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NEW TECHNOLOGIES FOR SURVEYING BUILDING RUINS

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ABSTRACT:

Over the centuries, our rich architectural heritage has been exposed to many different phenomena: total neglect, continuous use, constant transformation and a partial loss of integrity. Destructive events and, sometimes, lack of use mean we have inherited some structures as ruins. This paper illustrates the potential for applying new technologies to the metric documentation of building ruins and, in particular, the integrated application of three-dimensional scanning systems and simplified digital photogrammetry. The survey of Bivona Castle is presented as a case study. This castle, of medieval origin, is collocated in the hinterland of the Calabrian coast towards the Tyrrhenian Sea. Before the coastline receded, the building overlooked the sea and over time it was used for both military and productive purposes. A series of transformations and a long period of total neglect have brought about the collapse of most of the structure and made restoration necessary. A restoration project is currently being prepared.

1. MEASURING BUILDING RUINS

Over the centuries, our rich architectural heritage has been exposed to many different phenomena: total neglect, continuous use, constant transformation and a partial loss of integrity. Destructive events and, sometimes, lack of use mean we have inherited some structures as ruins. We have a cultural obligation to study these transformations and safeguard their traces simply because they are often the only way of allowing the *material* and documentary conservation of architectural elements. That is particularly true for those cases in which the degradation and the precarious conditions of the buildings make it difficult to start the valorisation processes. In this case only careful investigation can characterize and highlight such traces, allowing them to be preserved and valued.

1.1 Metric survey of ruins: specific issues

Building ruins can be defined as complexes whose structures have totally or partially fallen down but which are for the most part above ground.
Surveys of these buildings usually have to meet diverse requirements, some of which are common to architectural surveys and others more characteristic of archaeological sites. The objectives of documentation include an evaluation of elevation consistency and stratigraphy, an evaluation of the structural layout, and the quantification of decay symptoms. It is essential that the material reality of the edifice be documented because the analysis of this reality is used to identify decay phenomena and their complex interacting mechanisms. The survey has to select the properties of the object that define its morphology and bear witness to both its transformation over time and its present condition.

1.2 How new technologies can deal with specific issues

In the case of building ruins the identification of the significant points to be surveyed is often made difficult by an uncertain building outline, the collapse of parts of the structure and the presence of infestant vegetation. The risk of defining the shape arbitrarily, and therefore not univocally can be avoided by deploying surveying instruments capable of high-resolution metric (three dimensional scanning systems) and photographic (high resolution digital cameras and photogrammetric techniques) data acquisition. The density of data acquired reduces the need for extrapolation, integration and interpretation during the graphic restitution phase, in contrast with the situation when traditional survey techniques are used. Furthermore the measurement accuracy of the acquisitions phase is preserved more or less unaltered in the final graphic results.
Given the high density and non-selectivity of the documentation collected the analytic phase (and the subsequent graphic restitution phase) can take place after the measuring phase. The application of new technologies makes subsequent interpretations of certain aspects of the building, whose importance may not be immediately evident during campaign operations, increasingly viable.

Scanning system procedures during the acquisitions phase are mostly automatic which makes it possible to minimize the time spent on site. These scanning systems have similar characteristics to "remote sensing" survey techniques which operate at a distance from the object being surveyed, registering its characteristics with no need for direct contact. Both these characteristics are extremely useful in situations, all too frequent in ruined buildings, where unreliable structures make it imperative to pay particular attention to questions of security.

The final graphic output is the result of a gradual refinement of 2D and 3D graphic computer techniques that strengthen the descriptive capacities of the representations. This increases the usefulness of these representations for the planning of conservation projects.

Figure 1. Aerial view of Bivona Castle

3. BIVONA CASTLE

The monumental nature of Bivona Castle, the historical importance of its vicissitudes, its archaeological interest and the splendour of its surrounds combine to make the castle one of the most significant items of cultural heritage in the Vibonese territory in Southern Italy. The structure, totally abandoned for almost three centuries, is situated a short distance from the coastline.

The mighty defensive complex, built on the site of a Roman villa to defend the port that already existed in the 3rd century b.C., testifies to the strategic importance of the site for controlling the port and the traffic it generated. The ancient port of Hipponion was still active in the modern era, until it gradually silted up, as a late sixteenth century testimony to the presence of a "Port of Bivona" demonstrates.

The archaeological significance of the area where the castle was built can be deduced from the considerable quantities of re-utilised building material found in the castle walls.

The castle structure includes a donjon (which may have originally been a coastal watchtower), approximately 25 metres long and 15 metres wide, built in the late 12th century. The architecture of the castle, consisting of a quadrilateral enclosure about 49 metres long and 32 metres wide with sloping perimeter walls and round towers on the corners (the northern tower, which was perhaps the oldest, has fallen down), shows evident characteristics of the Aragonese era, as one would expect given the vast programme of works undertaken by Alphonse II in 1494 to reinforce the defence systems of Calabria Ultra.

In the middle of the sixteenth century the castle was transformed into a cane sugar mill and premises for cooking the sugar and storing the sugar loaves were constructed in the keep, formerly the residence of the garrison, to which another storey was added.

Both the lower level of the building and the level immediately above are internally divided by a partition that runs longitudinally; on the ground floor this partition created a long corridor that led to a barrel-vaulted hall and to two cross-vaulted rooms. Fallen

Figure 2. The rooms inside the castle are not accessible at present as they are entirely obstructed by fallen building material (view from the points model surveyed using a laser scanner)

building material has filled the two large subterranean rooms that used to be accessed through a door on the southeastern side of the keep: the first step to this door was found during the work carried out in 1969.
The north-eastern tower, operated the millstones of the press, located in the storeroom that abuts onto the external wall of the castle.
In the courtyard, to the north of the entrance to the keep, one can still see the opening of the external well below which there is a barrel-vaulted cistern. An aqueduct fed this cistern and the others that were certainly present.
The cane sugar mill ceased to operate after 1680 partly because sugar production was becoming less and less economically viable but also because a swamp had formed nearby some decades earlier. The castle was soon abandoned and by 1710 it was described as being in ruins.

Figure 3. View of the inside of the castle (3D points model)

3.1 Previous surveys

The only surveys of the ruins of the Castle prior to the research presented here were those published by Francesca Martorano in the volume "Chiese e castelli medievali in Calabria" (Rubbettino, 1996).
The graphic documentation of these surveys does provide morphological information on the castle but it lacks the necessary information for testing measurement reliability and it offers no observations on the constructive aspects or on the phenomenology of decay of the structures and wall surfaces of the castle.
Large portions of the construction have fallen down, others are falling down now; the only consolidation work (a partial intervention), took place almost forty years ago. Many parts of the curtains are missing and the totally unprotected crests of the walls are vulnerable to the effects of external agents, which are no doubt accentuated by the coastal meteorological and environmental conditions.

4. 3D DIGITAL SURVEY

4.1 Data acquisition

In order to document the Bivona Castle standard topographic survey techniques were applied when setting up the transverse network and measuring targets; three dimensional scans were used for the detailed survey and simplified photogrammetric sysytems were adopted for the production of rectified images.

The transverse network and the system of coordinates

The survey took place within a local reference system, defined by the coordinates of the datum points that materialise the principal transverse network. The extreme vulnerability of structures in a ruined state frequently requires the progress of phenomena such as instability and physical decay to be monitored. The realisation of further survey campaigns had to be taken into consideration when setting up the transverse network; different surveys can be directly compared provided a common reference system is adopted: the vertices of the transverse network, which are its on-site materialisation, should therefore be made sufficiently stable and also well documented.
The transverse network is the back-bone of the entire survey because it defines the local reference system; it is made up of a non-oriented closed polygon to which an other transverse is attached. The geometry of the transverses was designed as regularly as possible, keeping the lengths of the sides as homogeneous as possible, to ensure that the vertices required for surveying the targets would be available in all areas of the structure both inside and out. The transverse network has 9 vertices the coordinates of which were calculated and compensated empirically.
48 targets, distributed throughout the entire structure, were measured from the vertices of the network and used for aligning the scans.

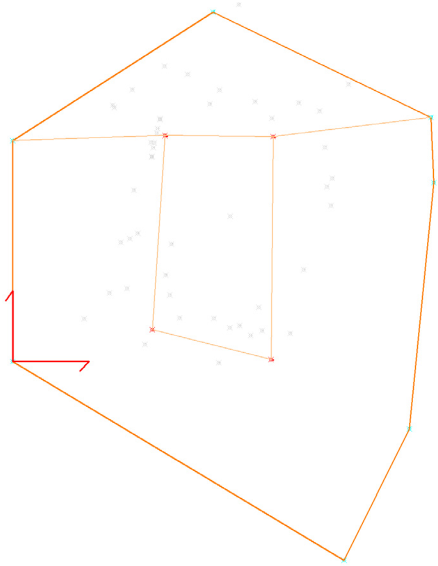

Figure 4. Diagram of the topographic network: the local reference system used, the transverse network, the targets

3D Scanning

Three-dimensional scans were used to realise the detailed survey. The acquisition from different positions made it possible to reciprocally integrate the shadow zones and to obtain an almost complete points model of the castle. 14 scans were taken outside the castle and 19 inside.

Photographic shots

The photograms were taken under "pseudo-normal" shooting conditions, with the shooting axis as nearly as possible to being perpendicular to the building elevations, to ensure that the scale

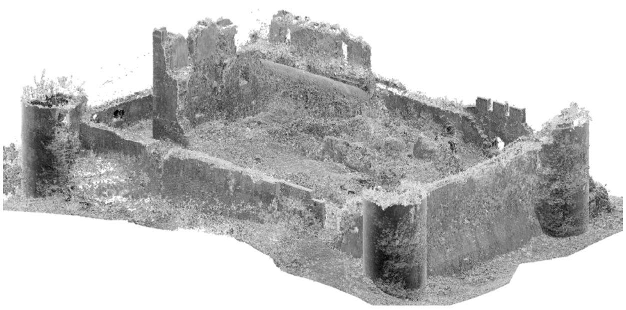

Figure 5. View of the points model surveyed using three-dimensional scanning

Figure 6. Photographic survey of the elevations

of the image was more or less uniform over the entire photogram. The elevations of both sides of all the walls were documented. The photograms were shot as flight strips thereby ensuring that adjacent photograms were sufficiently superimposed.

4.2 Instruments used

A Leica TCR705 total station, complete with accessories, was used for the topographic survey.
Scanning was carried out using a Leica HDS6000 laser scanner; the scanning resolution adopted was centimetric in correspondence to the surfaces considered.
Photographs were taken using high-resolution digital cameras.

4.3 Data elaboration

All the data acquired using three-dimensional scanning was referenced in the topographical reference system. The coordinates of the targets, distributed throughout the entire structure and measured topographically, were used to align each scan.
Horizontal and vertical sections were obtained from the global points model by means of section and orthogonal projection operations.

5. GRAPHICAL OUTPUT

5.1 Optimisation of the graphic restitution to meet the requirements of the restorers

A metric survey should be understood as an integral part of the complex process of documenting the research carried out on an object. An operation as complex as the project for the conservative restoration and valorisation of Bivona Castle, requires interdisciplinary cooperation among experts from different disciplines. Everyone needs, albeit with diverse specific requirements, metrically accurate, computerized documentation of a graphic nature.

The need for interaction among multi-disciplinary fields of expertise makes it imperative to find an effective equilibrium between information content and descriptive simplicity in the graphic documentation that is essential for various types of analyses and for drawing up projects. The metric survey of Bivona Castle was the starting point for all the successive analyses that had the objective of planning the conservation of the structure. The "standard metric survey" was, therefore integrated by various experts with information pertaining to both the state of

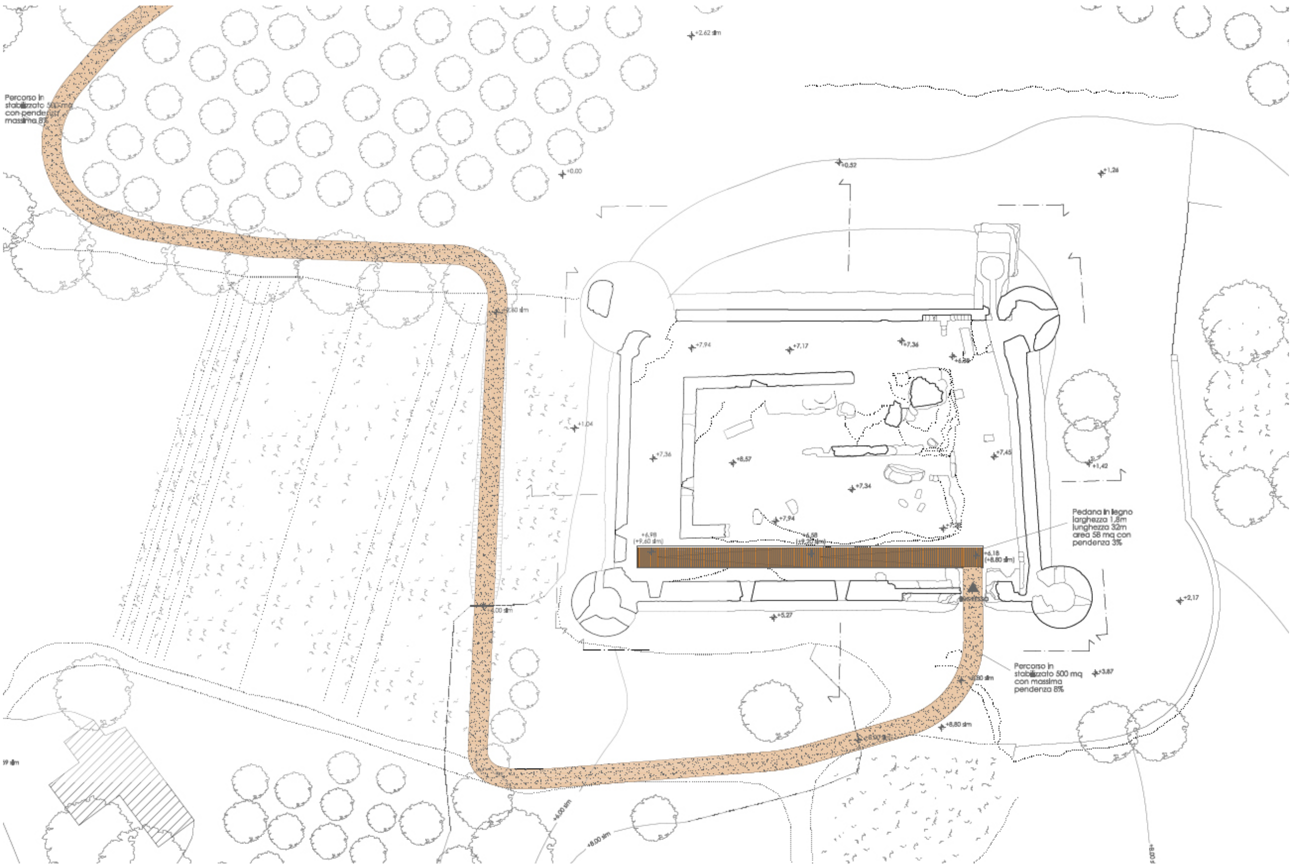

Figure 7. Project plan of a new pedestrian path

Figure 8. Example of the graphic restitution of the survey: a transversal section of the castle

conservation and the identification of pathologies, with hypotheses as to their underlying causes. Similarly, a topographical DEM proved essential for designing routes for visiting and structural evaluation was made possible by the analysis of the crests of the walls. Direct visual analysis is always a fundamental starting point for completing such precise analyses. The state of conservation of structures and materials, as observed and verified by inspections, was plotted onto the rectified images and onto the ortho-photos. This resulted in thematic maps, which completed the graphical documentation required for the restoration plan.

Graphic restitution, produced in a numeric form and memorised in a database, was carried out to a nominal scale of 1:100.
The graphic output, produced by vectorial representations and integrated by raster images, consisted in:
- 3 plans at the following heights: +7.95 m, +9.00 m, +15.50 m;
- 4 external elevations
- 2 vertical sections, one longitudinal and one transversal.

All graphic output was referenced in a local reference system; contemporaneously the transformation parameters in the reference system of the entire survey were known and memorised using special UCSs in the DWG files.

Vectorial restitution in the elevations and sections was integrated by the rectified images realised for every portion of flat wall whilst raster images obtained from the points cloud, exploiting the analogy between the rendered reflectivity data and the photographic image, integrated the representation of curved or strongly three-dimensional elements. For each point measured during scanning, the intensity of the signal reflected which depends, albeit not exclusively, on the colouring of the surface being analysed, was memorised. This information makes it possible to obtain images that strongly evoke the corresponding photos, obviously corrected beforehand to remove all perspective distortion.

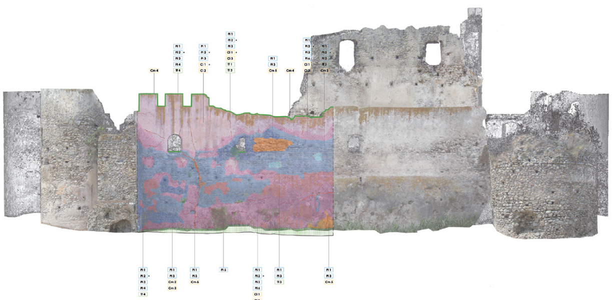

Figure 9. Decay and restoration intervention mapping

Figure 10. Example of the graphic restitution of the survey: the elevations integrate rectified digital images for the flat parts and the orthogonal view of the range maps

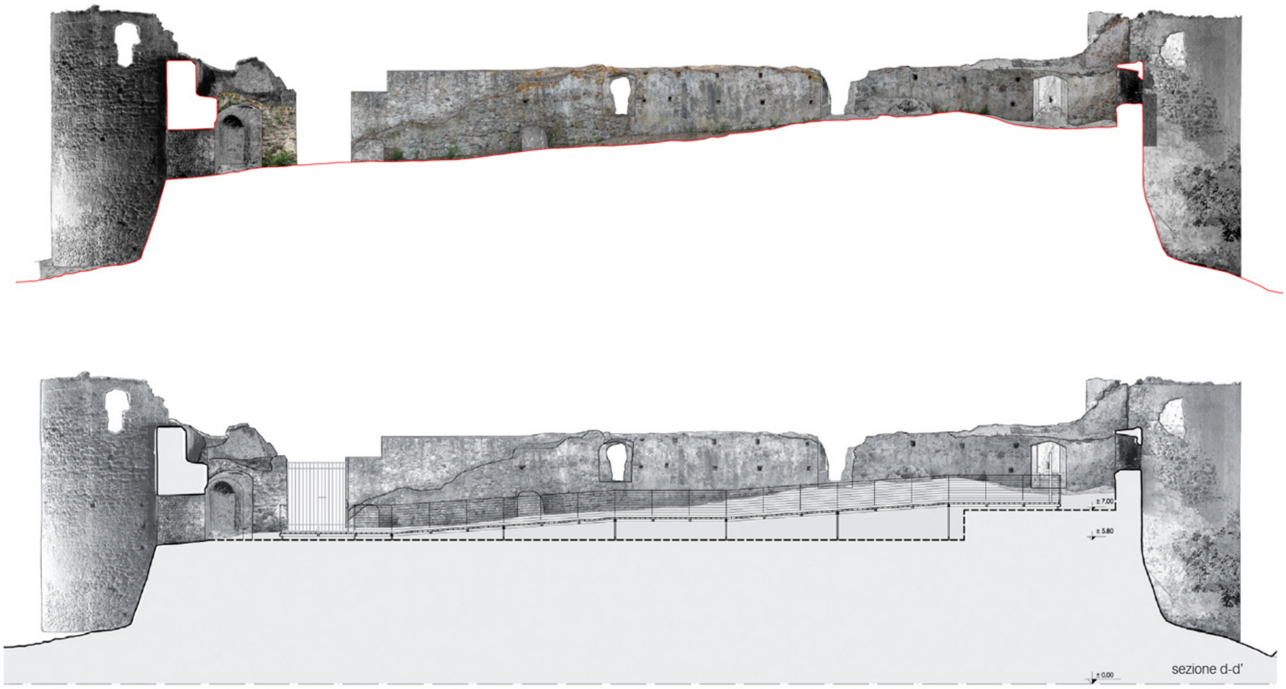

Figure 11. Survey (up) and project (down) longitudinal section along the elevated walkway in project

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The graphical output were made by Valentina Bonora and Michela Pavan.

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