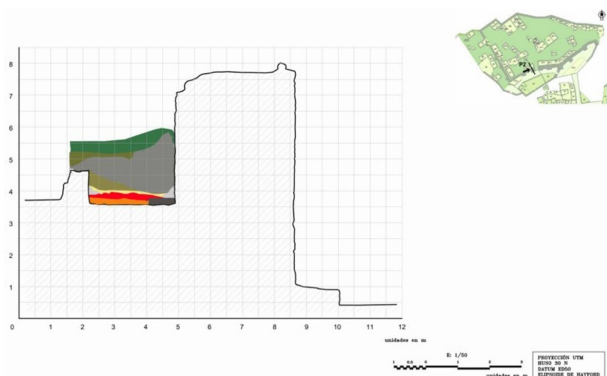


Figure 7: Screenshot of the virtual model supported on the digital terrain model generated by a photogrammetric flight.



## Conclusions

The topographic survey with laser scanner technology has involved, primarily, an advance in the exhaustive knowledge of the wall of the citadel of Vascos, and has allowed for the reproduction of some of the principal building elements, which can be used to distinguish its exact parameters in 3D. Differentiating the more accurate parameters in 3D is extremely beneficial for, e.g., the identification of previous structures.



**Figure 8:** Hypothetical section of the citadel wall with the drawing of the excavated stratigraphy.

Secondly, the survey has provided a fundamental element that will allow us to reproduce the excavated stratigraphy, which is no longer present and is essential for understanding and facilitating the interpretation of its varied origins (Fig. 8).

The survey provides elements of control of the structures, their distortion and their conservation, which can be used as high-precision tools to allow for the analysis of possible interventions to carry out.

In addition to research aspects, these tools are suitable for the dissemination of information and the future museology of the site.

The investigation will continue developing those aspects that have posed greater problems for the use of laser scanner technology, such as the crown of walls and areas of steep drops where access with the instrument has been a problem. Nevertheless, we will continue surveying the wall of the medina to generate an orthophoto-map, showing its structures with maximum accuracy. Thus, we will obtain a tool for the analysis of the historical processes associated with the construction of the walls and defenses of the city of Vascos.

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