Methodology of Analysis and Virtual Recomposition: The Case of Retrosi, Amatrice

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Abstract. This paper is an initial report on an interdisciplinary project regarding an integrated methodology for analyzing architectural heritage damaged by earthquake, combining 3D survey, critical survey and virtual reconstruction. The case study using this methodology was Retrosi, in the municipality of Amatrice (RI), Italy, damaged by earthquakes on August 24th and on October 30th, 2016. Researchers from different disciplines (Representation, Restoration, Building Science), worked together to obtain an analytical understanding of the building criticalities caused by the earthquakes. The method is based on a semantic model linked to a database in which specific building elements, constructive, structural, masonry types etc. are classified as data, that includes instabilities and damages.

Keywords: 3D survey · Virtual recomposition · Semantic model · Architectural heritage

1 Introduction

This work was undertaken as part of the International II level University Master's degree in Architectural Restoration and Heritage at Roma Tre University (directed by Elisabetta Pallottino), which deals with the study of historical centers and, in recent years, particularly, those damaged by the earthquakes involving a multidisciplinary team[1].

The goal was to obtain an investigative tool, by which to analyse various aspects about damage buildings. Using the well-known 3D Survey procedures [1], it is possible to realize clear visualizations and measurements which can offer ever new elements to recognize the dynamics of collapses, the alterations of the individual building units and facilitate the recomposition of the configuration just prior to the earthquake.

[1] In the International II level Master's degree, the Design Workshop is conducted by: Francesco Giovanetti, Michele Zampilli (coordinators), Paola Brunori, Chiara Cortesi, Francesca Geremia, Marco Grimaldi, Francesca Romana Stabile. The Survey Workshop is conducted by: Marco Canciani, Giovanna Spadafora, Mauro Saccone.

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2 Methodology

Understanding the original conformation of building damaged by an earthquake is objectively very difficult, due to the fact that partially damaged structures and widespread collapse hide the underlying structures. On the other hand, the same seismic event can help uncover the sections of wall hangings, highlighting the construction features. It is evident that this type of analysis would require a very detailed and complex mode of reading, analogous to those usually employed in archaeology [2], in particular in the procedures of virtual anastylosis [3].

In this study, we develop a method that involves three phases:

The first two phases are for the acquisition and then reading and analysis of the post-seismic data and the third phase to compare the post - seismic data with pre-seismic data for a guided recomposition.

(a) In the first phase, the acquisition of data was achieved using modern survey systems that permit the gathering of a large quantity of metric, morphological and colorimetric data through the integration of 3D survey techniques available today (whether range based - that is based mainly on the use of 3D laser scanners; or image based - that is, based on photogrammetric survey procedures) [4] (Fig. 1). It is evident how the 3D survey techniques proved to be particularly effective in this operative context, where the precarious safety conditions curtailed the possibility of direct surveys.

Fig. 1. Structure of the database with fields defining building type, coating, architectural details and damage and a semantic model, linked to database.

(b) The second phase consists of the analysis and interpretation of data and aimed at reading the wall structure in all its components: the structural elements and construction detail, the types of masonry, the materials and construction techniques, the surface finishings. In the case of damaged buildings, to these categories of analysis must also be added those relating to the analysis of the damage.

(c) On the basis of the two previous stages, the third phase aims at the virtual recomposition of the buildings in the pre-seismic state [5, 6]. The procedure was based on the comparison between its state preceding the earthquake, derived in this case from photographic images, and a semantic model that describes the post-seismic state, linked to database. The system, by database queries, allows highlighting the categories of damages or those relating to the repositioning of the elements.

3 The Case Study: Retrosi (Amatrice)

The case study is the small village of Retrosi, which is located at an altitude of 1000 MAMSL in the valley of Amatrice, on the slopes of the Monti della Laga, between the Tronto and Velino gorges [7], along the Via Salaria, one of the oldest Roman roads. Those lands, called “Lazio abbruzzese” (The Latium of Abbruzzo) being at the extreme northern edge of the borders of Lazio, near Marche and Abruzzo, were known in the Middle Ages as *Summatine*, from the ancient Roman name *Summata*, settlement of Amatrice, *Summa Villarum* [8] (Fig. 2). Since 1676, the small villages of the valley, including Retrosi, were subjugated by the Universitas of Amatrice, until 1810, when they entered into the Municipality of the city and still the situation to this day. The first earthquake of which there are records date back to 1639: Amatrice was almost totally destroyed, as were many of its villages. It was followed by the earthquakes of 1672, 1703 and 1730, 1859 and 1979. The geological studies of the area inserted, in 2012, Amatrice and Retrosi within Zone 1 - high risk level.

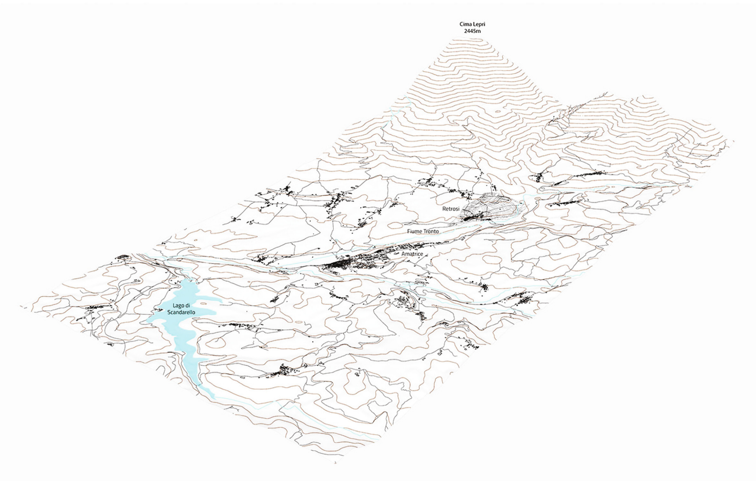

Fig. 2. A 3D model of the territory between Amatrice and Retrosi.

In August and October of 2016 a devastating earthquake caused serious damage to the village of Retrosi and currently make it difficult to interpret the original urban texture. The main square, on the western end, is aligned with the small Church of San Clemente, attended by the inhabitants of the village since 1580 [9], and connected to it from the slightly sloping ridge road (Fig. 3a, b). Next to the houses, which represent the predominant type, lined along the ridge road, are the buildings of greater value, also distinguished by size.

Fig. 3. (a) The village of Retrosi. Cadastral map superimposed onto a rectified aereophotogrammetric image; (b) Orthographic image of the point cloud relative to the survey of the urban fabric

3.1 Analysis of the Aspects Related to Traditional and Modern Construction Methods

Regarding the buildings in Retrosi, there are many similarities with the near Abruzzesi materials and constructive traditions. First of all, the masonry texture consisting predominantly of ashlar stones, rough-hewed or squared, layered with little mortar and with few diatoni (bondstones) to strengthen the binding between the outer layer, inner layer and the core; in the section of most ancient walls, one can see horizontal elements made with thin wood sections, as seismic safeguards (together with the traditional metal chains). Furthermore, original portals can still be found *in situ*, built mainly in pietra serena (gray sandstone), although there are examples of limestone or of arenaria (sandstone) with the piers and keystone decorations with engraved motifs of ancient medieval iconography (Fig. 4).

Fig. 4. Examples of Retrosi building elements: (a) roof with decorated rafter tails; (b) brick chimney; (c) (d) (e) portals and windows in grey sandstone or limestone; (f) keystone decorations with medieval iconography.

While the development in building, especially elevations, over the course of time are evident in the different dimensions of the construction material, in the use of brick and, sometimes, in the re-proposal of portal and window frames using nonlocal materials.

In the case study regarding a specific building (Fig. 5), near S. Clemente church, some architectural elements are well machined and noteworthy: the arched portal disposed in axis, the balcony slab and corbels in stone support (some restoration), well clamped in the masonry, two stone troughs beneath the windows of 1st level, framed, like the other of the upper levels by thick plates also in stone.

The principal types of masonry are two:

Type A, relative to the first level is of fair craftsmanship and constructed, like the cornerstones along the entire height, with square blocks, also of considerable size, arranged alternately front and side (those of the head are probably bondstones to reinforce the entire wall) and mortar joints of varying thickness;

Type B of the second level is more typical of many buildings in Retrosi, with roughhewn ashlar blocks for the outer layers, filling stones for the inner one, with a few binding diatones; a medium-sized wooden beam reveals the anchoring of the slab to the masonry.

From the photos of the pre-seismic state, one can observe how the second level, corresponding to the B-type masonry, was plastered, while the entire right corner, as well as the first level masonry (type A), was left as exposed bricks.

Fig. 5. a. Collapse of the central part of the façade with an example of well clamped angular masonry; b. Partial collapse of the structure in concrete blocks; c. Collapse of the angular masonry; d. Bulging angular masonry; e. The Church after the collapse of the roof; f. Masonry connected without the necessary clamping (evidenced by the lesion at the vertical plane of contact).

3.2 Analysis of the Aspects Related to Instabilities and Damages

Regarding those aspects related to the seismic event, one need take into account that the "traditional masonry suggests the idea of a possible division of the building organism into elementary portions" (Fig. 6) [10].

In the case study of the building, the elements that have suffered the most damage due to seismic action were mainly: the second level masonry (type B), partial collapse in the central area probably due to its modest construction quality; the roof, which underwent a failure derived from the collapse of the underlying wall; the masonry of the front of the second level (the sides), which shows a bulging in both the horizontal and the vertical plane (shown by the sections *in situ*). Among the elements that instead have suffered minor damage, the masonry type A is the most integral, because of its constructional characteristics; the balcony, although loaded by the debris of the collapsed central wall, is still standing, thanks to the shelves firmly anchored to the masonry.

3.3 Analysis for the Virtual Recomposition

The procedure for virtual recomposition is based on the comparison between its pre-seismic state, in this case from photographic images, and the post-seismic state and derived by the database queries. The data derived from the instrumental detection was

Fig. 6. The building before and after the earthquake October 30th, 2016.

integrated: some notes and annotations on the spot drawings, that integrate the survey data, supplement the interpretation and facilitates the transition from the pre-seismic state to post-seismic state and vice-versa (Fig. 7). The database connected to the specific elements of the models, has an organized structure with fields related to constructive aspects (types of masonry, coating, architectural detail and seismic aspects (masonry quality, types of damage).

In the virtual recomposition process (Fig. 8), therefore, it is possible to query the system and extrapolate what still is *in situ*, what can still be reused and returned to its original position, and what needs to be rebuilt, improving the characteristics resistant to earthquakes. In general, therefore, this operating methodology lets one obtain a series of data useful towards any future restoration or, where possible, reconstruction project.

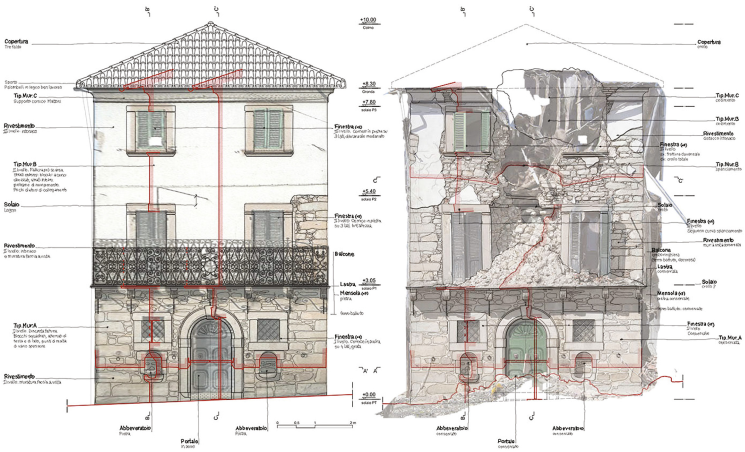

Fig. 7. Orthographic images of the model with notations on the constructive characteristics (left) and the types of damage (right).

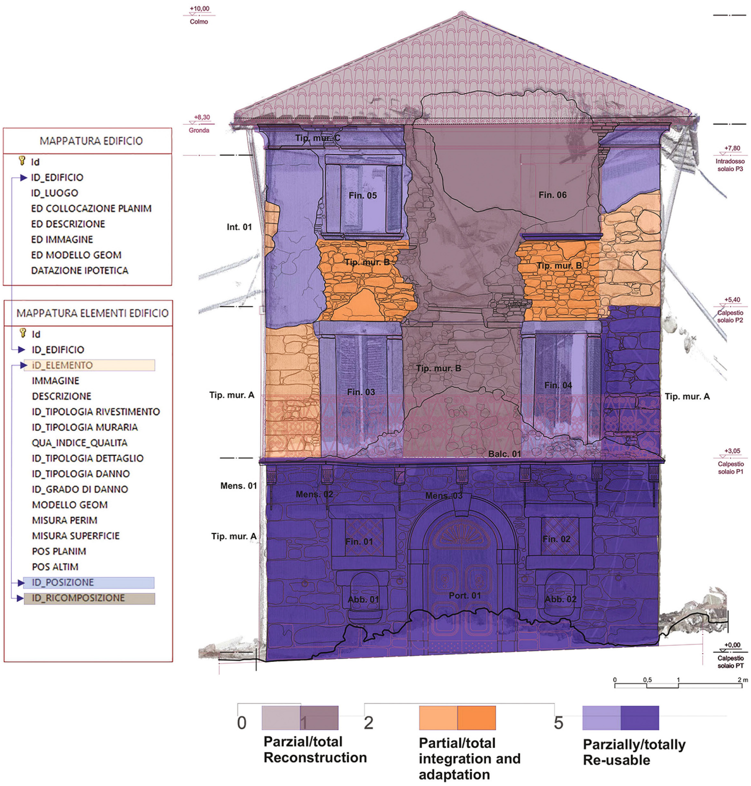

Fig. 8. The virtual recomposition of the facade.

4 Conclusion

The operating methodology herein presented permits an analytical reading of the morphological-structural components to be carried out, on individual buildings, and identifying the original and the intervening characteristics due to the earthquake.

The data resulting from the procedure thus adopted goes into the creation of a database, allowing us to: a. describe the codification of the damage caused by the earthquake and the occurring instabilities; b. point out the traditional technical-constructive solutions proven effective; c. draw up a chart of the architectural and structural elements and their relationships, so as to relate the structure to its environmental and cultural context. The virtual recomposition, in bringing out the traditional architectural qualities that distinguish the individual buildings, assists the work of recomposing the formal image of the damaged sites, and represents an effective operational tool in the hypothesis of a future reconstruction.

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