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STEFANO BERTOCCI
FEDERICO CIOLI

Franciscan Landscapes

Conservation, Protection and Use of Religious Cultural Heritage in the Digital Era

vol. 1

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This volume collects the papers presented at the concluding conference of the European project 'F-ATLAS: Franciscan Landscapes: The Observance between Italy, Portugal and Spain' that took place in Assisi, May 11-13, 2023.
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VOLUME 2

INTERDISCIPLINARY PERSPECTIVE IN THE POST-EARTHQUAKE RESTORATION OF MONUMENTAL RELIGIOUS BUILDINGS. THE FRANCISCAN CONVENT OF SAN GUILLERMO DE TOTALAPAN IN MEXICO

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Abstract

Cultural heritage buildings are invaluable remnants of history and culture, necessitating preservation against human and natural threats. Earthquakes, particularly in seismic-prone regions, pose severe risks to these structures due to their historical construction methods predating modern seismic codes. Monumental buildings, despite their unique attention, face higher vulnerability due to their size. Safeguarding these structures is vital for transmitting cultural heritage to future generations. This requires compatible strengthening interventions, often implemented reactively post-earthquake. A case study on the San Guillermo de Totolapan Franciscan monastery in Mexico, damaged in the 2017 Puebla earthquake, exemplifies the need for proactive restoration and structural improvements. An international interdisciplinary research mission aimed to understand the monastery's structural issues and proposed restoration methods. Despite subsequent restoration work deviating from these recommendations, the study underscored the importance of evaluating architectural and structural consistency and seismic performance to prevent future damage to cultural heritage.

Keywords: restoration, cultural landscape, Unesco site, Mexican monasteries.

Fig. 1
Degradation survey and analysis.

1. Introduction

Cultural heritage buildings constitute important bequests from the past, both from historical and cultural perspectives. To this aim, they need to be preserved and maintained towards human and natural hazards. Within this context, earthquakes represent one of the most catastrophic events. In seismic prone areas, the relevant hazard of the territory is combined with the significant vulnerability of constructions and the unquantifiable exposure of goods. Dealing with the seismic risk, as the seismic codes have been introduced only in the 20th century, most of the historical constructions all over the world have been realized following empirical concepts. Hence, these buildings tend to suffer heavy damage during the most severe seismic events. Concerning the monumental structures, although the specific constructive attention that these buildings received, they are particularly vulnerable due to the scale effect given by their significant dimensions. Because of these considerations, it is worth noting that the seismic mitigation of

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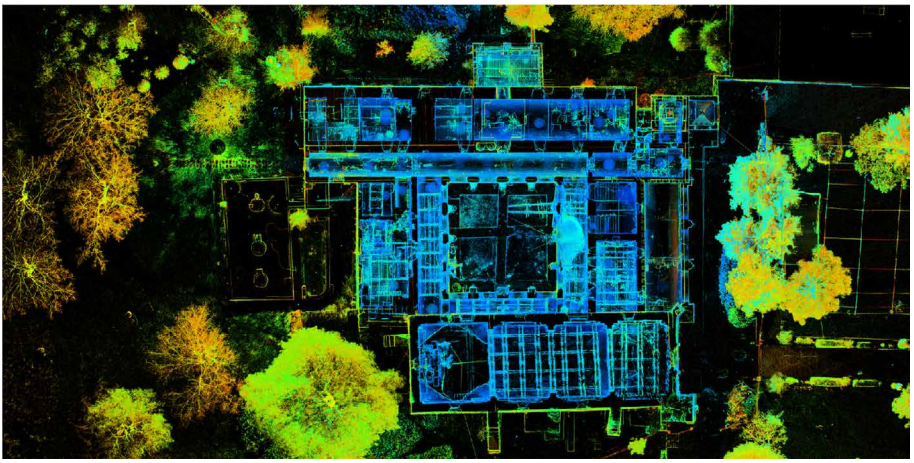
Fig. 2
Planimetric view of the point cloud of the whole complex.



these buildings constitute an important target of contemporary societies in order to transmit cultural heritage to the future generations. To this aim, compatible strengthening interventions need to be planned and designed. In the worst case scenario, the interventions are not realized as preventive measures, but they follow the occurrence of a seismic motion hitting a territory. In this case, large parts of the cultural heritage may be threatened by artistic and structural damage, so that the interventions will concern: i) the refurbishment of the initial architectural and logistic conditions; ii) a structural improvement in order to guarantee a better performance in case of a future earthquake. In this study, we present an interdisciplinary research conducted on a Franciscan monastery in Mexico, San Guillermo de Totolapan, located in Morelos State. The building suffered heavy damage after the 2017 Puebla earthquake. The ground motion led to the collapse of the central cupola of the church, a partial collapse of a corner tower of the facade as to significant damage to the whole complex. An international mission devoted to interdisciplinary research was realized in order to investigate the monastery and finalized at proposing those methodological indications for a compatible restoration. A diagnostic campaign based on different steps was carried out based on a cognitive approach targeted at understanding the investigated good. Although the conducted restorations have followed an alternative path without accounting for the evidence of the research carried out by the international team, the study of San Guillermo de Totolapan became the occasion to investigate the architectural and structural consistency of the monastery, as to assess its performance under seismic motions, in order to understand the main features that led to the occurred damage.

opposite page
Fig. 3
Perspective view of the point cloud of the whole complex.

2. San Guillermo de Totalapan, Morelos

2.1. Territorial localization and historical evolution

The Convent of San Guillermo Abad consists of a church and a monastery composing the structural aggregate of the Convent. It is considered a historical monument by the Mexican people since 1946 when it was included in the '*Ley Federal sobre Monumentos y Zonas Arqueologicas, Artisticos y Historicos*' on August 26th.

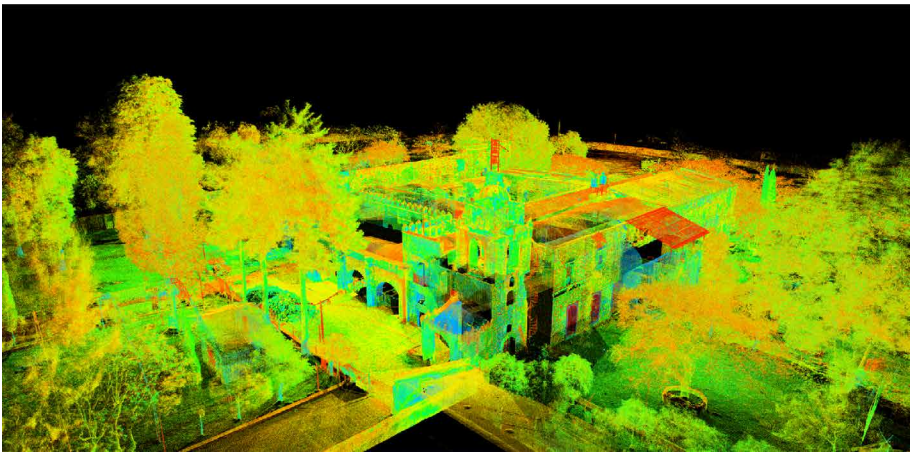
Since 1994 it is recognized as a World Heritage Site by UNESCO, together with the other fourteen monasteries belonging to the '*Primeros Monasterios del Siglo XVI en las Laderas del Popocatépetl*'. In fact, the monastery is part of a series of Franciscan structures realized at the beginning of the 16th century by the Franciscan orders in the wide territory around the Popocatépetl volcano, in the states of Morelos and Puebla. These complexes were built to evangelize large numbers of indigenous; to this aim, the Franscican tried to merge some of the local sacred elements with the architectural project, first of all the Popocatépetl volcano which is visible from every monastery.

From a distributive and formal point of view, the San Guillermo convent is characterized by architectural elements recalling the 16th century ecclesiastical architecture, such as the squared cloister, the outdoor spaces, the garden dedicated to activities involving the local population and the orchard, which represented a place for meditation, for work and subsistence.

The whole complex, including the exteriors, measures approximately 31.000 square meters, while the built area alone measures approximately 3.700 square meters. From a structural perspective the building has been realized adopting a single building technology, i.e. a bearing wall system made of simple local volcanic stones and mortar slaked lime. The vaults are made of the same materials, as visible from the cracks caused by the 2017 earthquakes.

2.2. Architectural evidence

The convent consists of several spaces with different functions that have undergone many changes over time. In particular, the following elements can be identified: the entrance-garden, the portico, the Church, the Convent, the Clock Tower. The complex is characterized by an enclosed and regular space all around the church and the monastery, which makes the plan of San Guillermo convent clearly visible inside the Totolapan village context. The external courtyard of the religious building was an integral part of the prayer rituals, which the pre-Columbian peoples carried out outdoors (Bertocci et al., 2020).



The church represents the northern element in the structural aggregate of the complex. It is characterized by a single nave surmounted by barrel vaults with lunettes at the presbytery. The nave is subdivided into three arches that discharge on square section columns leaning against the perimeter walls. In correspondence of the presbytery, the structure points out a hierarchised and elevated system, aimed at replicating the effect of the central cupolas at the intersection of the transets. Between the unloading columns of the arcades, niches embedded in the walls are highlighted, with the presence of small altars realized between the end of the 17th century and the beginning of the 18th century.

The church is characterized by the presence of the Choir, located on the upper floor and reachable through external stairs. The façade is simple but well-balanced, consisting of a central arch that serves as the main entrance, framed by two slender circular towers erected on square bases. Just above them, in correspondence with the inner choir, there is a circular rose window with visible ashlars and the figure of St. Augustine. Before the earthquake, the façade ended with a sail that unfortunately collapsed. The rest of the complex is located on the southern side of the church. Adjacent to the main facade of the ecclesiastic construction, a two-levels portico is visible. The latter is formed by three lowered arches supported by polygonal section columns and covered by single barrel vaults made of lava stone ashlars of variable size. In ancient times the arches were buffered to prevent direct access to the convent and they have been reopened during a restoration in 1964. According to the local population this is the first open chapel used by the Augustinians to begin the process of evangelisation while they were building the church and the rest of the premises, but considering the position of the main entrance this is improbable.

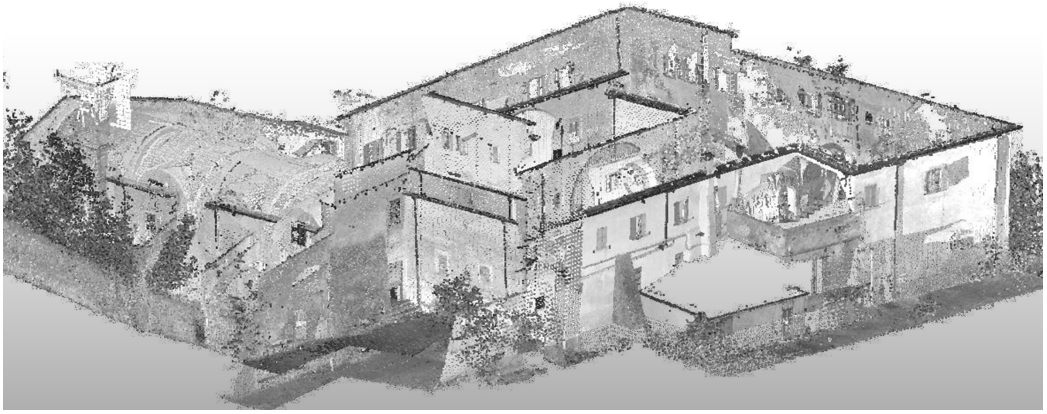


Fig. 4
Orthoimage of the main elevation of the complex.

Directly connected to the portico and the church, there is the rest of the monastery. The convent is mostly organized around a central courtyard, with distributive corridors serving the different rooms of the constructions. These can be accessed through three entrances, the first two to the west, one from the portico, the other from the garden near the clock tower, and the last one to the east directly from the orchard. The whole ground floor is addressed to operational activities and religious functions. On the upper level are the bathrooms, the library, a dining room and the dormitories of the novices and superiors. The whole complex is characterized by geometrical decorations made in the plastered surfaces of the masonry walls. On the outside, regular stones are drawn on the facades; in the inside, more riched decorations are exhibited, with plastered surfaces of the vaults characterized by polychrome decorations.

3. Interdisciplinary research

The 2017 Puebla earthquake struck on the 19th September 2017 in the Puebla state, in Mexico country. The estimated magnitude was about 7.1 Mw and was clearly felt in large part of the country. The seismic motion led to over 6000 injured, with over 300 people killed and numerous buildings collapsed. In 2018, an international mission between the Consulate of the Italian Republic, the University of Florence, the Instituto National de Antropologia e Historia (INAH) and the Universidad Nacional Autónoma de México (UNAM) was promoted, in order to investigate the San Guillermo de Totolapan after the earthquake. Therefore, an survey campaign was carried out.

In order to propose compatible restorations and effective strengthening interventions a detailed knowledge path has to be done. The latter has been made developing a multidisciplinary approach consisting of geometrical, historical, material and structural data's acquisitions. The cross correlation of the different expertise has finally allowed a comprehensive understanding of the complex, its main structural deficiencies and its historical evolutions. It is worth noting that, even in case of absence of specific constructive or historical information on a construction, the building itself allows obtaining the most significant knowledge. This is particularly true in case of an earthquake. In fact, the decorative apparatus of the complex would have discouraged the execution of destructive tests to reveal the structural consistency of the system. Nonetheless, the seismic motion has led to a diffuse severe damage, with the cracks permitting to understand the structural discontinuities of the system given by volumetric additions occurred along the centuries.

3.1. Architectural survey

Concerning the geometry of the monastery, a digital survey using range based and image based technologies was carried out in order to obtain a 3dl pointcloud database. Proceeding with a fast campaign, in only one week of investigations the following acquisitions have been collected: 407 high resolution scans (37 of which were acquired by INAH Morelos); About 3.000 photos; 200 total station reference points.

The interpolation of the laser scanner data was fundamental to guarantee the geometrical reliability greater than cm of the whole complex, while the photographic data was fundamental used to create photogrammetric textured models for the mapping of the lesions and of the main instability. Thanks to this it was possible to appreciate all the phenomena caused by the seismic event, such as the out-of-plane mechanisms, the collapse failures extracting elevation maps (Bertocci et al., 2018).

3.2. Material degradation

The geometric survey has been later integrated to photogrammetric acquisitions targeted at documenting the current state of conservation from a material perspective, pointing out the structural crack patterns along the different parts of the structure. These studies have permitted a specific focus on the material degradation. This concerned those degradations of materials active before the earthquake and due to neglect and lack of maintenance, as well as purely anthropogenic causes such as engraved decorations to increase the adhesion surface of a future layer of plaster. In general, widespread phenomena such as the presence of moisture, biological attack, scabs, the presence of vegetation, have been pointed out.

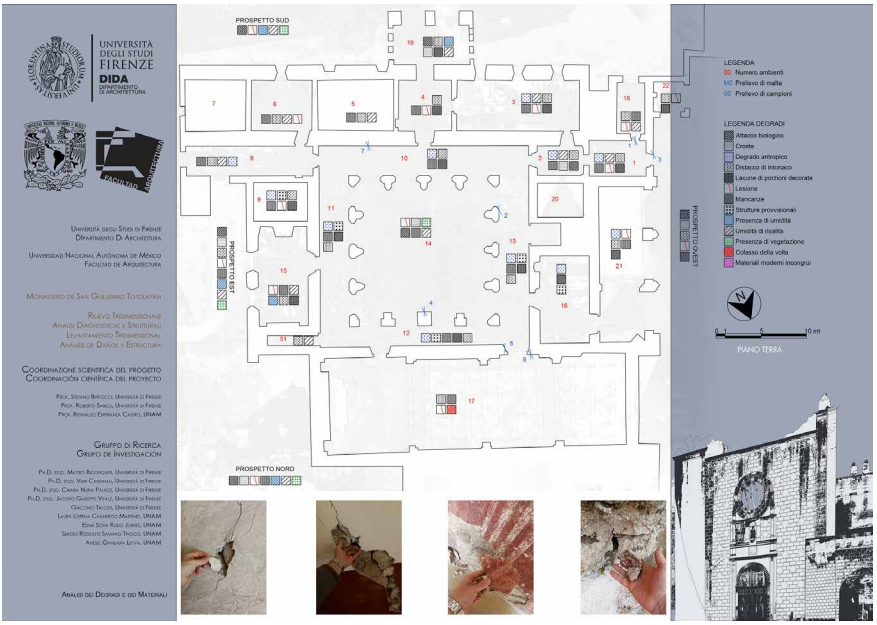


Fig. 4
Degradation survey and analysis.

In particular, on the external facades, various deterioration due to the percolation of rainwater were highlighted, which have favored the widespread formation of biological attacks and swelling of the plaster layer, in some cases causing it to detach.
Thanks to the collaboration with DiaCon S.r.l., Spin-off of the University of Florence, it was possible to carry out an extensive thermographic survey. The latter allowed, to put in evidence some problems not visible to the naked eye, such as for example ashlars dislocated on the rose window above the access to the main façade of the church, as well as other problems related to masonry technology.

3.3. Structural evaluation of damage

The previous steps were finally integrated in order to assess the structural damage of the aggregate. To this aim, the Sheet for the structural damage evaluation to cultural heritage church model published by the Italian Department of Civil Protection together with the Ministry for Cultural Heritage has been adopted. Although this system has been conceived for the churches on the Italian territory, given the architectural traditions of these constructions which came from the European style, it has allowed a first evaluation of the complex. The structure is divided according to its main macro-elements in order to

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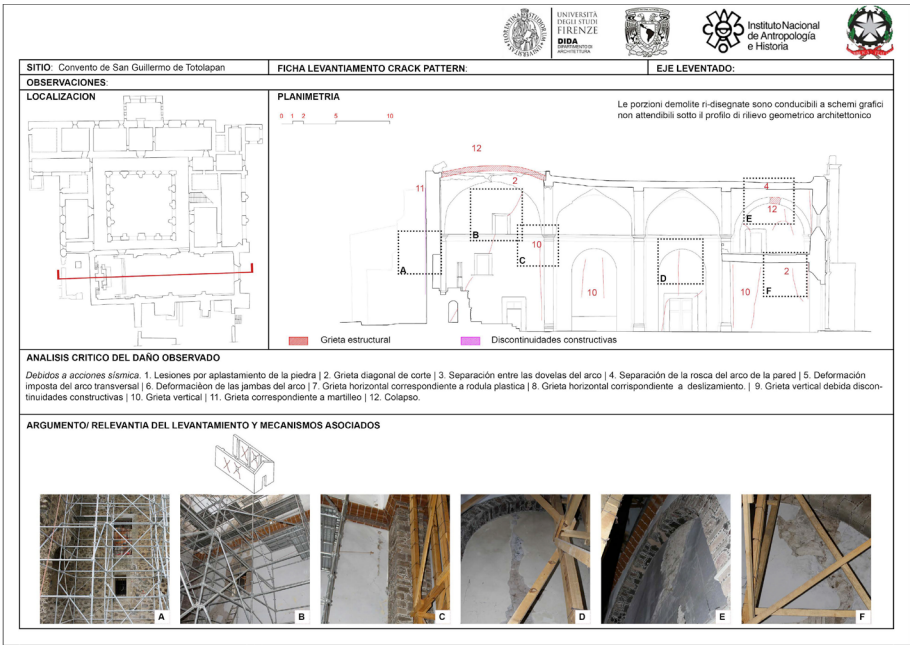
Fig. 5
Survey sheets for the different macroelements of the monastery.



consider the different portions that activate the mechanisms. At the same time, for each one of them, the system associates the different cracks to predetermined levels of damage, classified between Damage 0 – no damage, to Damage 5 – Collapse. A maximum number of 28 macro-elements are available, involving the different parts of an ecclesiastic complex (the facade, the transept, the apsis etc.). In Fig. 05 some examples of the in-situ sheets that have been realized during the campaign are shown. Considering the whole complex, a final index of 0,74 was obtained, indicating the level of damage suffered by the structure. This number was computed as a ratio between the sum of the damage grades for the different macro-elements of the system and the maximum number achievable based on the number of considered mechanisms. The obtained value indicate a general heavy damage of the structure. As we can see for the previous figures, many parts of the monastery collapsed and many cracks passed through the bearing structures from one side to another. The outcomes of this phase were two: i) indicate the serious level of damage of the system; ii) understand the structural features of the aggregate, its historical evolution and structural units. In fact, whenever a masonry system was not realized together with careful corner connections between the orthogonal walls, the structural detachments of the buildings have been highlighted by the seismic excitation. This leads to structural damage and to the occurrence of the failure out-of-plane mechanisms.

3.4. Rethinking San Guillermo

Rethinking a refurbished San Guillermo de Totolapan complex would have regarded a series of issues which recall the ideological questions of the restoration interventions. How to intervene? Should the original architecture be reintegrated in its original configurations? Should the evidence of the earthquake be marked as traced in the restorations? In addition, many vaults made of incoherent stone structures and mortar collapsed. How these systems be realized in order to fulfill the architectural features of the building still guaranteeing adequate safety levels?

Unfortunately, many of these questions have not been answered, as a series of interventions and restorations have started tout-court refurbishing the old architectural system of the building. If this can be arguable from the point of view of a restorer, this is also debatable considering the need of seismic improvements that the system has exhibited. To the author's opinion, when the cultural heritage is at stake, in order to have compatible interventions the restoration should be carefully pondered. Although this may require time to investigate and understand the structural consistency of the system, is the only way to conduct robust research aimed at proposing appropriate interventions.

4. Conclusions

This research produced a preliminary restoration design for the whole complex, that according to INAH could have been used to ensure an international and multidisciplinary approach for the Heritage conservation, in particular Totolapan. In 2019 a series of conferences organized by INAH in Mexico City have been made, in order to show Mexican architects and firms the european approach to restoration. Our project was presented but the work in the monastery was already began not following our suggestion, and receiving many critical advise by the experts invited. Anyway our project showed the possibility of the integrated approach in the restoration of Mexican Heritage Building.

Credits

This contribution could not have been made without the work of many people. Between them, out acknowledgements go to Prof. Roberto Sabelli, Prof. Stefano Bertocci, Reynaldo Esperanza Castro, Dr. Chiara Palazzi, the Italian and Mexican students that attended the in-situ investigations.

Bibliographical References

Bertocci S., Esperanza R., Bigongiari M. 2018, *Il rilievo digitale come strumento di analisi dei fattori di rischio sismico. Casi studio in Messico: un isolato urbano a Città del Messico e il Monasterio de San Guillermo a Totolapan*. In Minutoli F. Reuso2018. *L'intreccio dei saperi per rispettare il passato, interpretare il presente, salvaguardare il futuro*. pp. 129-140.

Bertocci S., Esperanza R., Bigongiari M., 2020 *Il monastero di San Gugliemo a Totolapan e la strada dei monasteri alle falde del Popocatepetl (Morelos e Puebla, Mexico)*. In Bertocci, Parrinello, Architettura eremitica Sistemi progettuali e paesaggi culturali, Edifir, Firenze.

Cardinali V., Castellini M., Cristofaro M.T., Lacanna G., Coli M., De Stefano M., Tanganelli M. 2023, *Integrated techniques for the structural assessment of cultural heritage masonry buildings: Application to Palazzo Cocchi-Serristori in Florence*. J. Cult. Herit. Manag. Sustain. Dev., 13, pp. 123–145.

Manuale per la compilazione della scheda per il rilievo del danno ai beni culturali, Chiese MODELLO A – DC, Presidenza del Consiglio dei Ministri, Dipartimento della Protezione Civile (in Italian).

Roeslin S., Juárez Garcia H., Elwood K. J., Dhakal R. P., Gómez-Bernal 2017, *Puebla, Mexico earthquake: final report of the New Zealand Reconnaissance Team. Bulletin of the New Zealand Society for Earthquake Engineering*, 2020. 53(3): pp. 150-172.

Vitale J. G. 2020, *Un sistema di gestione dei dati diagnostici per il progetto di conservazione, Building Information Modeling (B.I.M.) I casi studio: Firenze Mura (GIS) e L' Ex Convento de San Guillermo Abad Totalapan - México (BIM)*, PhD Thesis, in Italian.

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Integrating historical research with technological progress opens exciting possibilities to create comprehensive digital archives, virtual reconstructions, and immersive experiences that can bridge the gap between the past and the present.

Stefano Bertocci is Full Professor at the Department of Architecture of the University of Florence. He led numerous research projects on the opportunities offered by 3D digital surveys and remote sensing in archaeology, architecture, and urban planning. His major works include research on Architectural Heritage in Europe and Latin America, wooden architecture in Russia and investigations of various archaeological sites in Europe and the Middle East.

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