

VISIBLE AND THERMAL IR DOCUMENTATION OF A MASONRY BRICKWORK BUILDING

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ABSTRACT:

Documentation of Cultural Heritage is a challenging task that is benefited from the new trends in digital acquisition systems. Graphical documentation is not a matter of providing right plans or drawings but also the cleverness to keep and transfer knowledge through them. Digital imaging sensors have contributed to spread the application of digital close range photogrammetry especially in monuments and sites, mainly because of costs reductions in hardware and software, on the one hand, and resolution and flexibility of either small or medium format cameras, on the other. The analysis of some damages or sources of alterations is not always fulfilled with visible imagery. Furthermore, the capability to determine alterations or damages through non-visible sensors is very much appreciated by structural analysts or architects when they have to afford challenging situations in restoration works. Examples of such situations are moisture infiltrations, heat losses and last but not least rendered brickwork structures. This paper shows a documentation process that makes use of both visible and thermal IR imagery to analyse and map alterations on a masonry brickwork building. For that purpose, outer as well as inner shots were acquired and processed in order to plot on top of the metric imagery structural information and alterations. Additionally, analyses carried out with this unconventional approach are displayed and compared with ground truth data compiled by restoration experts.

1. INTRODUCTION

Restoration activities of either cultural heritage monuments or traditional buildings require different surveys in order to extract appropriate information and make useful decisions. It is quite common the provision of ground and elevation drawings by means of surveying or photogrammetric techniques, including in recent years also measurements with terrestrial laser scanning systems. Initially, those drawings were 2D line-based. In the 1990s, texture-based products such as digital rectified photography or orthoimagery started to complement or even replace the former in the digital era. Nowadays, it seems that exhaustive 3D models such as digital surface models are essential to analyse both outer and inner superficial features, mainly when dealing with complex scenarios and shapes. They are basically carried out by means of either terrestrial laser scanning or automatic image matching. Depending on the purpose and the aim, simplified 3D models can also be provided using photo-tacheometry. However, all these surveys could be enhanced with the use of multi-spectral sensors. An approximation to this kind of surveys can be found in Brumana et al, 2005 and Giunta et al, 2005.

It is quite common to carry out diagnoses and inspections of buildings by thermographic techniques, helping the understanding of thermograms with visible photography basically, as well as with other non-destructive techniques (e.g. thermocouple, moisture meter, ultrasound inspection, GPR), and prior to destructive checking. The other way round is also possible, surveying with high-end hardware and software based on laser scanning and photogrammetry, and make use of thermography on the side.

This paper is going to concentrate on visible and thermal images, as well as visual inspection and diagnosis to document a typical brickwork country house (Fig. 1) next to the

Polytechnic University of Valencia, surrounded by a countryside of agricultural fields, prior to restoration. This paper also reviews the potential of integrating visible rectified photography in combination of thermograms for fast and efficient graphical documentation purposes.



Figure 1. Country house

2. THE COUNTRY HOUSE: LA ALQUERÍA DE LA BOLA

Being an anonymous vernacular building (Fig. 1), there are neither evidences nor historical data for this building. The present construction, made of brick, wood and onsite prefabricated cement and sand adobes, as well as poorly reinforced concrete beams and both metallic and wood joists, corresponds to the transition from traditional to contemporary materials and systems. We think it could be built up approximately in the 1940s.

This country house was not made in one round, but in several steps, with different construction bodies that were added step by step, yielding the actual shape of the assemble. Nowadays, this country house appears as a compact building, one and two stories high, with a courtyard at the entrance, terraces and tiled roofs.

Regarding the slabs, the roof and both internal and external façades, this country house damages may be summarized in the following aspects:

- Corrosion of iron bars inside concrete beams and joists. Cracking, splitting, surface spalling and disintegration, characteristic of a really poorly reinforced concrete, almost near the surface of the beams. Lack of concrete protection against moisture.
- Roof damages comprise both insect and fungi attacks on the wooden beams and joists, moisture and rotting. Additionally, the tile roof itself needs some repairs due to existing holes.
- External façades show some loss of material, dirtiness, growing of vegetation, cement mortar repairs (that stop the perspiration on the walls, absorb moisture and expel out mineral salts into the wall). Most of the moisture exists on the Northern wall, although it is possible to find some remains on the Eastern and Western walls. The internal façades show the same phenomena as the external ones but to a lesser degree.

3. IMAGING EQUIPMENT

The equipment used to carried out this project was an off-the-self compact zoom digital camera, Canon PowerShot S70 (Fig. 2a), 3072x2304 max resolution (7.1 Mega Pixels), wide angle lens (equivalent principal distance to 28 mm) up to tele (equivalent to 100 mm).

Regarding the thermal camera, we used a FLIR Systems ThermaCAM B4 (Fig. 2b). It has a high thermal sensitivity as low as 0.10°C and produces clear noise-free infrared images (7.5-13 μm) with a resolution of 320 x 240 pixels. For the purpose of measurement, we used a wide angle lens (field of view 41° x 31°).



Figure 2. Cameras: a) Canon PowerShot S70; b) ThermaCAM B4

4. THERMAL AND VISIBLE INSPECTIONS AND MAPPING

Thermal imaging systems have long been designed to be sensitive to energy in the infrared portion of the electromagnetic spectrum. A thermographic image is essentially a map representing variations in radiation intensity. According to the black body radiation law, all objects emit infrared radiation based on their temperatures. Therefore, there is a strong relationship between infrared radiation and temperature. Analysing temperature and its gradient can help us to detect deterioration areas, heat losses, the location of hidden architectural features such as walled up windows and beams, detachment of mortar (mainly on inaccessible areas).

This section shows different building inspections on the aforementioned country house, corresponding to both inner and outer building parts. The first set of images (Fig. 3) tackles the southern façade. They were taken on a sunny day, late in the morning and in January, 2007. It is obvious on both images the lack of whitewash due to the partial cement mortar rendering. Meanwhile this difference in colour is apparent on the visible image (Fig. 3a), the thermal one (Fig. 3b) shows cement mortar areas warmer than their surroundings. Metallic features such as tubes behave in a similar way.

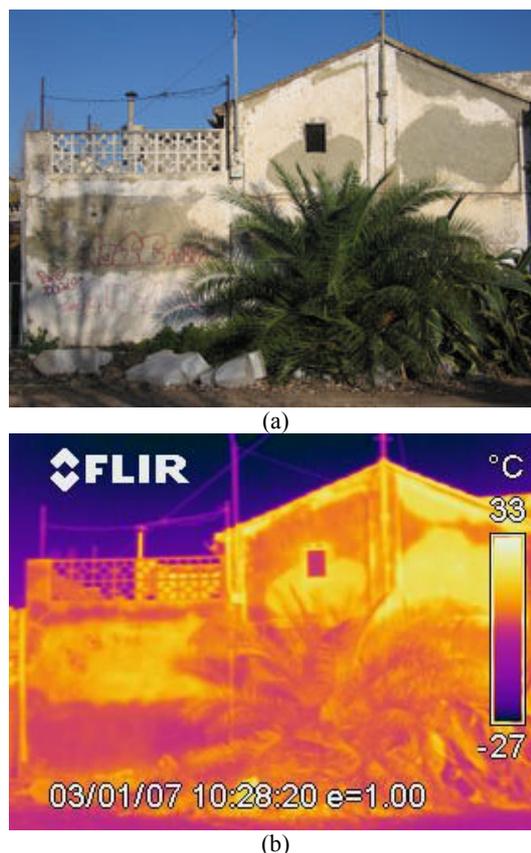


Figure 3. Southern façade: (a) Visible; (b) Thermal IR.

Analysing the same façade from inside, first storey (Fig. 4), similar results are obtained for the thermal image in spite of spatial resolution (Fig. 4b). However, the information regarding this heat transfer difference is not achieved at all from the visible image. This thermal image would suggest some need of painting to avoid heat losses in the future. Bricks structure is well-defined in the visible image and can also be guessed from the thermal IR image. On the other hand, mortar rendering on

this side of the wall does not affect heat transfer from the exterior of the building. Particularly interesting is the cool stripe area on the left hand side of the image reflecting some moisture presence in the corner. Besides, wood trunk's cover shows thermal differences because of the inner framework.

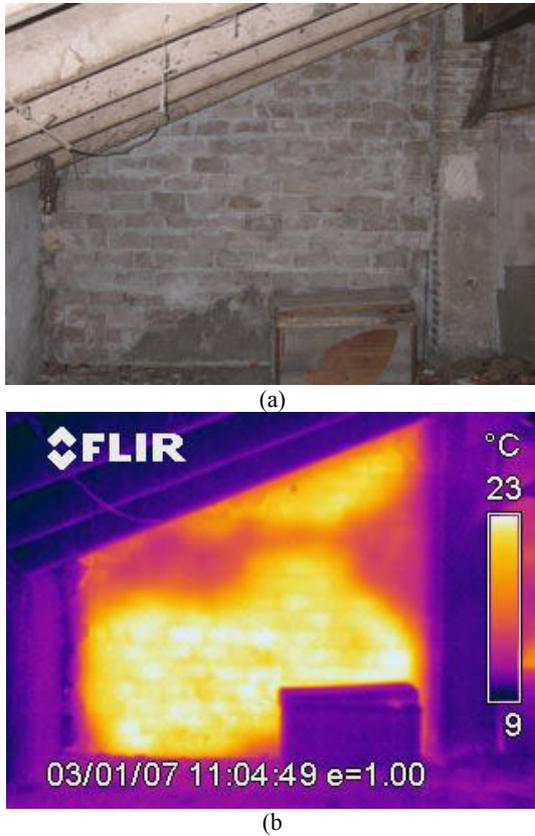


Figure 4. Outer wall pictures taken from the first storey: (a) Visible; (b) Thermal IR.

Next set of images was taken inside and empty room on the first storey in order to reflect the floor structure of regular beams. It was even possible to report beams by means of thickness. Fig. 5 shows one out of seven pairs of images (visible and thermal), used to build up a vector map about the structural analysis on this level (Fig. 6). For that purpose, visible images were rectified without control points by making use of a wooden square target and mosaiced to create a continuous raster image. In a similar way, thermal IR images were also rectified over the visible mosaic to overlay beams drawings (in AutoCad format).

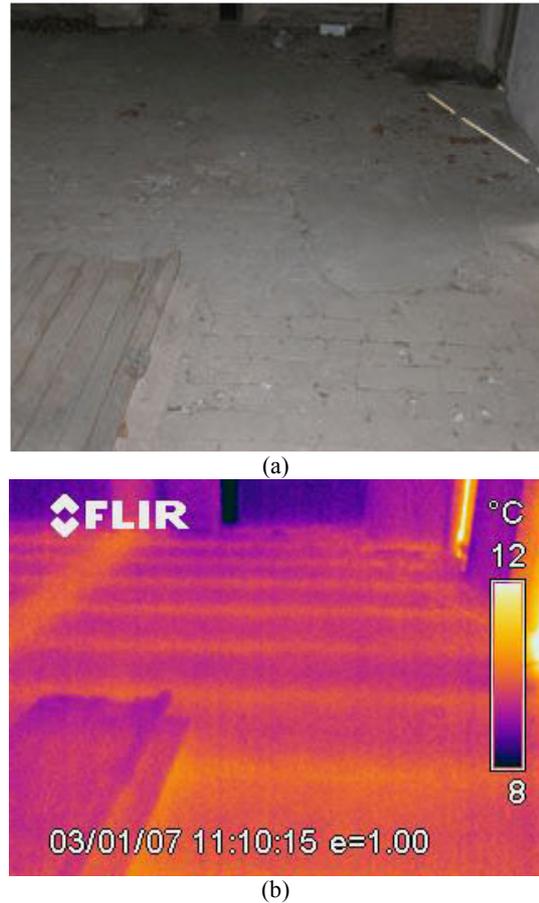


Figure 5. First floor pictures taken from the first storey: (a) Visible; (b) Thermal IR.

It is interesting to notice how the heat transfer from the beams is transmitted outwards in a way that is hardly dependent on upper materials with small thickness (diameter smaller than 4 cm) such as bricks and plaster.

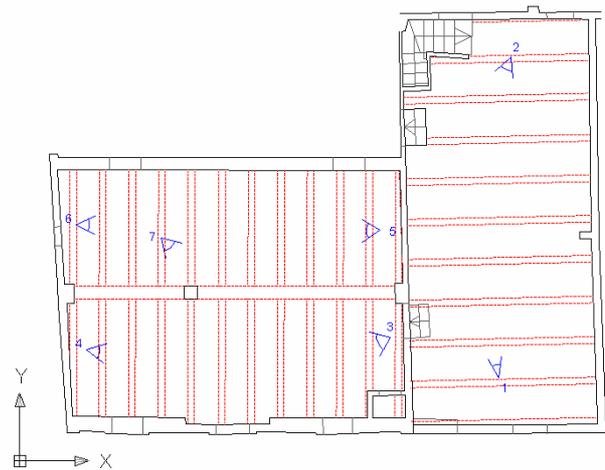


Figure 6. AutoCad drawing of the beams framing the first story. This cad images was built up after acquiring seven pairs of images (check angular symbols)

The last set of imagery was taken on the same building but on the Western façade (Fig. 7). They were shot in the morning before midday. The visible image allowed us to inspect the outer part of the building, finding a cement mortar wall with a

clear walled up (rendered with different colour on the right), four windows and some moisture shapes, some of them invisible to the eyes. Additionally, it was possible to locate some attachments near the ground as well as some plaster detachments. The thermal image also allowed us to both differentiate brickwork activities on the façade (the layout of the upper fourth of the wall is neatly different to the rest), and identify a pilaster in the middle of the facade, as well as some moisture spots as well as some water channels.



(a)



(b)

Figure 7. Western façade: (a) Visible; (b) Thermal IR.

After rectification and merging of the visible and thermal IR imagery, it was possible to draw a vector elevation map with alterations and damages on the façade (Fig. 8).

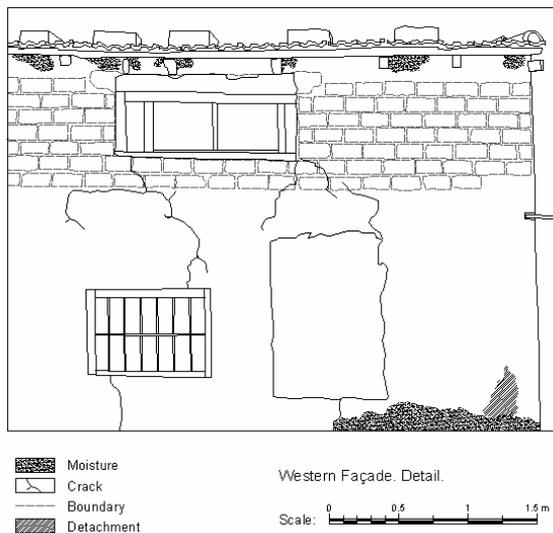


Figure 8. Drawing of the upper right part of the Western façade.

5. CONCLUSIONS

This paper shows some promising results after using both visible and thermal infrared imagery to record and monitor masonry brickwork buildings. In addition to the visible imagery, thermal imagery allowed us to increase the knowledge of alterations in the building and on the exterior walls, e.g. invisible moisture shapes due to water infiltration and plaster damages as initial processes of detachment. Additionally, it helped us to identify inner structural details from the outside such as the central pilaster laying on the Western façade, the brick format, the beams on the first or second storey, and the lintels on the top of the windows.

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