ABSTRACT

A methodology of investigation and diagnosis on the built patrimony of historic centres in seismic areas is presented with the aim of collecting an extensive knowledge on the structural typologies and behaviour of historic masonry buildings. This investigation is also the base for the prevention and/or repair of damages caused by earthquakes. Small historic centres or residential buildings in larger centres have been considered for long time as “minor architecture”, but they are meaningful testimonies of the local cultural heritage and express the evolution of a society and of its cultural identity. The results of the investigation carried out on different Italian historic centers, allowed also a critical review of the reliability of the analytical models and of the effectiveness of the repair techniques applied in the past decades. The guidelines emerging from the research results are here presented. A “minimal” diagnostic investigation program is also suggested, in order to support the designers in their projects and to set up appropriate mathematical models to study the vulnerability of the structures.

INTRODUCTION

The study of the effects of the earthquakes which struck Italy, in Umbria and Marche regions in 1997, in Abruzzo region in 2009 and in Emilia region in 2012 showed as most retrofitting interventions realized during ‘80s and ‘90’s, after previous seismic events, were carried out with upgrading interventions made
by incompatible materials and structures. These interventions still consist of: substitutions of timber floors and roofs with r.c. (reinforced concrete) structures, jacketing, grout injections, etc. Most of them caused unforeseen and serious out-of-plane effects (large collapses, local expulsions), due to the “hybrid” behaviour activated from the new and the old structures. That effect was not clearly predictable by the existing assessment methods, which were then also suggested by the Italian standards. They proposed in fact analytical procedures based on hypotheses often not easy to be satisfied in old historic stone masonry buildings, as the effective strong connection among the structural components and the presence of stiff floors, both characterizing the favorable “box” behaviour of buildings under seismic actions.

It was also clear that the main cause of inappropriate choices of intervention techniques was due to the lack of knowledge on the material and structural behaviour of the peculiar type of construction techniques used in the past centuries for the buildings.

A good level of knowledge of the historic masonry building can be achieved considering: i) the geometrical, technological and constructive characteristics of the surveyed buildings; ii) the material and structure properties; iii) the materials and the techniques used for past and modern restorations; iv) the damage state, the possible collapse mechanisms of the buildings and structures, considering also the ones that were already retrofitted. This last point is aimed to put in evidence the vulnerability of the structures.

The object of the above mentioned research should not be the single building, but the whole historic centre (even if small) considering also the complex buildings formed by different “structural units”. These units should be clearly recognized to understand the eventual historic evolutions, the interaction among these units and the global structural behaviour of the complex building, also called “aggregate building”.

Hence there is the necessity of defining a “minimal” investigation program, eventually carried out by the municipality or by other wider districts, in order to support the designers in choosing the right analytical model for the safety definition and the appropriate intervention techniques for their projects, part of the rescue plans. In order to collect properly the data, a computer method, as a data base, is, as a consequence, necessary, with the support of a survey template, to be filled partly directly on site and partly with the help of historic documents.

The extensive damage survey of the buildings was useful to produce an abacus of the typical damages occurring in the different constructive typologies, as already previously done for churches (Doglioni et al., 1994), and a critical evaluation of the repair techniques and suggestions for future interventions (Penazzi et al. 2000; Binda et al., 2003). The better knowledge of the damages led to the consequent systematization of the mechanical models able to describe their specific behaviour, f. i. by kinematics models, both for in-plane and out-of-plane mechanisms.

So, one of the purpose of this research can be to provide a useful tool for: drafting a series of recommendations for the design, execution and effectiveness evaluations of non-invasive repair and strengthening interventions, of the structural seismic improvement of masonry buildings of the historic centres.

The research started at the end of '90s in Umbria and Abruzzo regions (Binda et al., 2004a and 2004b), supported by the Italian Department of Civil Protection and the Ministry of Cultural Heritage, allowed to put in evidence the high vulnerability of the many historical centres struck by the Umbria-Marche earthquake in 1997. The site was hit by a previous earthquake in 1979, thus most buildings were retrofitted according to the seismic code in force at that time, which basically recommended the application of upgrading interventions and the evaluation of safety by using assessment procedures based on the favourable box-behaviour of masonry structures.

Very unexpectedly, the in-situ survey and cataloguing of damage after the last seismic event pointed out that a large part of the collapses were induced by the strengthening measures performed according
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