

The Katholikon of Osios Loucas Monastery: In situ investigations

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Abstract

The Monastery of Osios Loucas, Boeteia, Greece (UNESCO World Heritage Monument) is of high architectural and artistic value. The Katholikon (main church of the complex), hosting precious mosaics, frescoes and marble works, has suffered severe damages during its lifetime.

The available documentation contains general information. It is not explicit and sufficient for the structural behaviour of the monument to be studied. Furthermore, information about the construction type of masonry in various parts of the monument is not available.

In situ investigations were carried out, using mainly the non-destructive technique of the radar. The aim of these investigations was to identify the construction type of masonry and to contribute to a better understanding of the monument's bearing system. This is a prerequisite for the interpretation of damages and for the design of adequate intervention measures. Selected results of this application are presented and commented upon.

Résumé

Le monastère de Osios Loucas (en Béotie), d'une valeur architecturale et artistique élevée, est considéré comme l'un des plus importants monuments byzantins en Grèce (UNESCO Monument du Patrimoine Mondial). Le Katholikon (église principale du complexe de monastère) a subi des dommages graves pendant son histoire.

La documentation disponible contient le plus souvent des informations générales et n'est ni explicite ni suffisante pour que le comportement structural du monument soit complètement étudié. En plus, les informations concernant le type de construction de maçonnerie dans les diverses parties du monument ne sont pas disponibles.

Des recherches in situ ont été effectuées, en utilisant principalement la technique non destructive du radar. Le but de ces recherches était d'identifier le type de construction de la maçonnerie et de contribuer à une meilleure compréhension du système statique du monument, qui est nécessaire pour l'interprétation des dommages et pour l'étude des mesures d'intervention. Des résultats de cette application sont présentés et commentés.

Keywords

Radar, three-leaf masonry, masonry construction type, structural behaviour.

1 Introduction

The Katholikon of Osios Loucas Monastery (Fig. 1) acquired its actual form in the period of 11th-12th centuries AD. The monument, decorated with marble works, mosaics and frescoes, has suffered severe damages during its lifetime. Within the framework of works undertaken by the Hellenic Ministry of Culture, with the aim to repair damages and to improve the seismic behaviour of the monument, in situ investigations were performed using the radar technique [1]. The aim of the in situ investigations was: (a) to identify the construction type of masonry in various parts of the monument and to, subsequently, (b) contribute to a more thorough knowledge of the bearing structure of the church.



Figure 1. *Katholikon of Osios Loucas Monastery: (a) the exterior, and (b) the interior.*

2 Short description of the monument

The monastery complex of Osios Loucas consists of two adjoining churches: The smaller church of Panaghia (Virgin), and the main church of Katholikon. The Katholikon of Osios Loucas, the better-preserved Middle-Byzantine Church in Greece, is a two-storey church, famous both for its architecture and for its precious mosaics.

One of the main difficulties encountered by researchers in their effort to understand the structural scheme of the monument is the lack of sufficient written information about the Katholikon, including the construction type of masonry in various areas. That is why the need for in situ investigations using various techniques including that of radar is pointed out in the relevant initial structural analysis study [2]. Hence, the results of the conducted radar measurements helped drawing valuable conclusions regarding the construction type of masonry and subsequently the overall structural behaviour of the monument.

3 Application of the radar technique and problems encountered

In the recent years, the non-destructive radar technique alone or in combination with other techniques (e.g. endoscopy, thermography, etc.) is widely applied to monuments; the accuracy of the obtained results may be quite satisfactory ([3], [4], [5], [6], [7]).

In the case study presented here, preliminary trial measurements were made in regions where the geometry of the stones is known (e.g. in the corners of the walls). The results were very accurate (Fig. 2), and allowed both for adequate settings for the radar, and for the dielectric constant of the stones that are mainly used in the church to be estimated (~ 9.0).

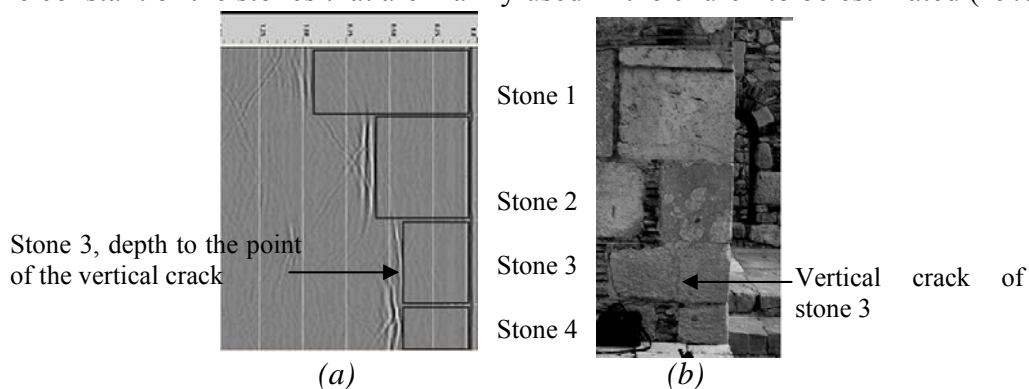


Figure 2. *(a) Vertical profile in the south-west corner of the church, (b) Picture of the same region.*

The main difficulty faced during the investigation was due to the marble, frescoes, mosaics or plaster that cover the interior face of masonry. The accuracy of measurements is significantly affected, thus making the assessment of the results rather questionable ([7], [8]). As in many locations the marble and/or the plaster are detached from masonry, strong reflections of the emitted pulse are observed, not allowing for the in-depth investigation of masonry. Thus, in the interior of the Katholikon, the application of radar gave reliable results only in the locations where the plaster or the marble pieces were bonded to masonry.

4 Results obtained by radar

As mentioned before, in the case of the Katholikon of Osios Loucas Monastery, the aim of radar investigations was twofold: (a) to identify the in-depth geometry of masonry and (b) to contribute to a better understanding of the bearing system. For this purpose, various parts of the monument have been investigated. Almost 260 radar measurements were made in the interior of the church and 110 measurements in the exterior face of perimeter masonry. Over 500m of masonry were scanned (along horizontal and vertical paths).

4.1 Eastern façade of the Church

Three different construction types are identified on the eastern façade of the Katholikon (Fig. 3a), according to the percentage of bricks used between stones, the size and the level of elaboration of stones. Those differences can be taken as indication of different masonry construction methods in-depth as well. Radar measurements also seem to confirm this hypothesis: In the lower part of the church, between the east-south corner and the hexagonal niche of the Sanctuary (Figure 3b), there is a region where the thickness of stones does not present significant variability, and it does not exceed 55-60cm, whereas to the right and to the left of this zone, (a) the measured thickness varies significantly from stone to stone and (b) there are stones as thick as 80-100cm. This geometrical observation is still to be interpreted, on the basis of historical data as well. On the contrary, the varying thickness of stones of masonry left and right of this intermediate region is in agreement with the usual form of the external leaf of a three-leaf masonry.

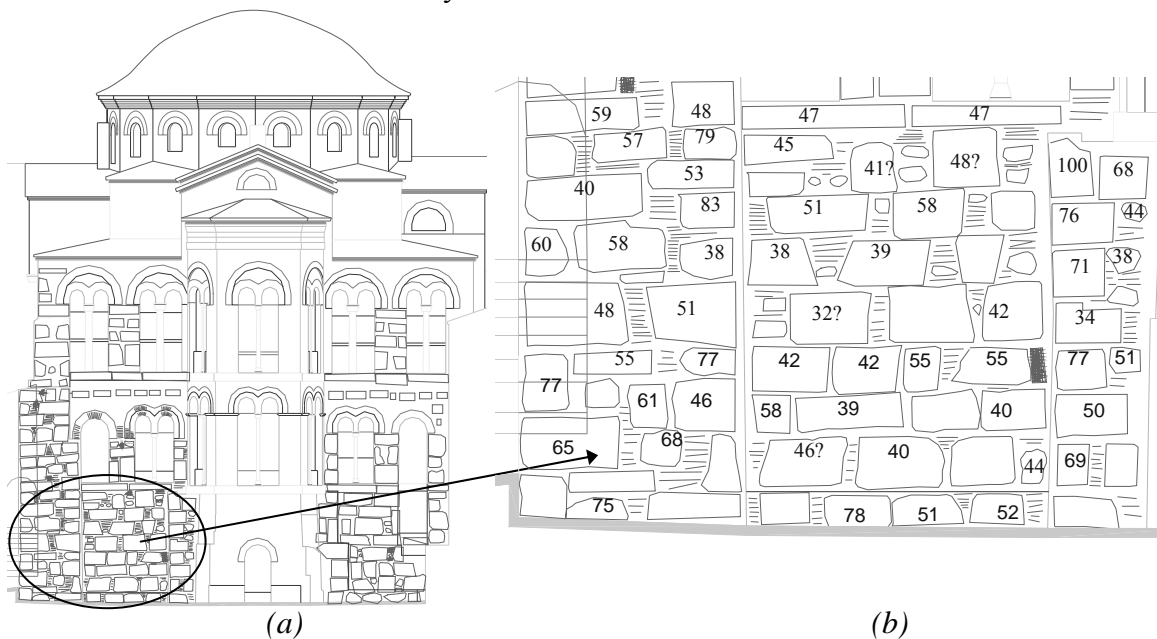


Figure 3. (a) Eastern façade of the monument, (b) Indication of the stone thicknesses of the outer leaf (in cm) at crypt level.

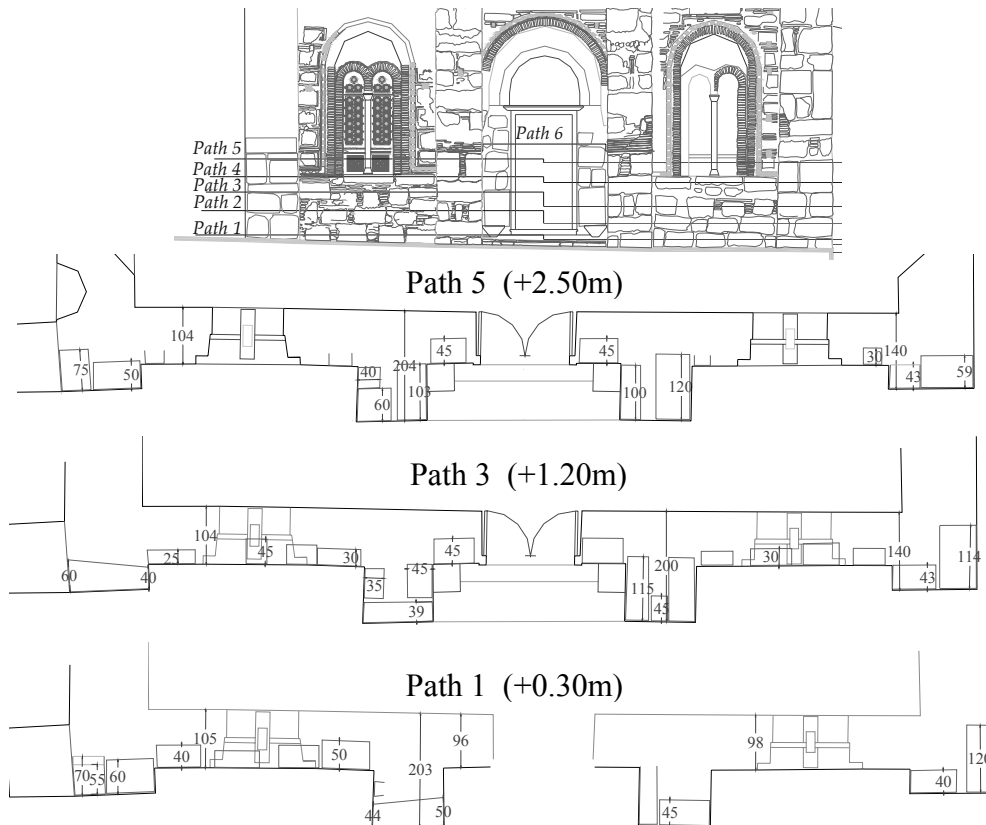


Figure 4. The western façade of the monument. Results of the radar measurements (in cm) along three different paths (ground floor level).

4.2 Perimeter masonry of the Church

Due to the limitations mentioned above, the construction type of perimeter masonry was investigated mainly from the exterior of the monument. In Figure 4 (where the thickness of stones is given in cm), typical results obtained by radar are shown for the west façade of the church. The results indicate a three-leaf masonry, given that the thickness of the stones of the inner leaf of masonry is always smaller, or at maximum equal, to the thickness of the stones of the external leaf. As measurements from the interior are not available, the entire geometry of masonry of perimeter walls cannot be reproduced. Actually, if one assumes that the stones of the internal face of masonry are of approximately equal thickness with those of the exterior face, the region of filling material in the three-leaf masonry results to be of rather limited thickness. If, on the contrary, an internal leaf similar to that detected in the Katholikon of Dafni Monastery [7] is assumed, a completely different picture of the masonry should be adopted. As the differences in geometry have significant effect on the mechanical properties of masonry, the results show an urgent need for further investigation of perimeter masonry from the interior (for instance by locally removing the already detached marbles or plaster).

4.3 Interior of the Church-Masonry Piers

In the interior of the church, mainly the piers have been investigated. The main problem encountered was due to the fact that the entire interior surface of masonry is covered by marble, mosaics, frescoes or plaster. To cope with the difficulties described in Section 3 and to obtain as much as possible-reliable picture of the construction scheme of piers, horizontal and vertical scanning was performed, in all accessible faces of the piers, whereas a rather dense grid of scanning paths has been selected. The case of two typical piers, namely the pier Y32 and the pier I34, are presented and commented upon in this section.

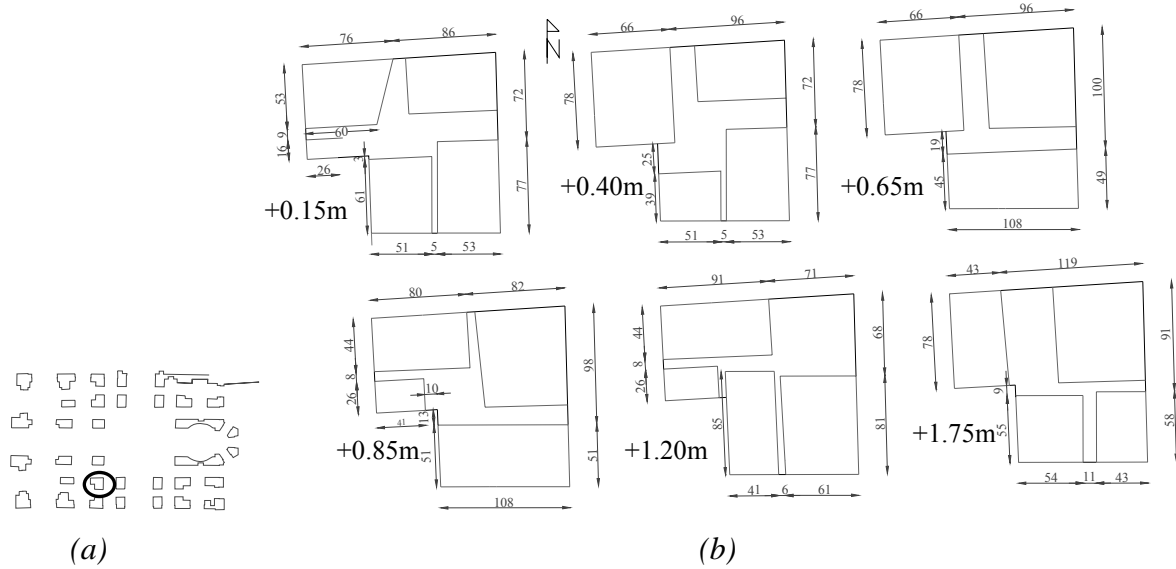


Figure 5. (a) Position of the pier Y32 in plan, (b) Horizontal sections of the pier Y32 (gallery-Yperoon), at various heights measured from the floor level.

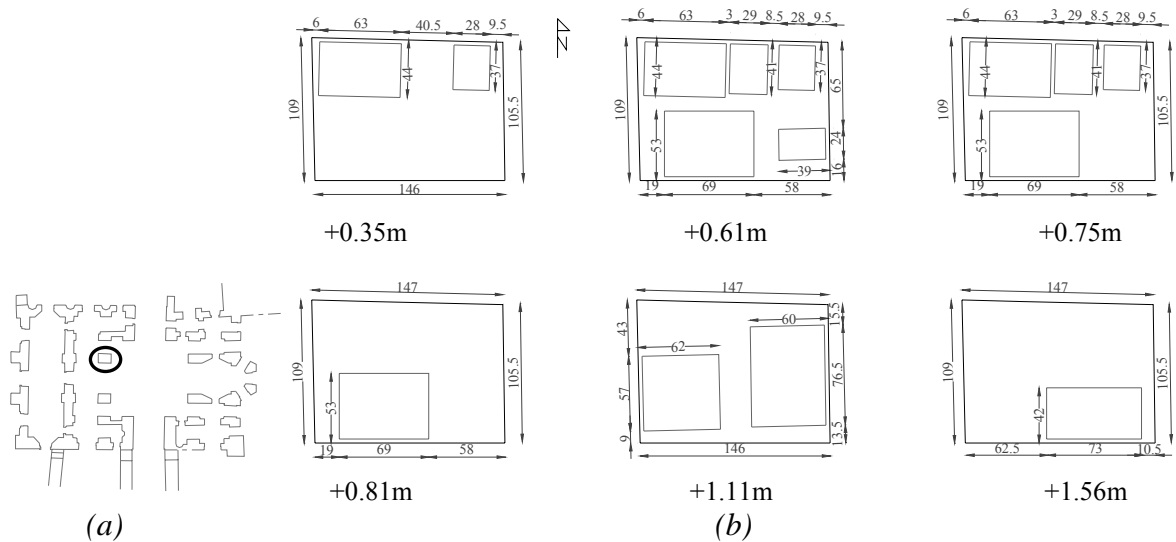


Figure 6. (a) Position of the pier I34 in plan, (b) Horizontal sections of the pier I34 (Ground floor), at various heights measured from the ground level.

The reliable results obtained for the pier Y32, in the level of the gallery (Yperoon), as well as its position, are summarized in Figure 5. One can clearly see a solid construction with large size cut stones, carefully interconnected along the height of the pier. The nature of the space between the stones is not known. It is, however, of limited volume; hence, of limited effect on the mechanical properties of the pier, even if the most unfavourable assumption of a poor quality filling material is retained.

The reliable results of radar measurements taken in the pier I34, in the ground floor of the church, are summarized in Figure 6. It has to be mentioned that in pier's I34 case, the results were reliable to a somehow limited extent. The profiles taken in some regions (that remained blank in the sketches) allow for the assumption of extensive use of bricks to be made.

In general, the construction type of pier I34 seems to be of lower quality than that of pier Y32 (smaller size stones, not carefully overlapping in subsequent layers). This difference in quality of construction seems to be in contradiction with the fact that the pier of the lower

storey is subjected to higher actions than the pier of the higher storey. In a monument of the importance of the Katholikon this cannot be attributed to conceptual or to construction errors, thus, there is an obvious need for further investigation.

5 Conclusions

On the basis of the data presented in this paper, one may conclude that the application of the radar technique to masonry can yield reliable results regarding the outer leafs of unplastered masonry. However, when masonry is covered (by plaster or by frescoes and mosaics), the gathered information may be inconclusive or ambiguous. Therefore, the technique should be applied with caution. Additionally, radar measurements prove to be of significant importance, as they allow for more reliable investigation of the structural behaviour of monuments.

Last but not least, personnel taking radar measurements should preferably be familiar not only with the technique but with the examined monument as well; this is a prerequisite for adequate interpretation of measurements.

Acknowledgements

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