Chapter 38
Seismic Performance of a Mixed Masonry–Reinforced Concrete Building

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ABSTRACT

The 6th of April 2009, a quite strong earthquake of magnitude ML =5.8 (Mw=6.3), struck in the city of L'Aquila. The seismic event caused serious injure to several masonry buildings, compromising a large part of the valuable historical and architectural heritage. The present work deals with seismic performance evaluation of an existing mixed masonry-reinforced concrete building in downtown L'Aquila city. A comprehensive discussion on the current limit capacity of the building based on the visual inspections of the occurred seismic damage, the experimental data from a wide campaign of on-site tests on the material properties, the results of numerical simulations from different naturally discrete models of the mixed masonry-reinforced concrete structure are presented. The seismic performance is evaluated through well-recognized N2 nonlinear static procedure. The Frame by Macro-Elements method is used to define an equivalent 3D frame representation of the structure. The obtained numerical results are directly compared with the surveyed damages.

INTRODUCTION

The seismic event, stroke down the L'Aquila city, caused conspicuous and widespread damage to existing building stock. The centre of the city, primarily composed of masonry-type buildings, was affected by partial collapses and/or severe damages. The seismic performance assessment of the building, object of the present study, is the final product of the research activities conducted

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at University of L'Aquila through the Division of Earthquake Engineering (UOIS) immediately after the earthquake.

In this work, the authors try to revisit the multidisciplinary experiences conducted by several researchers of L'Aquila University through a peculiar case study in the area of earthquake engineering, history of architecture, architectural restoration, structural analysis, material mechanical behavior characterization, computational mechanics, geology and geotechnics (Antonacci et al., 2009).

As a part of a broader research activity aimed to defining the structural behavior of the local shaken buildings (Ceci et al., 2010, Ceci et al., 2013), the present work analyzes specific features of the overall investigation process carried out for the evaluation of the seismic performance of a bank building resulting to be sustained by a mixed masonry-reinforced concrete structure. The building possess several peculiarities characterizing its seismic behavior, such as a C-shaped non-regular plan shape, a vertically-varying geometry, and a complex resistant scheme, coming out from an important partial demolition and reconstruction intervention, dating back to the early 70's. A reinforced concrete frame, inserted into the original masonry walls scheme, starting at the second floor level, and preserving the masonry facade, realizes the current structure.

The seismic performance evaluations follow the directions suggested within the Italian building code regulations (NTC2008 and Instruction Document of Feb. 2nd 2009, n.617). Along the path, a few remarks are given, based on the direct comparison between the observed behavior and the predicted one. In order to properly define the computational model of the structure, aiming to its performance evaluation and possibly to design the structural retrofitting interventions, a good knowledge of geometry, construction details and mechanical parameters of materials are needed. The knowing section consists of a first part of general building description in which the types of structures (RC and masonries), their actual geometry and all experienced building transformations are commented and a second part characterized by the tests campaign outcomes. A certain number of visual inspections, endoscopies, single and double flat jack, electromagnetic, ultrasonic and radar testing have been carried out, followed by the building structural analyses aimed to assess the seismic performance in which special attention has been devoted in accurate geometry, constraints and materials description. The structural modeling is carried out adopting the Frame by Macro-Elements method for which the masonry structure is idealized as an equivalent 3D frame (Gambarotta & Lagomarsino 1996; Brenchic & Lagomarsino 1997,1998; Magenes et al. 1998) in which only in-plane wall behavior is described. The actual frame elements, in which columns and beams idealize walls and spandrel beams, are derived by 2D macro-elements with compressive-bending and shear failure mechanisms. Reinforced concrete columns and beams have been modelled with standard beam element in which the elasto-plastic behavior is concentrated in given hinges.

According to the code suggestions, knowledge level (KL) has been determined and the type of seismic analysis has chosen according to the N2 nonlinear static methodology (Fajfar & Gaspersic,1996) in which N stands for nonlinear analysis and 2 for two mathematical models (MDOF and equivalent SDOF). The basic features of the method are related to the use of two separate mathematical models for the evaluation of the seismic demand and capacity: the response spectrum method and the pushover nonlinear static analysis. Enhanced versions of the methodology (Fajfar, 1999, 2000) combine the advantages of the visual representation of the capacity curves directly with inelastic demand spectra. The load distribution used during the pushover analyses is related to the assumed displacement shape. This feature leads to a transformation from a MDOF system to a SDOF equivalent one within specific hypotheses on the structural behavior.