

## A Methodology for Approaching the Reconstruction of Historical Centres Heavily Damaged by 2009 L'Aquila Earthquake

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**Abstract** The paper illustrates the preliminary results of a research carried out on a historical centre heavily damaged by 2009 L'Aquila earthquake; in particular it presents shortly the Rubble Removal Plan realized and more in detail, the analysis conducted on a sample block. The detailed knowledge of the block is essential for identifying probable causes that led to the present damage scenario and for planning consciously the reconstruction and restoration of the historical centre.

**Keywords:** Earthquake, historical centre, collapse

### Introduction

During the 2009 L'Aquila earthquake several historical centres (Onna, Castelnuovo, Villa Sant'Angelo, etc.) were severely struck, with heavy damages extended to the whole built-up areas and collapses of large portions (sometimes even of the totality) of many urban blocks.

Because of the entity of the damages suffered by these centres, the problem of the possible restoration of their surviving, or little damaged, portions and of the reconstruction of the wide zones completely collapsed, or irreparably damaged, involves the need of handling much more complex situations than those implied in other cases. In fact, it presupposes the possibility of formulating in rigorous terms the question of the seismic safety of urban aggregates and giving to it encouraging answers.

On one of these centres, Villa Sant'Angelo, a research activity has been started with the aim of supplying a scientific support for the local administration in managing the post-earthquake actions on the historical centre with the final goal of defining the criteria according to which the possible reconstruction should be carried out.

The general planning of the research, begun in the Summer 2009, encloses three levels of analysis: (i) planning of the rubble removal from the public streets with the aim of giving the possibility to reach urban blocks currently obstructed in order to study them; (ii) surveying of all urban blocks from the point of view of their constructive features and of the seismic damages occurred; (iii) defining of the structural problems involved in the restoration and reconstruction of the urban centre.

Till now only the first step of the research (Rubble Removal Plan from Public Streets and Squares) has been carried out because the successive ones can be undertaken only after the removal has been executed – operation yet to be performed.

In this paper after a concise introduction about the Rubble Removal Plan, the analysis conducted on a sample block is described in detail in order to highlight the general problems involved in the execution of the second level of the research.

## Rubble Removal Plan

The need for a preliminary study entirely devoted to the design of a general “Rubble Removal Plan & Public Streets Securing” was motivated by the inaccessibility of the sites caused by both the presence of debris, that obstructs the open spaces (streets, squares, blocks’ internal courts) and the precariousness of many of the surviving building portions facing the public streets (Fig. 1-left).

This situation prevents, and in some cases makes even impossible, the analysis of the historical centre – from the point of view of typological aspects, building features, damage modes – and therefore precludes the possibility both to formulate an opinion about the causes that led to a so heavy damage scenario and to propose an assessment of the safety of surviving buildings. The aim of this plan, is not to restore the access to the forbidden area for the inhabitants, but to allow starting the survey operations and the successive design of the securing of individual blocks by the technicians who will be charged by the municipality. Thus this plan will provide the municipality of an operational tool by means of which, on the basis of general and standardized criteria, it will be possible to remove the rubble from the historical centre.

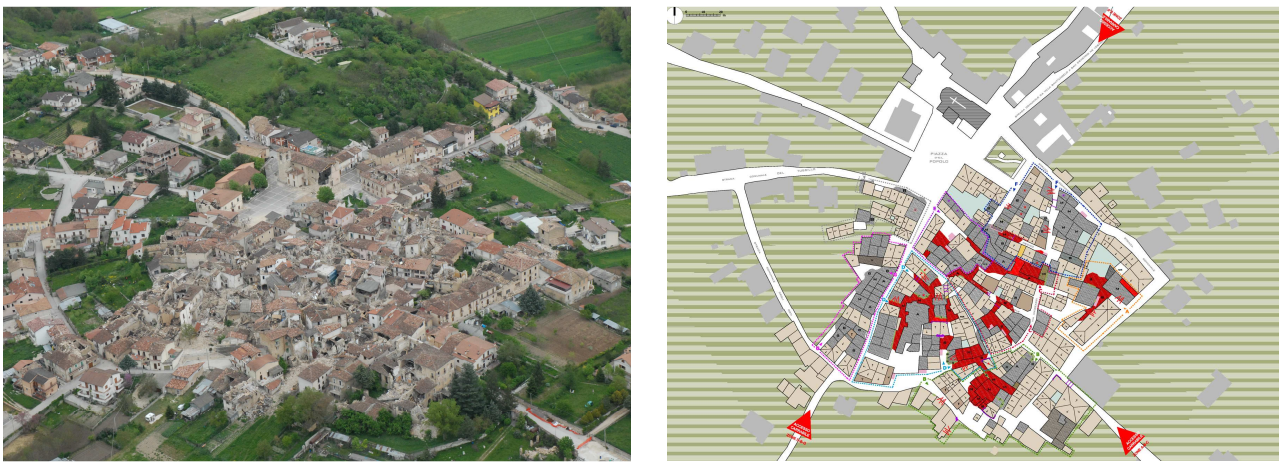


Figure 1: Aerial view of Villa Sant'Angelo historical centre (left) and “map of the collapse state” with the interruption of public streets due to the presence of rubble (right).

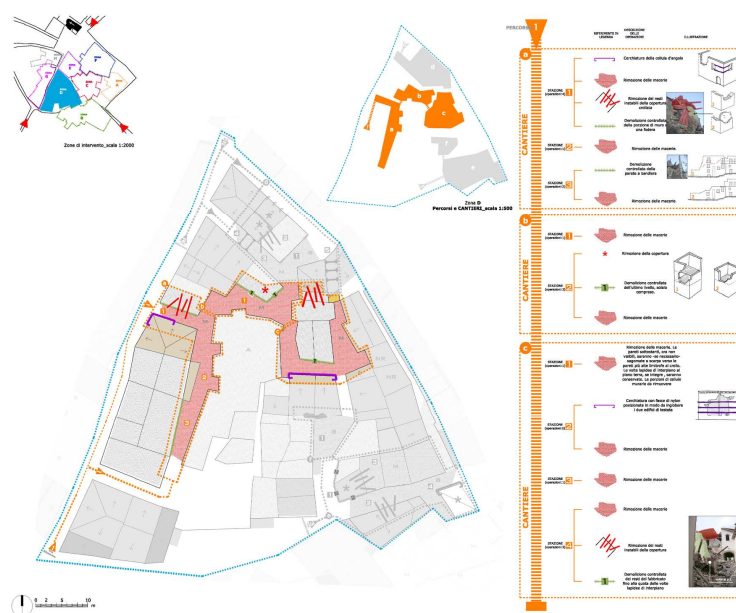


Figure 2: Detail of the “Rubble Removal Plan & Public Paths Securing”

The plan is based on two basic criteria: (i) defining the operations that are strictly necessary to restore the viability of streets and public open spaces, making only the indispensable removal, (ii) and

selecting – during the execution of interventions – stone materials from collapses with a view to their possible reuse. The purpose is that of allowing the conservation of what remains of Villa Sant'Angelo, avoiding widespread culling of the surviving portions, in order not to remove the traces of the ancient centre.

The plan was drawn up following a methodology that can be concisely described by following 3 steps: (1) analysis of the collapses extended to the whole historic centre (map of the collapse state) (Fig. 1-right), (2) identification of the areas for which the rubble removal and the contextual securing of the facing fronts can be done without interfering with contiguous areas (intervention areas), (3) detection, for each intervention area, of pathways along which it is possible defining the logical sequence and timing of all required planning operations (Fig. 2).

### Methodology of Analysis for Heavily Damaged Urban Blocks

Waiting for the execution of the rubble removal plan, a critical thought has been started about the methodological approach by which to proceed to the analysis of the damaged blocks of the centre, when they will be accessible.

It was therefore defined, with reference to a sample block, a process of cognitive analysis and securing design directed to the conservation and based on a standardized methodology applicable to each block of the historical centre.

The sample block chosen belongs to those for which streets or public spaces were already free from the rubble, either because unaffected by collapses or because already cleared straight after the earthquake in order to perform the first emergency operations. Among the few blocks that were in these conditions the analyzed block was chosen as the one that presented the more composite effects with the aim to detect the most wide series of considerations that can be extended (at least theoretically) to other blocks: the sample block is indeed characterized by different damage levels ranging from extensive collapses (involving 2 on 3 levels of the buildings), to local collapse (summit portions, ..), and cracks of various severity.

The study of the block – aimed at obtaining information on building typologies, constructive features, damage modes induced by the earthquake – was performed by means of a systematic exploration of all these different aspects and trying to individuate a set of survey operations easily repeatable in other blocks. These operations, usually unproblematic in normal contexts, can become extremely difficult in presence of widespread collapses that introduce sometimes insurmountable uncertainties. The operations are:

- (i) identification of the walls delimiting building units (for this operation aerial photos of the block, pre and post earthquake, turn to be essential because of the possibility to deduce the configuration of vertical elevation walls from observing the roofs);
- (ii) metric survey (where possible, taking into account the dangerous situation in which one has to work) of the main dimensions of buildings units;
- (iii) identification, for each unit, of the total number of floors (specifying whether there are basements) and of the relative height of the units;
- (iv) identification of the shape of the roof (pitched, flat, etc..)
- (v) identification of the conformation of the soil (for steep slope blocks):
- (vi) identification of the constructive typology of floors and roofs and of the presence of inappropriate past interventions (r.c. riddles, r.c. or steel slabs, etc..)
- (vii) precise description of damages and collapses caused by the earthquake.

Through these operations a detailed knowledge of the block consistency has been acquired yielding two key results. Firstly, the hypothetical but documented reconstruction of the block arrangement before the earthquake and its comparison with that produced by the earthquake (Fig. 3). Secondly, the identification of the vulnerability factors that may have promoted (or amplified) some of the damages and collapses occurred – eg., the replacement of the original timber roof structures

with heavier r.c or steel structures – as well as, on the contrary, the resistance factors that may have reduced the effects of the earthquake – eg., the presence of anti-seismic historical protections (Fig. 4).

These two results should constitute a minimum content of the studies that will be carried out on other blocks, because they include knowledge elements that are necessary for a correct approach to the rebuilding project.

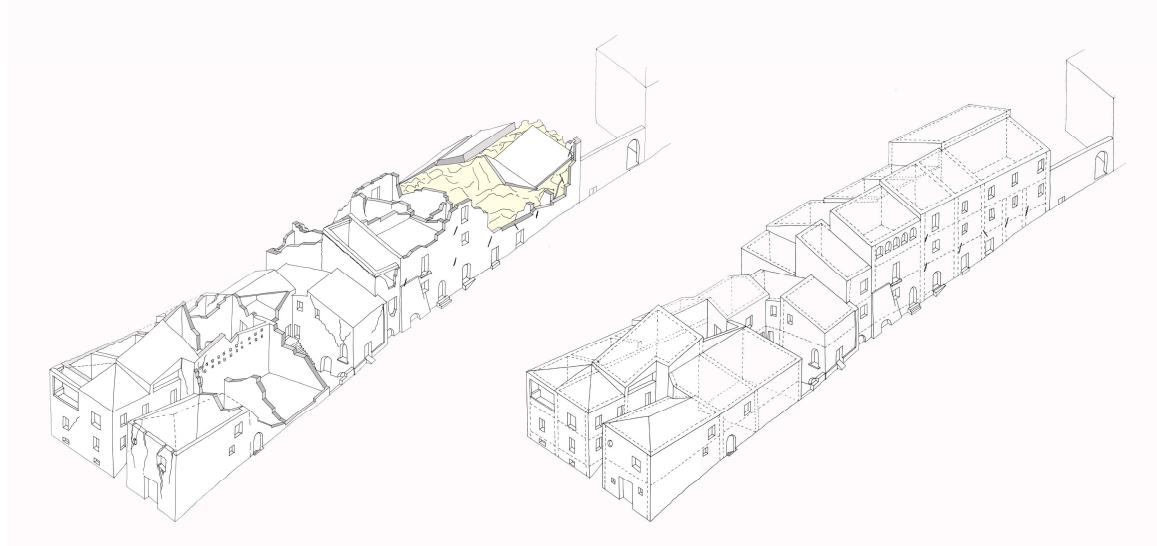


Figure 3: The sample block in the post and pre earthquake configurations.



Figure 4: Vulnerability (heavy r.c. roof structure) and resistance (anchored trusses) factors

### Sample Block's Safety and Preservation Design

On the basis of the detailed analysis conducted on the sample block it was possible to establish a pilot project for the securing and conservation of surviving buildings (or building's portions).

The project aims to removing the rubble located inside the perimeter of the block (not considered in the general rubble removing plan previously described and limited to streets and public spaces), dismantling the unrecoverable (or hopelessly compromised) surviving portions (both masonry walls and floors), securing the precarious but recoverable surviving portions.

With regard to the dismantling of unrecoverable portions, these were identified with:

- (i) small portions, even characterized by a good constructive quality, but whose (potential) conservation could make difficult the reconstruction of the whole building;
- (ii) portions characterized by serious deficiencies, either in the general arrangement or in their constructive aspects, whose (potential) conservation could require too expensive or technically difficult operations of disassembly and reassembly.

The need for the removal of only unrecoverable portions is motivated by the desire to minimize the loss of important cognitive elements.

With regard to the securing operations, these include various types (hooping, shoring, etc.) which differ depending on the consistency and on the problems of the elements to be retained. In general they are characterized by *minimum impact* requirements, related to functional (not to hinder the subsequent phases of the study), economic (because of the extent of works that will be needed for the whole historical centre) and structural (solutions that take advantage of surviving parts of the building to be conserved rather than those introducing new elements are suggested) demands.

Finally, some interventions are specifically aimed at the conservation of the surviving portions: for example the closing of "the edge of collapses" in order to limit the decay due to atmospheric agents, or the selection, cataloging and storage of stones having an architectural value.

The project is illustrated by drawings that explain: the actual state of the block (accurate description of collapses, cracks and rubble's location), the interventions (precisely located in the block, with a division into work areas), the project state (description of the block after the execution of interventions).

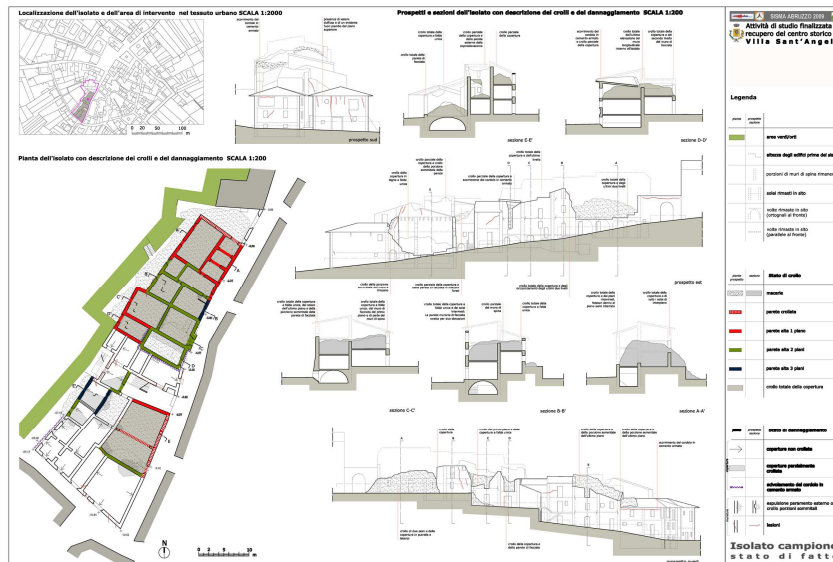


Figure 5: Present state of the sample block, with the extent of collapses, the location of rubble inside the houses and the cracks in surviving buildings.



Figure 6: Project state of the sample block

The comparison between the actual and the project states (Fig. 5, Fig. 6) allows controlling the amount of demolition to be carried out; such an aspect is of significant importance for the overall situation of the historical centre of Villa Sant'Angelo, where – given the widespread state of collapse (more than 50% of the urban texture) – could easily be implemented more extensive demolition than those effectively necessary.

## Conclusions

Facing the disastrous damage scenario caused by the 2009 L'Aquila earthquake on the historical centre of Villa Sant'Angelo, the first question which we should convincingly and reassuringly answer to, is if it is possible to rehabilitate damaged houses and rebuild collapsed ones, managing to ensure for them the same safety level that we are used to require for new buildings but without losing their original character.

The answer to this question is very difficult and involves different issues. As an example, we have not even mentioned some issues, although some of them play a, in a manner of speaking, preparatory role, first and foremost the problem of local amplification of seismic motion which, in many of Aterno valley centres, seems to have been registered. In this paper we only launched a methodological thought about what can, or can not, be conserved, and about which are the conditions to ensure the safety of what is preserved. Such a thought is obviously essential in order to define rational criteria for the restoration and reconstruction of the historical centre.

From this point of view, the study of the sample block presented in this work turns to be crucial.

The detailed knowledge of the block and the accurate description of damages and collapses it has suffered are essential for identifying probable causes that led to the nature and extent of the surveyed scenario and, at the same time, recognizing constructive solutions that prevented even greater damages. On this basis it will be possible to plan consciously the reconstruction and restoration of the historical centre and, before that, to decide if reconstruction and restoration constitute pursuable choices. This represents the third analysis level of the research undertaken on Villa Sant'Angelo, which is nowadays ongoing.

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## **Structural Analysis of Historic Constructions**

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## **A Methodology for Approaching the Reconstruction of Historical Centres Heavily Damaged by 2009 L'Aquila Earthquake**

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