THE MULTI-CRITERIA DIAGNOSTICS AND SURVEYS FOR UNDERSTANDING AND MONITORING THE ISSUE OF TECHNICAL RESTORATION IN THE TEACHING OF THE ARCHITECTURAL CONSERVATION

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Abstract

For few academic years, in the courses of Architectural Restoration of the Department of Science of Civil Engineering and Architecture of the Bari Polytechnic we are carrying out activities of non-destructive diagnostic related to the field of archaeological prospection and analysis of the conditions of decay of the historical architectural surfaces.

The paper intends highlight how the learning experience has allowed to understand the conservation status directly on the field of investigation. This knowledge, acquired in the learning experience, lets to refine the ability to program a diagnostic analysis process congruent with the visible degradation aimed at achieving better understanding of the building conditions, and guide the conservation project.

The application experiences are mainly related to the following types of activities:

1) archaeological prospecting

2) analysis of the decay of masonries (ancient and modern)

3) analysis of the degradation conditions of architectonical and artistic surfaces (ancient and modern)

The teaching model, in the first instance, had to bring out the big difference between the non-destructive diagnostic systems and the "minimally destructive" ones. the "minimally destructive" ones are specifically linked to the structural and seismic analysis, necessarily "numerically correct" and aimed to the quantitative definition of the physical parameters investigated.

The "indirect" analysis (qualitative) we are carrying out in our laboratories, through the measure of physical quantities not directly related to the strength characteristics (but still related through statistical algorithms), allows to give an assessment of the condition of the artefacts observed without any damage, even minimal. However this analysis allows characterizing the modifications of the behaviour of structures in the time, their decay conditions and the variation of the material density.

The most interesting result comes from the overlapping of different methodologies that can combine different levels of criticism giving each one the results to the issue posed from the other.

The involvement of the students in this process allows to focus on the difficult relationship between the design of diagnostic testing and the expected result at the end of the campaign, as well as focus on the issue

of define an appropriate diagnostic project to obtain a coherent result for the conservation project.

It may allow a more articulated reading of the artefact that highlights the complexities of situations often linked to the presence of more degradation factors. This is an extremely common condition in the field of architectural restoration and on which are centred the main troubles of professional activity on our field.

Keywords: diagnostic surveys in architectural restoration, learning through practice integrated methods of architectural diagnostics.

1. INTRODUCTION

Since the moment the theory of the restoration, in architectural field, chose the "scientific restoration" criteria at the base of each intervention, the preventive research, historical and material, was the starting point of each knowledge for the restoration project.

Starting from the historical concluding document of the third conference of Italians engineers and architects (1883), now considered the first “restoration card”, we assume the monument like the first document on itself, so, all that is possible to assume from the monument itself is the best base to guide in the process of the restoration design.

Obviously the aim of the restoration is to preserve all the phases of the monument, including stratifications, coverings, reinforcements... so sometimes, through the traditional surveying methods is not possible to know for certain the history of some parts of the monument, only because there are now not visible.

In many cases, until now, it was necessary to avail to expensive works only to guide the following intervention, or in alternative to give up the whole project for the lack of resources for the knowledge.

In worse cases, but often occurred in the past, the intervention, designed without sufficient knowledge, needed relevant modification in the course of the work with the impossibility of estimate the costs and often the inability to achieve a correct approach to the work.

2. FROM THE GEOMETRICAL SURVEY TO THE PREVENTIVE KNOWLEDGE THROUG THE MODELING (^{2} O.F.C.)

The first approach to the knowledge of a monument has to remain the survey. It is needed because it forces the designer to know in depth the architecture on which is working. and without a depth knowledge is impossible to focus on the unresolved questions of the building. In this way is recommended that the survey and the restoration design are demanded to the same working group.

To get the three-dimensional relief of cultural heritage can be used different technologies or acquisition methods, distinct in features and performance. The choice of which depends on the purpose of the final digital model, the geometrical and material characteristics of the asset, the conditions of the site, the economic resources and time available.

The application of digital three-dimensional survey methods allows you to generate digital models much more complete of geometric and colorimetric information in front of traditional survey techniques.

Regardless of which surveying technic and processing of the obtained data it is decided to use, the result is a "digital information model". A "queryable" model by which is possible to access to information related to the detected artefact (geometric reliefs, thematic surveys, plans, georeferencing, iconographic documentation and literature ...). Tolerance between the actual figure depends on the type of instrument used and the restitution method you choose. the depth and the type of information depends on the type of platform is chosen and the data that have been inserted.

Initially, despite the advantages of these methods compared to traditional ones, the high cost of the first active three-dimensional optical sensors (range based modeling) and passive (image based modeling), has restricted the spread.

Greater diffusion has been due to the advent of digital photogrammetry which entailed a great innovation compared to the equipment used and the algorithms at the base of the three-dimensional modeling leading to the achievement of a high level of automation of the photogrammetric process. In particular, with suitable software the orientation procedures - internal and external - and extraction of digital models can be made in

an automatic way (and not in an interactive manner or by specialized technicians). A further step towards the deployment of relief methods and three-dimensional modeling has been done, always in the field of photogrammetry, with the association of digital photogrammetry to new modelers, nowadays carrying algorithms able to read automatically the focal length and to correct optical distortion of the lens, starting to the exif data of the image file itself (or able to build up by themselves the data needed for the process, in case the exif data are not available). these techniques allow a significant reduction of both costs, and the level of specialization of the operator indicating photo modeling now as the basic technique for the architectural and archaeological survey.

The contribution these technologies can provide is clear: in the phase of detection allow the rationalization and speed of survey operations. In interpretation, conservation and storage of data, in the enhancement of the heritage through the web they make possible the creation of new infographic representations that easily meet the different needs of scholars and practitioners, as well as the general user.

The research activities carried out in recent years aimed at the codification of a working method devoted to the optimization of resources (often scarce) for the production of computer info-graphics models useful for the documentation from the heritage, to its study, management, maintenance scheduling and conservation , the prediction of the decay, even to the possibility of use and share these models through a web platform.

In this way we are carrying a research for use a 3d database to attach all the information about an historical building. at the moment exists several BIM software, but the process of transferring the "survey model" in the information management software is still very complex, and the database provided with the BIM software in use are still unsuitable to the very large type of information that a complex knowledge on an historical cultural object requires to put in a system.

2.1 Surveying architectural heritage for the restoration project

A first approach to this method there was relief in the context of the collapse of the Fortress of Finale Emilia tower in the Emilian earthquake in 2012. The morphological characteristics of the product as a result of the earthquake and the accessibility conditions in addition to the limited time and available economic resources have made it the photo-modeling tool particularly suitable.

In this case The Polytechnic of Bari work with the fifth year course of the Architecture degree in agreement with the Regional Directorate of the Ministry of Heritage and Culture. A number reserved course for six student followed by two university researcher and a tutor. This work, starting from the survey and ending with the restoration project become the degree work for the group of students.

Fig. 1. Frames relative to the loggia of Finale Emilia Castle Fortresses damaged by the earthquake that hit

the Emilia Romagna in May of 2012 .

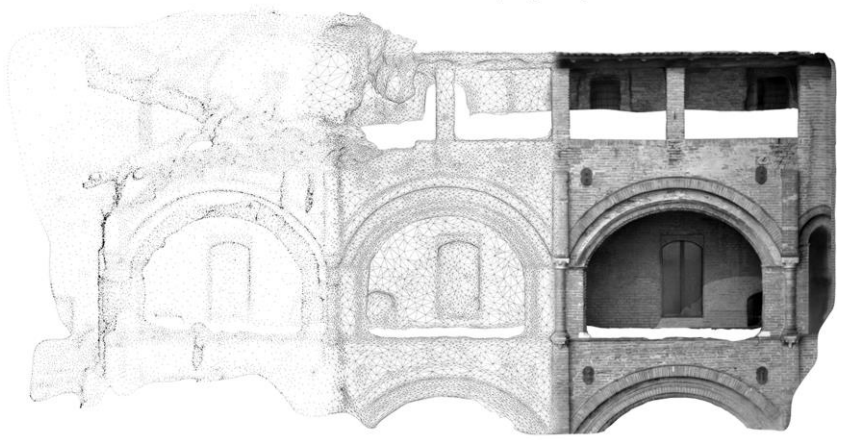

Fig. 2. Three-dimensional "collapse digital model" of the Finale Emilia Castle Fortresses loggia obtained with automatic development process (image matching) using the software 123D Catch by Autodesk by the students of the course: Maria Giovanna Rizzi, Serena Schiraldi, Gaia Spagnoletti, Graziana Tagarelli, Federica Vitarelli e Valentina Zaza.

2.2 Surveying archaeological heritage for the knowledge

In the Academic Year 2014-15 the same fifth year optional course was aimed to the study of the archaeological site of Egnatia. In particular, the first excavation area of the ancient city, excavated by the superintendent Quagliati in the first ten years of the twentieth century.

This area, due to his history, lack of many documentation about the excavation that makes very difficult to understanding his history. So the group of students have to flank to the study on the documents, a whole survey, both direct and indirect of the area. The direct survey, aided by a total station support, was usefull to elaborate a whole planimetric survey 1:50. and the phase plants of the area.

The Photogrammetric survey, this time produced by a Remotely piloted vehicle equipped for the remote sensing with a planned flight by gps control. The zenithal camera placed under the "drone" shot a series of ortogonal photograph of the soil.

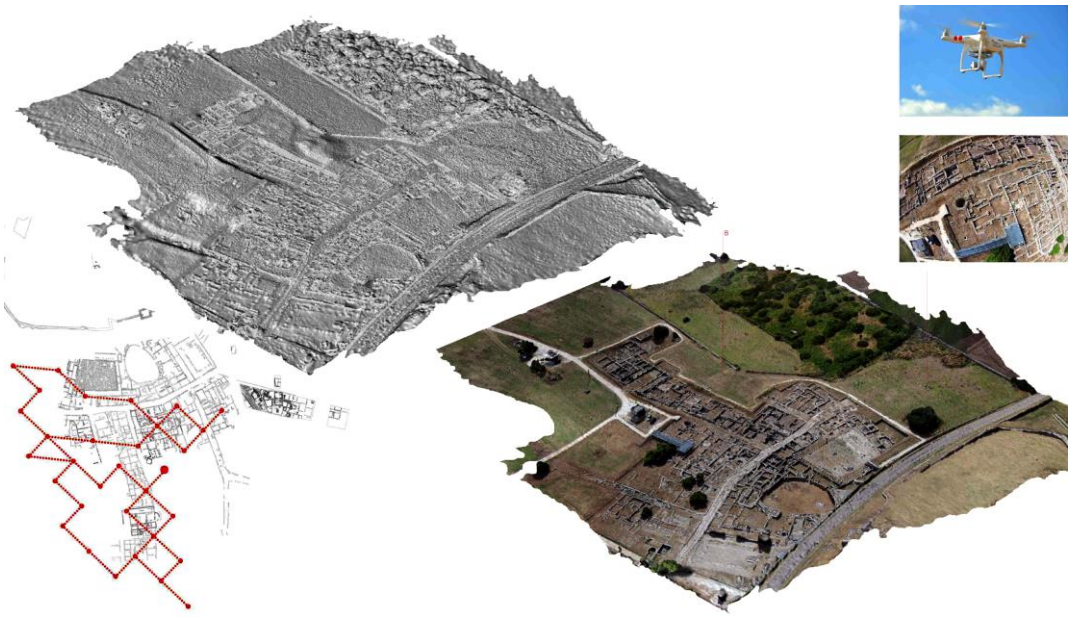

Fig. 3. Three-dimensional model merged and un-merged with chromatic data. the model shows clearly the soil microrelief and depressions. Model elaborated by the "pix4d" staff between the Photogrammetry Laboratory of the Polytechnic of Bari (geom. Pietro Grimaldi). Post production editing and interpretation by the students: Angelica Disabato, Vito Macina, Roberta Rita Maria Pinto, Virginia Polignano, Valentina Sica.

In the postproduction work, the photographs were matched by specific software. This time the platform used was the "pix4d" solution due to the availability of the "pix4d software centre for Apulia", between the Photogrammetry Laboratory of the Polytechnic of Bari (geom. Pietro Grimaldi).

Through the aerial zenithally photograph and the 3d model of the archaeological soil, it was possible to analyse the condition of microrelief, humidity, plant differential grow that is used in the aero-archaeological field to indicate the presence of ancient building hidden underground. So the group of student was able to track some hypothetical plan of the unexcavated part of the city.

3. THE PREVENTIVE KNOWLEDGE THROUGH INDIRECT NON-DESTRUCTIVE (OR MINIMALLY DESTRUCTIVE) INVESTIGATION METHODS (1 G.M.)

In the field of indirect non-destructive diagnostic tests, aimed at the characterization of the decay conditions of a specific artefact, are used all the analyses which indirectly characterize the quality of the object. In summary, we intend to measure the behaviour of structures and the level of decay through a reasonable proportion between the physical characteristics upon measurement and the compactness and strength of the material.

Obviously is necessary to compare the reaction of the investigated material to the analysis with a "healthy" sample material, or with the scheduled data recovered by a "undisturbed" sample.

The "proper" non-destructive investigations are characterized by analysis of the object without contact by reading the surface data (such as thermography) or by contact, analysing the mass through the release of magnetic or compressional waves (such as electrical, magnetic or sonic survey)

Recently it stands out investigations "minimally" destructive where are placed all those activities that involve taking more direct information of the artefact and therefore will involve limited partial removal or destruction such the mechanical strength evaluation by jacks dishes (single, double or corner), the extraction of carrots, the hole endoscopy, The mortar strength evaluation, all the analysis suitable for the evaluation of the granular, petrographic and chemical composition of the mortars and the stones.

3.1 Archaeological pre-investigation through the GPR analysis

The first diagnostic method we want to explain regards the GPR research on the Egnatia archaeological site: after the survey of the "Quagliati" area, we tried to understand the form of this part of the city enlarging the area of analysis over the edge of the excavations. So to the West of the area we perform a GPR survey: The GPR (Ground Penetrating Radar) is a geophysical survey method, non-invasive, used to obtain high-resolution information on the characteristics of the material being analyzed. The methodology GPR, through the use of electromagnetic waves, allows the definition of the interior features to the investigated object. In particular it is possible to identify interfaces between layers with different resistivity and dielectric constant. These parameters are correlated to physical factors such as the compaction, the surfaces clearness, the position and the characteristics of any buried artifacts, the presence of wet areas or cemented areas.

An electromagnetic pulse lasting a few nanoseconds, sent in the ground through a transmitting antenna, is partly reflected in the interfaces between the electromagnetic contrast levels and partly transmitted in the underlying levels. The reflected signals are picked up on the surface through a receiving antenna; the latter may be the same as used for the transmission (monostatic configuration) or separate from this a certain distance (bistatic configuration).

That investigation, given the particular complexity of underground pre-existences (immediately confirmed in the readings on the field of the first radargrams performed for the calibration of the instrument), was performed in tomographic mode: specifically covering the entire surface of the area with a dense grid of magnetic-graphic sections so as to allow a post-production interpolation in a solid tomography, or a solid "volume" segmentable in every slice and in every direction useful that carry-overs for each point investigated the value of the magnetic reflectivity reported into a chromatic scale. This technique allows the extrapolation of the horizontal sections interpolated at different levels of depth that give a qualitative indication of the archaeological state of the places.

Each image is comparable with a level of excavation. In the processing performed they were isolated some images to the profondity of about 1,5 meters below the ground. The emerging evidence confirms the continuation of the Quagliati district through alignments of the walls. An evident anomaly suggests the presence of a great cavity in which is possible recognize a furnace or a pit of considerable size. in the analysis is clear the sign of the diverticulum (visible at north and south of the area) separating two sides of the district.

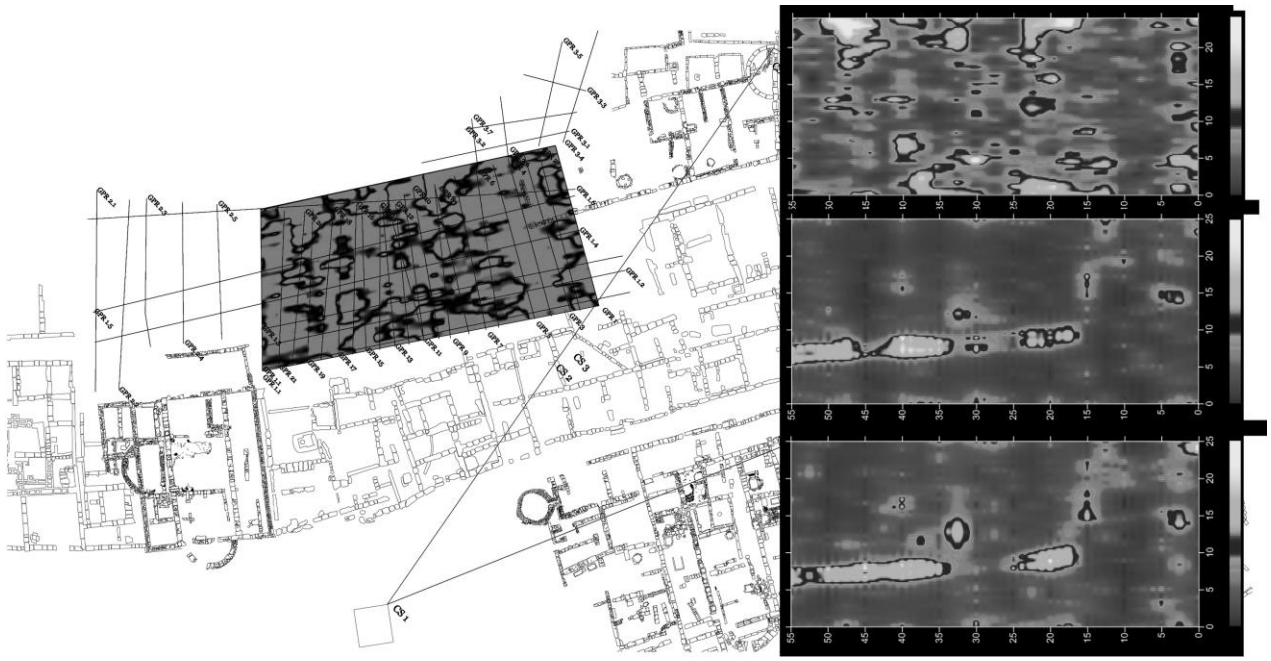

Fig. 4. Horizontal slices from the tomographic model of the terrain in the west area of the Quagliati District in Egnatia (Br). Analysis conduct by the Polytechnic of Bari thanks to the collaboration of Geatlas company srl within the Ministry of Education project FIRB 2012 "Archaeology of the Adriatic Puglia landscapes in Roman times: innovative technologies for sustainable identity planning". Post production editing and interpretation by the students: Angelica Disabato, Vito Macina, Roberta Rita Maria Pinto, Virginia Polignano, Valentina Sica.

The work on the site of Egnatia (Br) comes from the Ministry of Education project FIRB 2012 "Archaeology of the Adriatic Puglia landscapes in Roman times: innovative technologies for sustainable planning and identity". This project involves three research units: the Department of Science and Technology for the Environment and territory (Di.STAT) of the University of Molise (leader studies), the Department of Classical studies of the University of Bari, and the Department of Architecture and Civil Engineering Sciences (Dicar.) Polytechnic of Bari. The main partner: Superintendence for Archaeological Apulian Heritage of the Ministry for Heritage and Culture has given its authorization and every support to the conduct of the studies.

3.2 Architectonical application for the not invasive investigations

The non-destructive, or "minimally" destructive investigations are used by our working group largely in the teaching course. In the academic year 2014-15 the Polytechnic of Bari hosted two students of the degree course in construction engineering-architecture of the Universitat Politècnica de València, who have done an abroad degree thesis through an Erasmus scholarship study.

Their studies focused on the diagnosis aimed to the restoration on an historical church in Gravina in Puglia (BA). On this particular case of study there where present a complex configuration of different decays: a wide presence of ingression of moisture, despite the presence of newly created vertical interspace around the masonries; a complex presence of crack pattern, especially those affecting the richly decorated main façade.

The first analysis carried out consisted of a small test of the damaged wall area, and more precisely on the lateral side of the right canton of the facade. Identified the cement seams performed in previous restorations and well stated on the report with the usual round embossed marking on the cement plug. Were inspected by sampling the first three holes from the ground to the affected area (the portion which presented the maximum distance opening between the fractire edges). On direct investigation it has been possible to note the lack, in the first two holes, of the steel armor, while in the lower hole, in correspondence of the maximum opening of the fracture, the armor was present, well-fitting to the cement injection and in good condition, with no particular presence of oxidation.

In contrast with our first hypothesis related to the opening of the fractures for the effect of thermal expansion

and oxidation of the irons, we soon had to think again for a configuration of more complex damage, rather linked to the presence in the immediate in front of the main facade of un unamortized railway.

we chose to study the total condition of development of the fractures in the thickness of the wall. So we manage to draw some sections of the walls to investigate through video-inspection (endoscopy) and sonic tomography.

So we prepared the perforation needed for the endoscopy. The endoscopic tests in hole, in the field of restoration are a minimally invasive method that consists of making perforations of the object under investigation, with minimal loss of original material. The endoscope has enabled to incorporate information on the brickwork on the bore: the boundary nature, the type of material that composes it, fractures and their depth. It is used a flexible endoscope of just 7 mm in diameter that is useful with extremely small perforations at detriment of the mortar joints (of maximum width 12 mm).

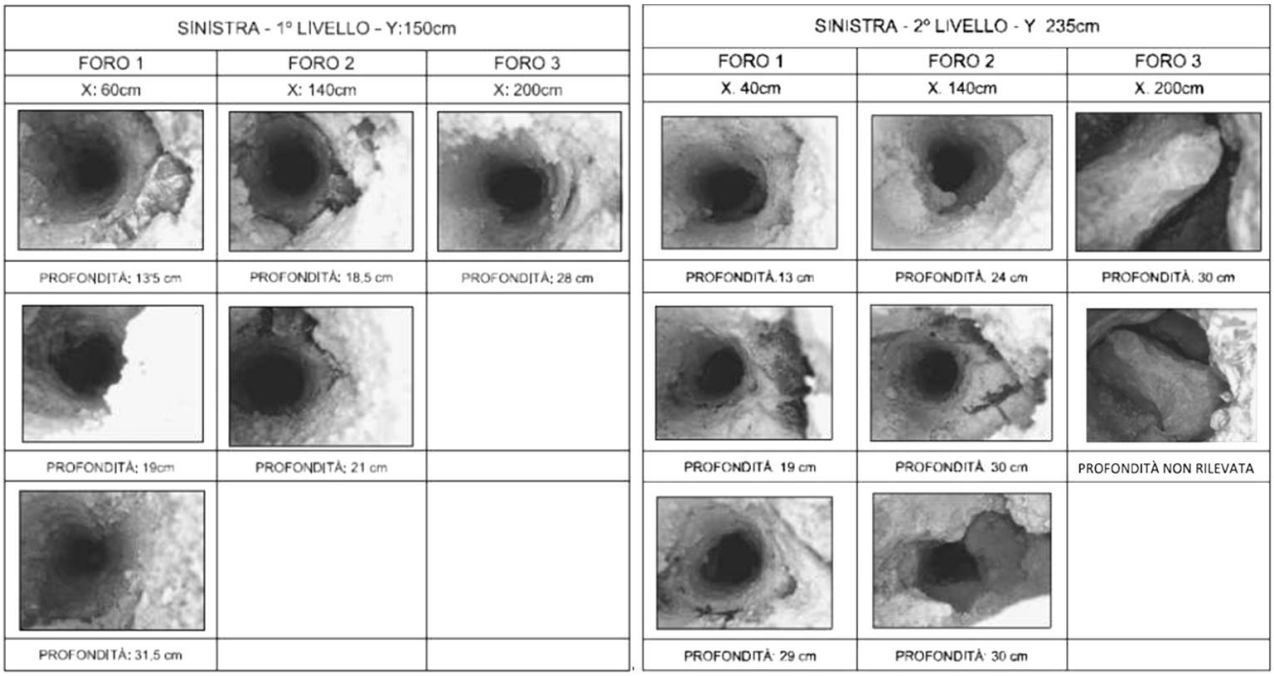

Fig. 5. Sampling of frames taken from video inspection. several punctures were performed for each of the levels investigated (for three or four levels depending of the wall analyzed). Work conduct with the students: Daiana Id Betan Schaer, Lorena Panadero Cocera.

From that analysis result a condition of total lack of joint between surfaces and inner of the wall. And a dramatically pulverization of mortars binders inside the wall filling. This condition of the wall leads us to promote another kind of investigation trough a sonic analysis.

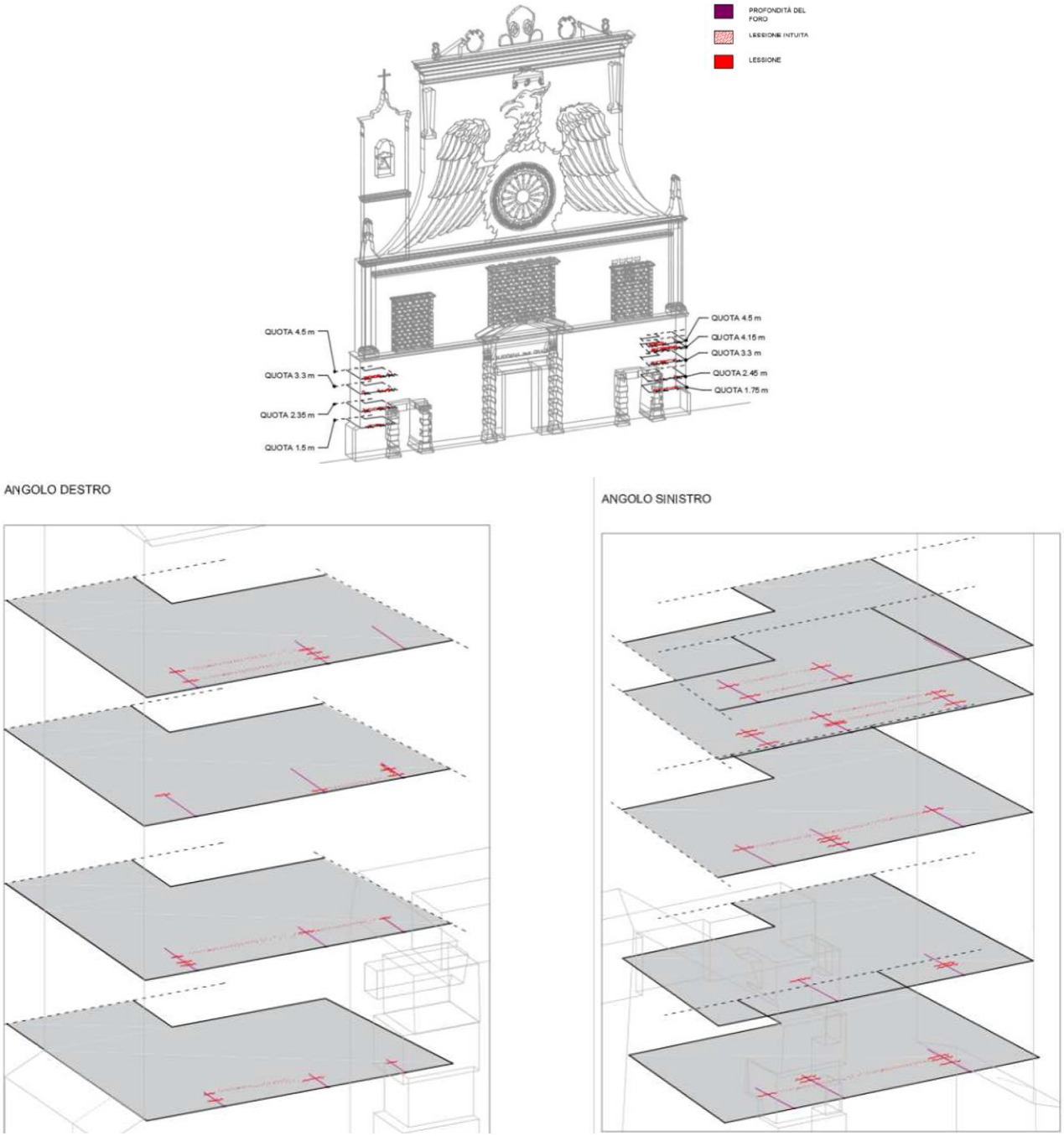

Fig. 6. Identification of the fractures detected inside the wall structure.
Graphics by the students: Daiana Id Betan Schaer, Lorena Panadero Cocera.

The sonic test is a non-destructive method to collect information on the structure without causing any damage to it. The most secure method of investigation for this type of analysis is a direct compressional wave propagation (acoustic) between the sender and the receiver. The field investigated in the present case is an acoustic sound field (using waves emitted by an “harmed hammer”) useful for the analysis of masonry composed of different materials. In summary, the system allows to read the wave flight time. By comparison with the time of flight expected in intact material is possible to deduce the state of decay of the material.

In this case, to have more accurate data as possible and to have a complete characterization of the section investigated, albeit only qualitative, it was decided to opt for a tomography: a section composed using data of the averaged readings of intersecting line of measures.

In each location of the receiver it is captured reading the flight time and the wavelength developed by a pulse emitted at each point on the opposite surface of the wall. The data collected are re-interpreted in a graph to interpolate. This technique allows to perform a sonic tomography that associates to each point of the section of a characteristic virtual velocity value and has the advantage (compared to a high number of samples) to develop a (qualitative) detailed diagram of the wall section. A more wave propagation speed match better mechanical characteristics.

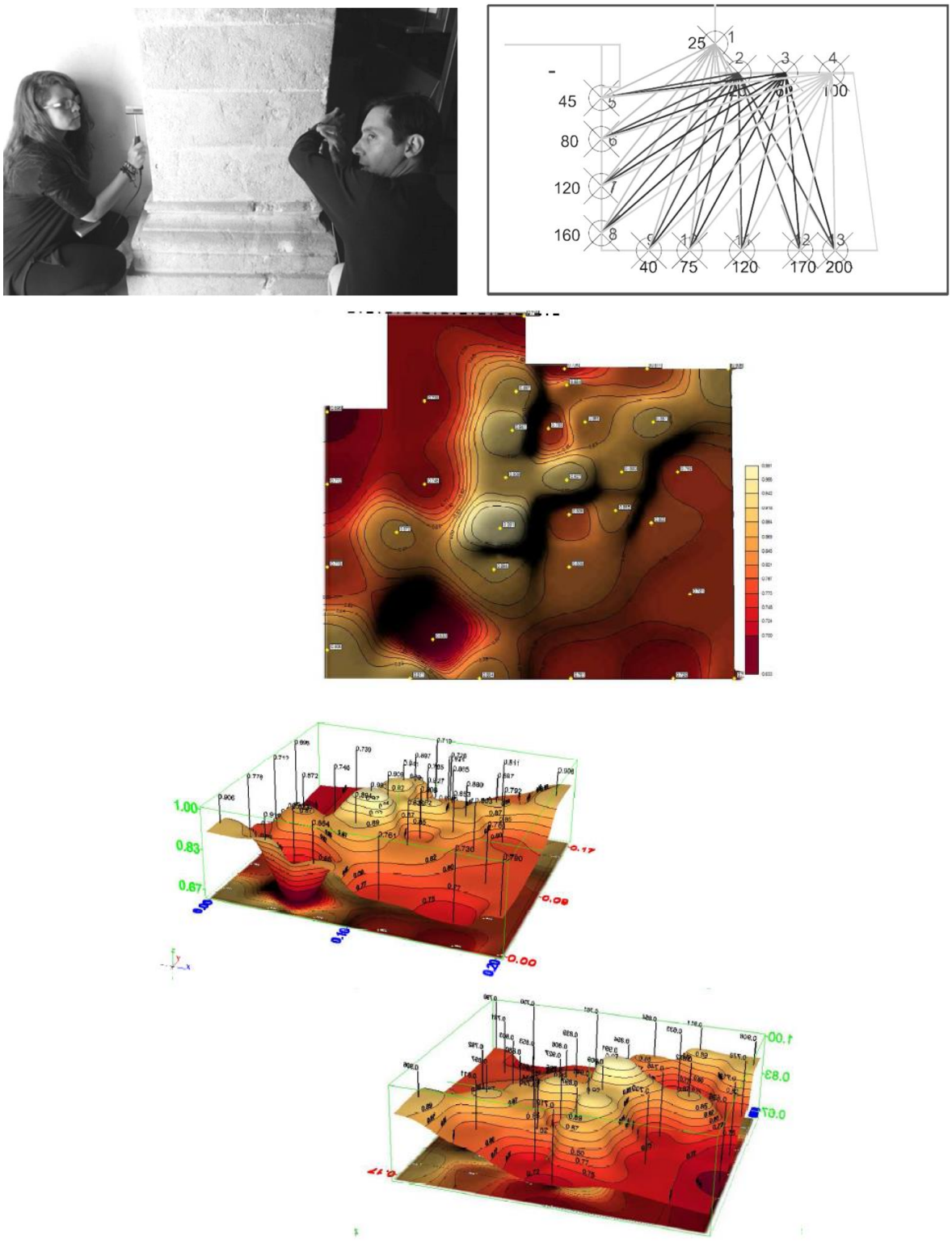

Fig. 6. Develop of the sonic interpolation diagram.
Graphics by the students: Daiana Id Betan Schaer, Lorena Panadero Cocera.

Put in evidence an extremely low condition of compactness of the masonries and the total lack of connection between the surfaces and the inner part of the wall, especially with the exterior surface.

4. CONCLUSIONS ([1] G.M.)

The work done directly by the students in during the workshop and teachings in the fifth year limited number courses (or during the final exam graduation), thanks to the active participation of the students in all stages, allows to develop a deep sense of knowledge of the object under investigation and the survey instrument, leading to not use aseptically diagnostic data, but rather to calibrate the survey according to the query posed by the issues of the restoration.

During the survey work it is essential to understand how these should be conducted in order to make optimal and appropriate the result as a function of the expected data. And it depends each time of different methods and factors which depend on the specific conditions of each artifact and that can not be categorized upstream.

In the case of architectural restoration, as in the opening has highlighted the need to entrust the geometric survey of a building to the same working group that will deal later the design, it is evident that even the investigation phase may not be as effective if their preparation takes place without the presence of a historical and architectural cognitive qualified component of the analysis group.

Our education system, we hope, will lead, to one side, the student who choose the career of the diagnostician to develop diagnostic projects that optimize the data according to the need of project requirements and, on the other side, to allow future architects and engineers the necessary competence, to use the diagnostic suitably avoiding unnecessary expenses and instead using judiciously the resources to optimize the effect of the design.

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