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Characterization of URM buildings and evaluation of damages in a historical center for the seismic risk mitigation and emergency management

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ABSTRACT

Recent Italian earthquakes have been highlighted the role of the historical centers and their high vulnerability. To define effective mitigation strategies, the historical environments must be accurately investigated. The first and fundamental step is an assessment based on the knowledge of dimensional characteristics, construction techniques and materials. The seismic vulnerability evaluation depends on the quality and completeness of information available for the buildings under examination. In this paper, the characterization of an historical center and its buildings has been treated considering a new approach and existing common techniques for assessment of buildings' dimensional characteristics. Using GIS, data collected on the investigated historical center has been analyzed to obtain the typological characterization of the surveyed buildings in order to evaluate the seismic vulnerability, urban resilience, and recovery strategies for historical center. Based on comparison with an existing classical procedure, the approach seems also very promising in order to carry out a first evaluation of post seismic damage.

1. Introduction

Recent Italian earthquakes have highlighted the role of the historical centers and within them the role of the unreinforced masonry (URM) buildings.

These URM buildings have shown their high vulnerability. The seismic risk mitigation strategies should be addressed also to the reduction of seismic risk of historical centers, in order to preserve their historic, social, and economic value.

Seismic risk mitigation strategies should take into account the peculiarities (in terms of role, use, and characteristics) of monumental and historical palaces and centers that make them different from modern town buildings. For example, requirements for retrofitting strategies for historical sites are significantly different from those of modern towns. Historical buildings often exhibit problems resulting from their original no - seismic resistant design, and their possible re-use should be considered based on natural hazards.

For the above reasons, in Italy, there are a significant number of historical centers that have become ghost towns. Natural events may have been the main reason for relocation of historical villages.

Several problems should be solved prior to their re-use for touristic, cultural, or other goals. A well-known cultural heritage site, if preserved and protected, is an excellent source of income and can significantly induce development in nearby areas.

To re-use and preserve historical buildings and entire historical sites, safety measures must be implemented. A significant number of studies have been carried out at different levels of complexity to analyze the safety of several monuments and historic buildings. Several approaches have been developed and many applications provided to maintain safe cities and villages [22,3–5].

In Italy URM buildings are the most frequent types; they are often the core of historical and heritage building stock [14,26] and represent a fundamental focus in the resilience of the towns [37]. The need to preserve, enhance, and develop the use and re-use of these types of buildings plays a crucial role in seismic risk analyses.

A significant number of studies have been carried out to mitigate seismic risk based on modern and more accurate approaches [37]. Modern approaches are based on multi-criteria and multidisciplinary analysis methods [36] that provide effective seismic risk governance compatible with social-economical and technical-scientific aspects (hazards assessment, structural engineering, architecture, urban planning, risk and planning management).

Due to the large number of buildings that require seismic retrofitting and limited available resources, correct spatial and temporal resource distribution should be based on strategies obtained from accurate seismic risk studies.

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Structural interventions should be able to guarantee the minimal strict safety of the site, maintaining the integrity and authenticity of ruins. For a reliable assessment and retrofitting design of the structures, knowledge of structural-geometrical characteristics, traditional materials and construction techniques is required.

To determine the best strategy to use to improve the resilience of towns, every possible approach must be based on a wide and accurate set of information. Quantification of dimensional characteristics of the buildings is a key step for seismic vulnerability evaluation and consequent implementation of structural mitigation strategies. The morphological, geometrical, and structural information about a town, its streets, buildings and their aggregation play a fundamental role in estimating potential damage [26].

The focus should be on data collection. The improvement of tools, procedures, technologies, and methods to investigate the seismic vulnerability of buildings is a crucial topic in modern earthquake engineering [10,14,7,9,28,1,25,20].

On a wide territorial scale, data collection is hard and expensive work. To simultaneously satisfy multiple needs, such as lower survey cost, maximum benefit, and more accurate information, novel tools are needed and maybe found by adapting other available techniques.

This work will provide tools to directly define information for seismic risk mitigation strategies. Based on proposed procedures, building's geometric characteristics have been evaluated.

The second goal of this work is to define a better method for the first survey of damage of buildings in the immediate post-earthquake phase, overcoming the use of tools based on expert and empirical evaluation or on-field survey (for example, [27,11,6,28,13]). Several studies of techniques to survey damage have been carried out, often based on satellite data sets and remote sensing methods [7,30,33].

In this paper, the results of a survey of a damaged historic center are reported. The survey uses an integrated approach with different survey methodologies and tools. An interesting case study has been considered: Romagnano al Monte (Salerno, south of Italy, Fig. 1). It can be considered as an unique "open" laboratory.

The focus is the use of aerial images to obtain accurate information on building dimensions and their damage with limited time and economic resources. The work shows the results of a novel use of information provided by techniques and methods which have become rather common in the last years. The proposed approach is able to define a rapid and accurate survey of urban characteristics (such as dimension of streets, etc.) that play a fundamental role for emergency management. This paper highlights that the employment of combined techniques in very different conditions, environments, countries, etc. is possible. The Unmanned Aerial Vehicle (UAV) and aero-photogrammetric tools have been used as remote sensing survey techniques.

2. The case study

A typological characterization of URM buildings and their damage is reported. The case study is the historical center of Romagnano al Monte (Salerno, south of Italy, Fig. 1). Its origins date back to the Middle Ages when a castle was built, approximately in the year 1000 A.C. It was located on the top of a rocky spur. On November 23, 1980, an MW = 6.8 (CPTI15, Italian Parametric Earthquake Catalogue 2015) earthquake shook the south of Italy (Irpinia Earthquake). In the town of Romagnano al Monte, in the epicentral area, the macro seismic intensity was characterized by a value of IMCS = VIII-IX, but the town was not destroyed to the same extent as other nearby towns.

In the most old part of the village, the buildings can be classified with one only type. Some differences are present for more recent buildings located in the more recent part of the village.

The buildings were generally small in size (up to 2–3 stories), typically had a rubble masonry structure with poor construction quality, and were generally connected with structural aggregates. In the more recent zones, structural types had somewhat heterogeneous characteristics: rubble, concrete block, and brick masonry were present, often variously combined in the same structure with several types of floor. Some resistant framed RC buildings built after the 1960s were present.

In several masonry buildings, partial collapse occurred due to the poor quality of masonry and its arrangement, with poor load-bearing capacities under both vertical and horizontal loads. Several buildings suffered severe damage with partial collapses, particularly for roof and floor structures. The damage at Romagnano al Monte [32] was mainly caused by the above event, and the damage distribution seems to have been fairly uniform throughout the village (Fig. 2).

Close to Romagnano al Monte several villages had more damage and they have been rebuilt and seismically retrofitted. A few months after the 1980 Irpinia earthquake, because of high damage levels and existing socio-economic problems, the Romagnano historic center was

Fig. 1. Localization and aerial view of the Romagnano al Monte village.