Armagedom – A Tool for Seismic Risk Assessment Illustrated with Applications

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Over recent years, many studies devoted to large-scale seismic risk analyses have been carried out in different regions and by various research teams. A wide variety of software is available to perform these analyses: they are more or less flexible and use different levels of precision to model ground motion and vulnerability of the built environment. All are based on risk calculation through the convolution of hazard and vulnerability. This paper presents a seismic risk analysis tool, Armagedom, implemented over the past five years on a variety of urban seismic contexts: Bouzareah (Algeria), four provinces in Iran, the French Departments lying along the French/Spanish border and Overseas Departments in the French Antilles. The objectives and requirements of these studies differed with respect to the level of precision that was sought and the surface areas examined. In order to meet differing project targets, three levels of seismic risk assessment were defined based on the macroseismic and mechanical approaches for vulnerability and damage estimation presenting different levels of precision: Level N0 estimates seismic risk on a regional territorial scale based on the macroseismic approach and existing statistical data; Level N1 yields the seismic risk at a district level based on the macroseismic approach and on visual evaluation of the vulnerability of structures over an itinerary in the area to be analyzed; and Level N2 also establishes the seismic risk at a district level, but the hazard description is represented by a spectrum and vulnerability is estimated based on mechanical models. The software, with a modular design, was developed in order to optimize computation time and to automate execution of the three levels of analysis. In this paper, the software modules are illustrated by maps derived from the seismic risk analyses performed. We further use the available event information to test, validate and update the methods and the software presented in this paper.

Keywords: Armagedom software; seismic risk analysis; macroseismic and mechanic approaches.

Introduction

A number of tools for evaluating earthquake-related risk, casualties and losses in the built environment have been developed over the years. Molina et al. (2010) present an overview of available risk and loss estimation software tools and their computation characteristics in terms of type of analysis and damage estimation. Strasser et al. (2008) and Hancilar et al. (2010) present comparative studies for the assessment of earthquake losses in the Istanbul Metropolitan Area performed by different software packages.

For more information about the seismic risk analysis program, the authors recommend the *Journal of Earthquake Engineering*, Vol. 12, Supplement 2 (2008), which provides a short description of existing software and their applications in different parts of the world.

A more recent study, GEM Technical Report 2010-5 (Crowley H. et al., 2010a,b), provides a detailed description (Summary of software, Methodology, IT Details, Exposure Module, Hazard Module, Vulnerability Module and Output) of the existing software for seismic risk assessment that is either open source or has been made available to the GEM Risk Team. Figure 1 shows the name of the software, the institution and the main contact for each of them. Damage estimation methods used by each of those software tools are discussed in Chapter 4 of the paper: Discussions.

Seismic risk scenarios are increasingly being requested for studies at the scale of cities and regions. In this context, we have been called on to carry out different seismic risk analyses with variable levels of precision, scales and input data. This situation has led us to seek solutions and formalize them in methodologies tailored to each of these varying demands.

The seismic risk assessment projects in the Antilles, with initial damage simulations for the cities of Pointe-à-Pitre and Fort-de-France (Le Brun et al., 2001), and subsequently over the island departments of Guadeloupe and Martinique (Monge et al., 2001) first motivated the development of a specific software tool in order to automate processes. The formulation of scenarios for projects in continental France (Sedan et al., 2008, 2009; Bernardie et al., 2006), in the French Antilles (Bertil et al. 2009; Roullé et al., 2010), in

Algeria (Sedan et al., 2006) and in Iran (Daryakhakpay & BRGM, 2009) has spurred rapid evolution in its functionalities.

Earthquake engineering literature introduces two main approaches for assessing vulnerability and thereby generating seismic risk scenarios:

1) The macroseismic approach relies on statistical processing of the damaged buildings on the basis of post-seismic observations in the field. Firstly, this approach develops a damage probability matrix (DPM) which express the probability of a given damage state to be present for a given level of macroseismic intensity within a given building stock. DPM express the probability of obtaining a damage level in a discrete form. In order to complete the DPM for non–populated levels of damage and intensity, vulnerability functions are developed using empirical vulnerability assessment methods (for example vulnerability index method: among others Benedetti and Petrini (1984), Giovinazzi and Lagomarsino (2004) and continuous vulnerability curves by Parameterless Scale of Intensity: Spence et al. (1992)).

2) The mechanical approach relies on analytical studies of the structure, involving either a detailed time-history non-linear analysis, capacity spectrum based method or collapse-mechanism methods which derive capacity curves, directly related to the mode of failure of the building.

Experience gained over the past years allows us to describe the requirements and limitations of each study and the calculation methods that are possible in view of the available data. Thus, we have purposely divided the first, macroseismic approach, into two methods termed “Level 0” and “Level 1” according to the degree of detail and the precision involved in describing the input data and hence, implicitly, the detail rendered in the results.

Thus, the three levels redefined from the two basic approaches (macroseismic and mechanical) and implemented in the Armagedom software package are described as follows:

“Level 0” corresponds to a very global assessment of the damage suffered by the built environment due to earthquake using simplified empirical methods and on the basis of existing data (generally available in national census data, publications, reports, databases, which might be completed with remote-sensing analysis). Vulnerabilities are described according to classifications A to F defined in EMS-98 (Grunthal, 1998). Seismic action is expressed in terms of seismic intensity values. Damage results are indicated at a township scale.

“Level 1” estimates damage and risk based on empirical macroseismic methods. The essential difference between Levels 0 and 1 lies in the quality of the input database involved. Level 1 uses a more precise description of hazard and the built environment typology. Level 1 vulnerability is expressed by a vulnerability index (Vi) calculated as described in the RISK-UE Project WP4-Report (Milutinovic and Trendafiloski, 2003).