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Photographic rectification of the graphic documentation of historical and archaeological heritage:

The case of the southern facade of the *Praetorium* tower in Tarragona (Tarraco, Hispania Citerior).

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Abstract: This article details the use of photographic rectification as support for the graphic documentation of historical and archaeological heritage and specifically the southern facade of the Torre del Pretori (*Praetorium* Tower) in Tarragona.

The *Praetorium* Tower is part of a larger monumental complex and one of the towers that connected different parts of the Tarraco Provincial Forum, the politic-administrative centre of the ancient capital of *Hispania Citerioris*. It is therefore a valuable example of the evolution of Roman urban architecture. The aim of this project is to provide accurate graphic documentation of the structure to facilitate the restoration and conservation of the tower, as well as to provide a more profound architectural and archaeological understanding of the Roman forum.

The use of photographic rectification enabled us to overcome the spatial and time difficulties involved in collecting data caused by the size and location of the building. Specific software made it easier to obtain accurate two-dimensional images. For this reason, in our case, photographic rectification helped us to make a direct analysis of the monument and facilitated interpretation of the architectural stratigraphy.

We currently separate the line of research into two concepts: the construction processes and the architecture of the building. The documentation collected permitted various analyses: the characterisation of the building modules, identification of the tools used to work the building materials, etc.

In conclusion, the use of orthoimages is a powerful tool that permits the systematic study of a Roman building that has evolved over the centuries and is now in a modern urban context.

Keywords: photographic rectification; documentation of historical and archaeological heritage; Roman architecture; Tarragona; Provincial Forum

Introduction

The Praetorium Tower is a solid building that, after 2000 years of history and numerous restorations, is some 29 metres long, 23 metres wide and a maximum of 23 metres high. It has a turriform body built in the 1st century AD, mainly of opus quadratum, as part of the monumental complex where the meetings of the Concilium Prouinciae Hispaniae Citerioris were held; today we know this complex as the Tarraco Provincial Forum (MACIAS et. al. 2011; Fig. 1). In Roman times the tower was the monumental end of the perimetric podium of a six-hectare public square between the temenos and the circus; its main purpose was to facilitate access to the square from the circus, which was built on the lower urban terrace. With the decline of the Roman city, the podium gradually disappeared, while successive modifications converted its far end into fortifications. Between the 12th and the 15th centuries the Castillo de Rey (King's Castle), the seat of the count-monarchs of an incipient Catalonia, was built in this sector. In the 17th century it was a military building and in the 18th century the city's prison. In 1813 it was partially blown up by Napoleonic troops, although it was immediately rebuilt as the provincial prison. This was the most serious damage caused to the building, as can be seen by comparing Alexandre de Laborde's engravings (LABORDE 1806; Fig. 2) made before it was blown up and Vicenç Roig's sketches that show its condition just after the explosion (SALOM 1997). In the mid-20th century the tower underwent a major restoration that gave it its current appearance. It now houses part of the Tarragona City Council Museum of History and receives more than 150,000 visitors a year.

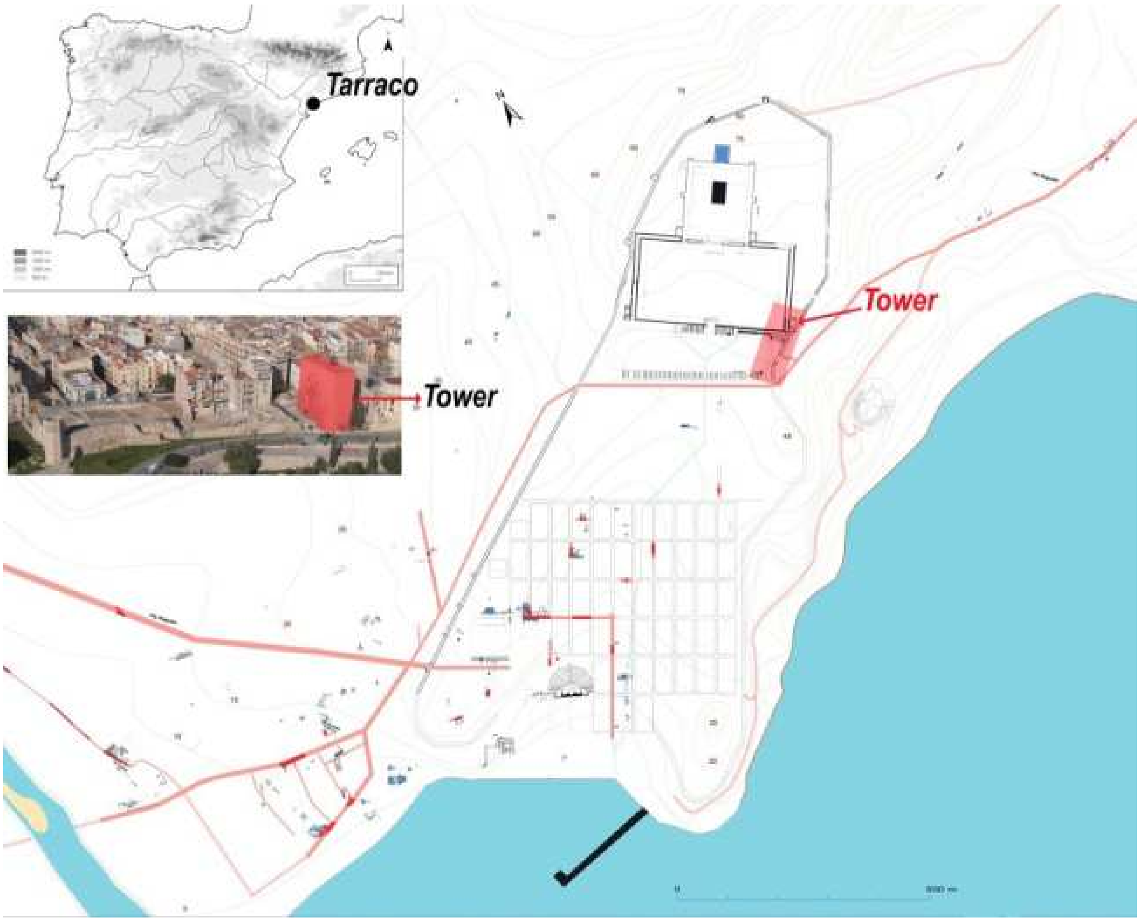

Fig.1 – Map showing the location of the *Praetorium* Tower (Copyright: Macias *et al.* 2007)

Both the study and conservation of the tower are scientific and methodological challenges. They require a documentation and interpretation phase based on the principles of architectural archaeology to identify and separate the vestiges of the numerous building processes that have resulted from its particular historical evolution and the diverse restoration projects that, unfortunately, have not always left any documental evidence. At the same time, its architectural characteristics and urban location require a precise graphical documentation method, an essential tool when monitoring architectural stability.

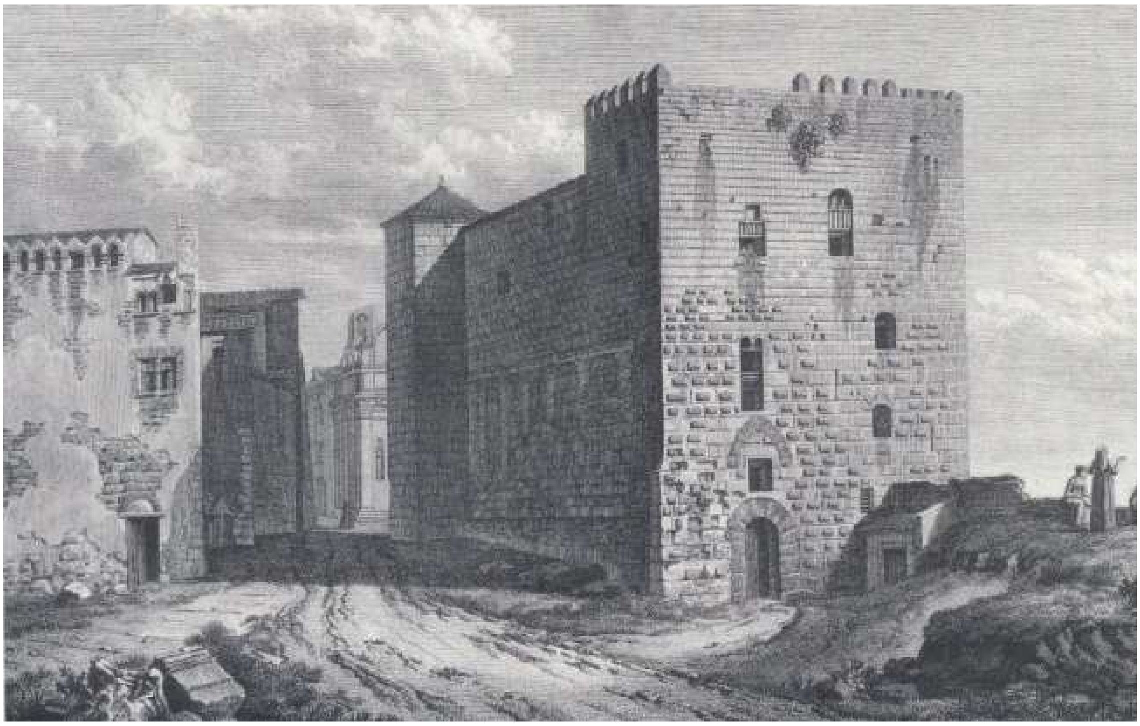

Fig.2 – Engraving of the Praetorium Tower at the beginning of the 19th century (Copyright: Laborde 1806)

Objectives

The document we present is part of a wide-ranging research project focusing on the photographic and planimetric documentation of the historical monument in a phase prior to the aforementioned requirements. One of the most significant actions was carried out on the western façade, where it is possible to see part of the foundations and a wall decorated with pilasters, evidence of the podium from the ancient Provincial Forum square. It is also possible to see the superimposed wall facings of the mediaeval to contemporary restorations. In methodological terms, the graphic documentation of a 23-metre-high, 26-metre-wide façade is not difficult, but in this case it is hampered by the fact that it is only 5.5 metres from the wall of a mediaeval church. The lack of depth of field meant that it was necessary to use an 18-metre-high lifting platform, the instability of which made it impossible to use a laser scanner. We chose photographic rectification as the methodology for our study and main objectives we attained were:

- the study of the constructive modules of the Roman-period building
- the identification of how the building materials were worked and a study of the tools used
- the definition of the architectural stratigraphy
- the generation of graphic support valid for conservation and restoration work

Methodology

The photographic rectification methodology is able to remove the effects of perspective distortion by turning a conical projection into an orthogonal one; it produces a scaled image with exact geometrical information. However, it should be remarked that the surface to be rectifie must have the same reference plane. Indeed, the surface that lie out excessively from the reference plane used, are going to remain geometrically incorrect.

There are currently many, easily available computer programs on the market. This large number sometimes makes it difficult to make a quick choice, as it offers a wide range of possibilities with the advantages and disadvantages of each type of software depending on the purposes and the time-space context of the study (ANDREWS *et al.* 2005).

The software used for this study was PhoToPlan Version 6.0 (Kubit), a program for the creation of orthoimages that works as an extension of AutoCAD (the version used was AutoCAD 2011; learning the program is easier if the user already knows how to use the technical drawing software). We chose this program to meet our different needs: the location of the structure combined with the adaptability and speed of data acquisition and processing. The study of architectural heritage in an urban context requires careful consideration of the current location of the archaeological remains, as this affects access and the time needed for the intervention (VINCI 2012).

Image acquisition

The software offers the possibility of processing the data with or without topographic control points (Fig. 3). In this case we used the method with topographic control points. Photos can be taken with any type of camera. For the applications proposed here we used the Nikon D-80, a high resolution digital camera with an 18 mm focal length. This focal range was an excellent compromise between a wide field of view, to photograph the largest surface possible for each frame, and the ability of the computer programs to process the images properly. In fact, the wider the field of view, the lower the number of photos needed to document an entire surface. On the other hand, the use of a wide-angle lens produces greater optical distortion on the photo (especially on the margins) and this makes it difficult, if not impossible, to obtain good rectification results. In our case, the focal length used was the maximum with which the program could correctly process the data. For photo acquisition the program requires:

- one front photo for each surface to be rectified
- the position of the image does not need to be strictly perpendicular, but can have an oblique trajectory, providing it is from the bottom up (this is an advantage because it avoids the use of extendable arms when documenting large structures).

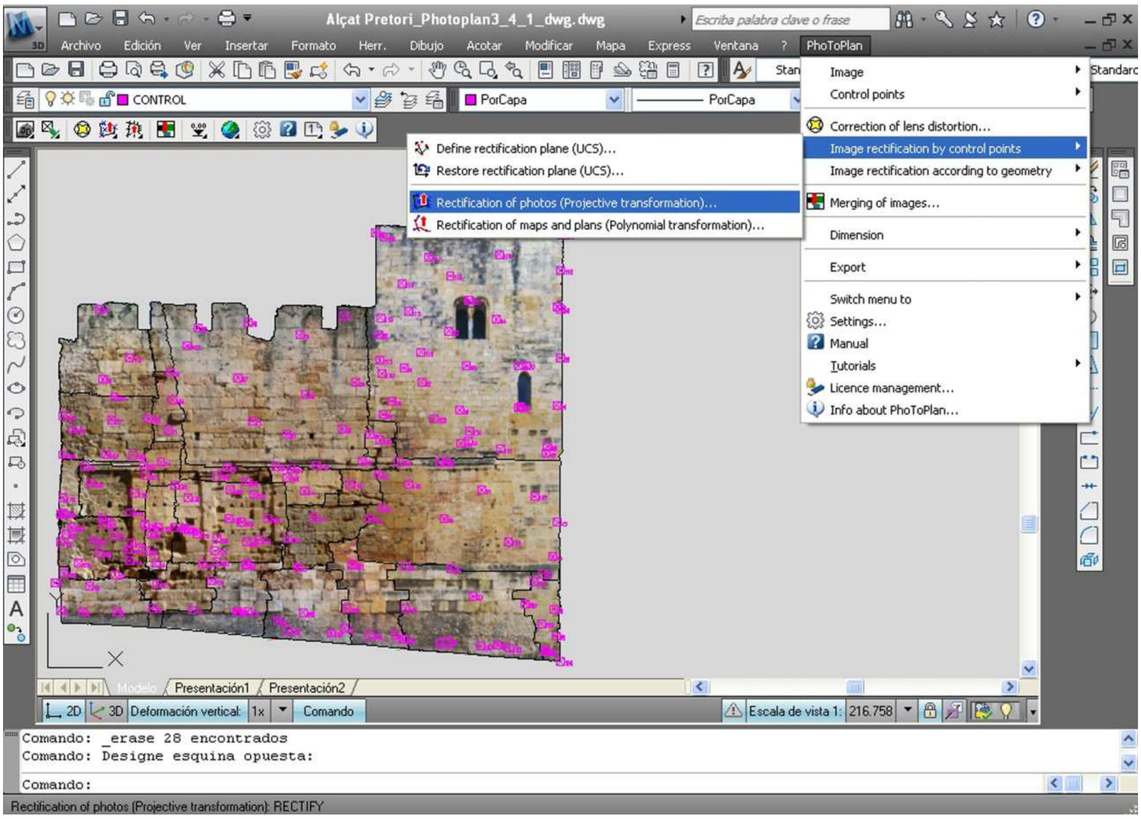

Fig. 3 – Screen capture during the topographic point control process (Copyright: M. Serena Vinci)

After taking the photos, the image is acquired by the software and the camera must be calibrated with the lens used for image capture, so that the software creates a file containing the calibration parameters useful for the image processing (the calibration parameters used are: focal length in x and y dimensions, measured in pixels; principal point coordinates – i.e. coordinates of lens optical axis interception with sensor plane -; skew transformation coefficient; radial distortion coefficents; tangential distortion coefficents).

Data acquisition and processing

With this method the program needs a minimum of 4 topographic control points (which were marked with a total station Topcon GPT-7000i series) on the edges of the structures and on the surface to be rectified; it is always better to use more than 4 points, as if one of them is not exactly determined, the software will perform a statistical compensation (based on all point recorded) with other recorded points. However, it is not useful to set more than 8 control points for each picture, as automatic compensation means that with more points of reference there is a greater possibility of accumulating a higher margin of error. Once the topographic control points and the image have been inserted and the corrections made to compensate for lens distortion, the points are matched to the photo (Fig. 4).

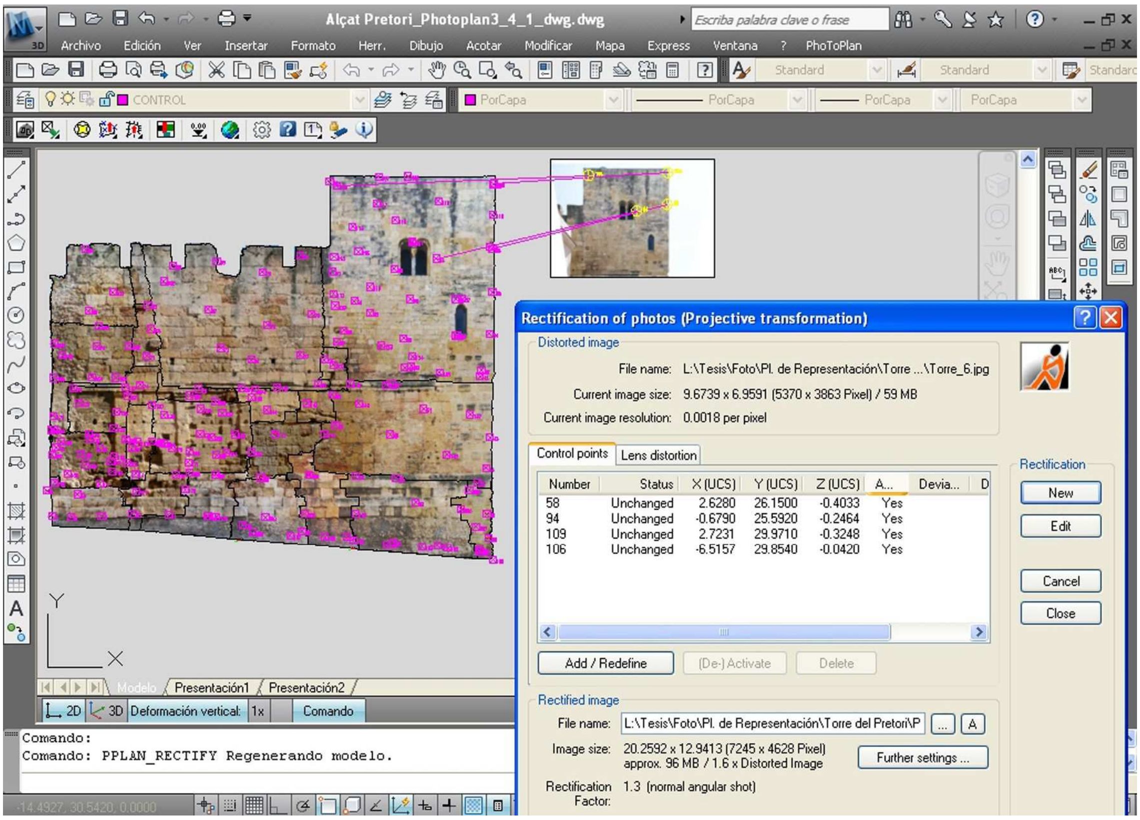

Fig. 4 – Screen capture of the process of referencing the images with respect to the topographic points (Copyright: M. Serena Vinci)

Study case: the southern façade of the *Praetorium* Tower in Tarragona

For the documentation of the southern wall facing of the building referred to as the *Praetorium* Tower, photographic rectification processed with PhoToPlan was the quickest method for image and data acquisition.

The building, which is in the square known as the Plaça del Rei, currently houses a branch of the Tarragona Museum of History. The main difficulty we had was the size of the wall facing (the height of the façade is about 23 m) combined with a shallow depth of field (Fig. 5). This meant that a large number of photos had to be taken to document the entire structure. The use of photogrammetry would have required double the number of frames for a successful solution (a pair of photos for each surface to be rectified); in this case, considering our purposes, it was more convenient to apply photographic rectification with control points and to process them using PhoToPlan. Due to the spatial situation, the photos were taken from different places: the lower part of the wall facing was photographed from the street and for the rest of the structure the photos were taken from an elevating platform (Fig. 6); this equipment allowed us to achieve a sequence of images and also to make a diagnostic analysis of the degradation of the stone. Altogether of 25 photos were taken with 6 topographic control points for each frame (bullseyes were not used for the topographic points; rather they were identified directly on the structure). As aforementioned, the surface to be rectified must have the same plane. In agreement with it, lesenes were considered as distinct elements during the rectification process. Afterwards, they were merged with the façade to form a unique mosaic-photo. We also placed a total station in different locations: on the street, just in front of the structure (for matching the control points on the lower part of the wall facing), in the nearby square (for matching the control points on the middle part of the wall facing) and on the roof of the building opposite (for matching the control points on the upper part).

Fig. 5 – The street adjacent to the façade with the pilasters (Copyright: J. Maria Macias)

Fig. 6 – The lifting platform during the documentation process (Copyright: J. Maria Macias)

Another difficulty was the time available to carry out the work, as the façade is located on a narrow road and we could only occupy it for a limited time.

TYPE OF STRUCTURE	CURRENT LOCATION	SPACE CONTEXT	SOFTWARE AND METHOD USED	DATA ACQUISITION	DATA PROCESSING
Southern wall facing referred to as the *Praetorium* Tower	The Museum of History in a city square	Very shallow depth of field (distance of between 5 and 6 m from the building opposite)	PhoToPlan with topographic control points	25 photos	6 topographic control points for each frame

Tab. 1 – Summary table of the features and the study context

Results and analysis

The main result achieved with the application of photographic rectification was a scaled image that allowed different studies to be carried out (Fig. 7).

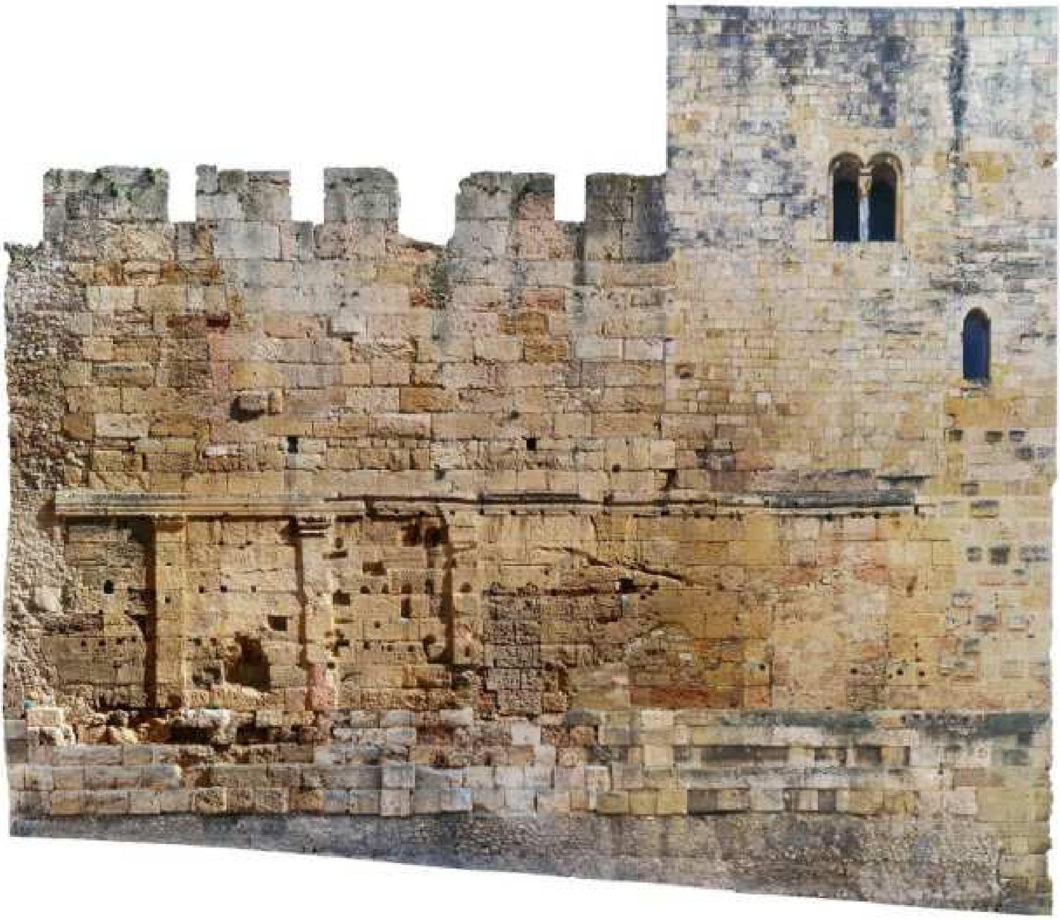

Fig. 7 – The orthophoto resulting from the process(Copyright: M. Serena Vinci)

Modulation study

Having acquired a precise vertical projection we were able to analyse the proportions of the decorative scheme, as well as producing a vectorial documentation implemented in computer-aided design programs such as Autocad. The processing of this information has allowed us to propose a hypothetical modulation based on the homogeneity of the construction (Fig. 8). We established that there was a distance of 2.99 metres between pilasters (the equivalent of 10 Roman feet), while observing that the height of the pilaster and its Tuscan capital was 4.73 metres (16 pes correctus). It is therefore possible to establish a golden ratio, given that the relation between the height and the separation of the pilasters is the number Φ. If we transfer these observations to the façade of the Roman circus, which was also decorated with Tuscan pilasters, we can see that the space between pilasters in that case is 16 pes correctus, the same as the height calculated in the Praetorium Tower. The same golden ratio is also found between the width and the height of the circus pilasters. Those ratios account for the planning and conceptual relationship between the Roman circus and the administrative plaza of the ancient imperial complex, where the existence of a compositive modulation for the urban planning has also been hypothesised (PUCHE et al. 2007.)

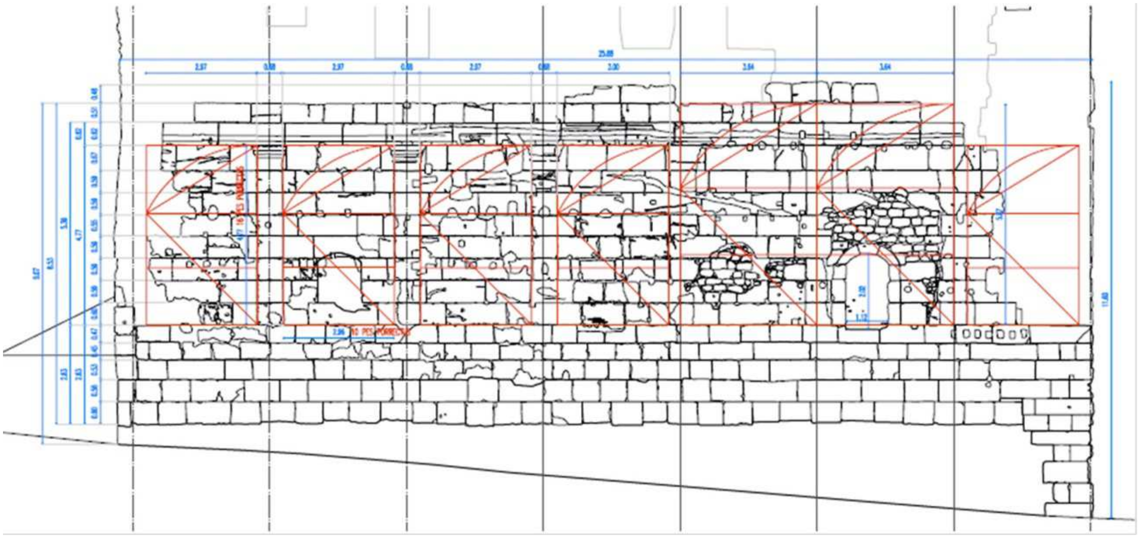

Fig. 8 – Vectorial drawing of the Roman part and a hypothetical modulation (Copyright: M. Orellana)

Identification of how the building materials were worked and a study of the tools used

We analysed how the building materials were prepared, paying particular attention to the study of the working tools used. The Tarraco Provincial Forum was built almost entirely of limestone (the limestone used in Tarragona is called “Médol” and comes from quarries located7 km from the city; GUTIERREZ 2009). The “softer” texture of this stone means that the tool marks have been better preserved; to classify them we needed to identify their shape, orientation and size (BESSAC 1986). The first step of the data acquisition and formal analysis of the structure was carried out in the field, although the integration of the visual analysis and the scaled image allowed us, above all, to measure the elements that were difficult to access. Moreover, the façade of the eastern wall of the Representational Square has interesting archaeological aspects, as it was decorated with pilasters and Tuscan order capitals that were carved with precision in the ashlars of the wall (Fig. 9).

Fig. 9 – Part of the Tuscan capital (Copyright: M. Serena Vinci)

The stratigraphic architecture sequence

The scaled image obtained allowed us to make an exact analysis of the stratigraphic architecture; a relative chronology of the wall facing was identified, focusing on the analysis of the Roman construction. Having analysed the Roman-period structural units (double foundations, the rear wall of the podium), the construction technique and process was analysed for each of them; for example, in the case of the foundations of the structure built of opus caementicium, the imprints left by the wooden planks indicate how the building materials were placed. It is also possible to see how the pilasters were carved on the wall itself after the ashlars had been laid (Fig. 10).

Fig. 10 – Part of the mixed foundations of the tower (Copyright: M. Serena Vinci)

Conservation

This part of the study was carried out with the collaboration of the Tarragona City Council, which undertook the conservation activities. The historical value of the monument required its preservation to be monitored, mainly due to the presence of a fracture on the façade we were studying. Additionally, the graphical information generated constitutes a graphic support for the future dissemination of the monument, which would be largely incomprehensible to a public that tends to see a historical monument as a single project, rather than as the result of diverse functional and architectural situations.

Conclusions

Photographic rectification provided an excellent support for the different studies, besides being perfect for the time-space context of our study. The main advantage of this method is that a scaled image can be obtained: the simplicity and speed of data acquisition and processing makes this method suitable for representing the object plane. The metric and geometric information obtained and the colour and surface details of the building materials allowed us to obtain a large amount of data quickly, efficiently and economically. These are all very positive aspects when planning the work. Photographic rectification can be used to produce a highly versatile ‘drawing’, which can be taken on site and easily read and understood by the many different specialists. It is also a good, more economical alternative to the laser scanner.

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