

Probabilistic seismic risk assessment using CRISIS2015 & USERISK2015. Application to buildings of Barcelona, Spain.

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Abstract—The probabilistic models to assess seismic hazard and seismic risk incorporated into the codes CRISIS2015 & USERISK2015, respectively, are applied to compute the seismic risk of buildings of Barcelona. The main procedures required to assess the seismic risk using these codes are briefly described in the present document. A new version of USERISK, which is being developed in the Barcelona Supercomputing Center was used in the present work. According to the results, the levels of seismic risk of the Eixample District of Barcelona are important due mainly to the high levels of seismic vulnerability of its buildings.

I. INTRODUCTION

The assessment of the seismic risk in urban zones is an essential task in order to take decisions oriented to increase the resilience levels of the cities [1].

A probabilistic version of the vulnerability index method (VIM_P) to compute seismic risk of buildings in urban areas was proposed by Aguilar et al [2]. This method is a modified version of the vulnerability index method (VIM) that was widely validated in the Risk-UE project [3, 4]. The VIM_P method can be applied by means of two codes: CRISIS2015 [5, 4], & USERISK2015 [6, 4]. A new version of this last code is being developed in the BSC. In the next sections more details about the theoretical background of both codes are included. Results computed in the present work for buildings of Barcelona are mentioned.

II. METHODOLOGY

In the VIM_P method three basic elements are considered to compute seismic risk: a) seismic hazard, b) seismic vulnerability and c) a seismic damage function. The seismic risk is determined when the convolution of the seismic hazard and the seismic vulnerability is computed [3]. For

terms of the annual frequency with which damage states D_k are exceeded ($\nu[D > D_k]$). For this purpose Eq. 1 is considered.

$$\nu[D > D_k] = \sum \sum P[D > D_k | V, I] P[V] \gamma^*[I] \quad (1)$$

where $\gamma^*[I]$ is the annual frequency of occurrence of the seismic intensity [7]. $P[V]$ is the probability of occurrence of the seismic vulnerability. $P[D > D_k | I, V]$ is the probability that damage D_k is exceeded given that a seismic intensity I ,

and a seismic vulnerability V have occurred. In Eq. 1 the total probability theorem is applied and it is considered that the intensity I and the vulnerability V are independent random variables [2].

A. Seismic hazard

In the VIM_P method the seismic hazard must be computed using a probabilistic method, based on the Esteva and Cornell approach [3]. A modified version of this probabilistic approach is incorporated in the CRISIS2015 code which was selected as the standard code to compute probabilistic seismic hazard in the VIM_P method [3]. The seismic hazard results must be expressed in terms of annual frequencies of exceedance of macroseismic intensities.

B. Seismic vulnerability

In the VIM_P method the seismic vulnerability of a building is represented by means of probability density functions (PDFs) beta type [2]. These PDFs describe the variation of a vulnerability index that mainly varies in a range between 0 and 1. Values close to zero mean low seismic vulnerability, and values close to 1 mean high seismic vulnerability [2, 3].

In order to assess the seismic vulnerability of a building is necessary to know basic information about the building. For instance, it is necessary to know data as location, structural typology, construction year, position into the square, etcetera. The seismic vulnerability of buildings can be assessed using USERISK2015.

C. Seismic damage function

In the VIM_P method the seismic damage is assessed by means of a semi-empirical function [4], which allows computing a mean damage grade μ_D (Eq. 2). Additionally, in order to generate a complete distribution of the damage a function is considered. These expressions allow determining probability of occurrence for five damage states. In the damage state five the total destruction of the building occurs [3].

$$(2) \quad \mu_D = 2.5 \left[1 + \tanh \left(\frac{I + 6.25V - 13.1}{2.3} \right) \right]$$

where V is the vulnerability index, mainly with values between 0 and 1; I is the value of the macroseismic intensity EMS-98 [8].

D. Seismic risk

Data of seismic hazard and data of the building are used by USERISK2015 to compute the seismic vulnerability and the seismic risk of the studied buildings. The seismic risk results are expressed in terms of annual frequencies of exceedance of five no null damage states [3].

III. APPLICATION AND RESULTS

The VIM_P method was used to compute the seismic risk of 69982 dwelling buildings of Barcelona.

A. Seismic hazard

The seismic hazard of Barcelona was computed by means of CRISIS2015. The seismic hazard results are shown in Fig. 1. According to the seismic hazard results the macroseismic intensity equal to 6 has a probability of exceedance of 10% in 50 years. In other words the return period of the macroseismic intensity of 6.0 is equal to 475 years

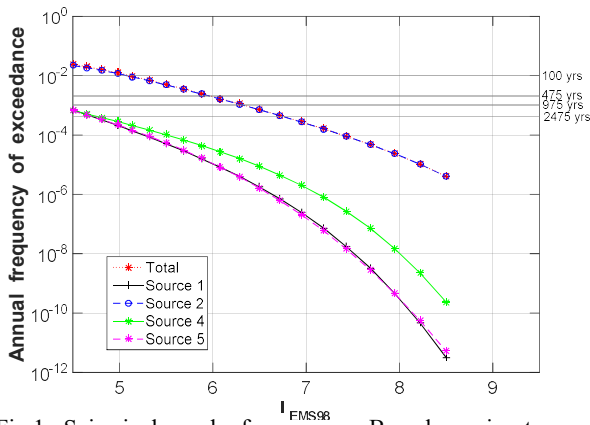


Fig.1. Seismic hazard of I_{FMS98} Barcelona in terms of annual frequency of exceedance of macroseismic intensities

B. Seismic vulnerability

Three seismic vulnerability curves were computed for each one of 69982 buildings of Barcelona. These curves can be used to obtain representative curves that characterize the seismic vulnerability of a group of buildings. Fig. 2 shows the representative curves of seismic vulnerability of 8432 buildings of the Eixample District of Barcelona. These curves of seismic vulnerability were computed without take into account regional vulnerability modifiers.

C. Seismic risk

USERISK2015 uses seismic hazard results (Fig.1) and seismic vulnerability results (Fig. 2) to compute the seismic risk of the buildings of the Eixample District (Fig.3).

Curves in Fig 3. represent the average seismic risk of 8432 residential buildings of the Eixample District of Barcelona. According to main curve of seismic risk (Fig.3), the buildings of the Eixample District can suffer, in average, a damage state of 1.5 each 475 years. In other words, in

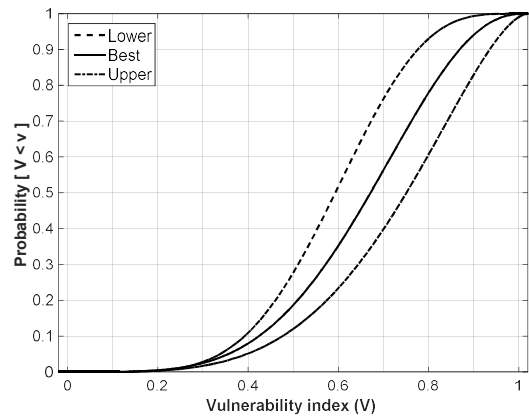


Fig.2 Representative curves that characterize the seismic vulnerability of 8432 residential buildings of the Eixample District

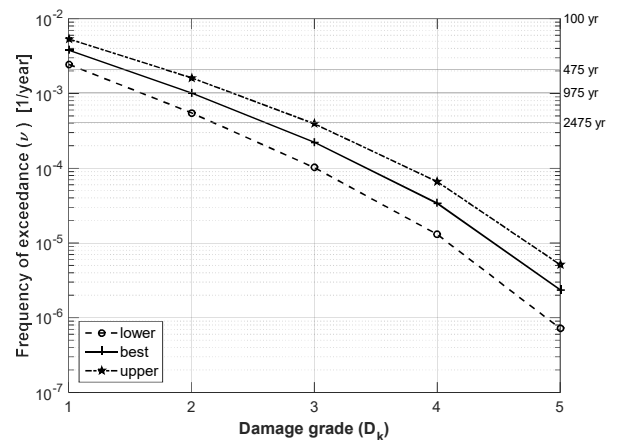


Fig. 3 Average seismic risk of the dwelling buildings of the Eixample District of Barcelona.

average, the damage state equal to 1.5 has a probability of exceedance of 10% in a period of 50 years.

However, if the regional vulnerability modifiers are considered then the damage grade that has a return period of 475 years is equal to 3.0.

IV. CONCLUSIONS

According to the results, it is possible to affirm that the procedure to assess seismic risk of buildings in urban areas using both codes CRISIS2015 and USERISK2015 is an appropriate procedure, because it is possible to obtain reasonable results in a reasonable time. For this reason, the appropriate use of the procedure described previously with its respective codes, can contribute to increase the resilience of cities of the world. On other hand, the seismic risk of the buildings of the Eixample District is important due mainly to the high vulnerability of many buildings of this district. At the same time, it is convenient verify the seismic vulnerability modifiers that can be used in any region. For the Barcelona case, by the moment, it is recommendable

consider that the minimum seismic risk corresponds to the case where the vulnerability modifiers are not considered, and the maximum seismic risk corresponds to the case where the vulnerability modifiers are considered.

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