EARTHQUAKE RISK IN CATALONIA: VULNERABILITY ASSESSMENT FOR DWELLING BUILDINGS

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ABSTRACT: The seismic vulnerability of all dwellings in Catalonia is assessed from the information given in the last building census (1990). First, a classification in vulnerability classes following the macroseismic scale EMS-92 is made from such information using expert judgment. The potential damage to each class for different ground motion levels is then derived through the use of the damage probability matrices, obtained in the analysis of observations collected after the Irpinia, Italy, earthquake of 1980. Finally, the distribution of damage to buildings of the city of Barcelona for two scenarios, MSK intensity VI and VII, is presented, as an example of the possible use of the results of this study.

1. INTRODUCTION

The Civil Defense Agency of the Catalan government promoted the assessment of the seismic risk at a regional level in Catalonia with the objective of establishing adequate preparedness measures for earthquake emergencies. The contribution presented here - a first step towards this end - deals with the assessment of the seismic vulnerability of all dwelling buildings in Catalonia.

Previous studies of this problem (Caicedo, 1993; Yépez et al., 1995) have applied to a section of Barcelona a methodology that requires individualized inspection of all buildings concerned. This type of analysis is not affordable for the complete Catalan territory, with nearby a million buildings.

A more practical approach is used here based on the following simplifying assumptions:

a. A short number of parameter available in a general building census is sufficient to characterize buildings for obtaining a first approximation to their vulnerability.
b. Through such parameters and with the help of expert judgment, buildings can be assigned to vulnerability classes of the European macroseismic scale (EMS- 92).
c. The seismic vulnerability of each of those classes is sufficiently well represented by damage probability matrices obtained in the analysis of data from recent earthquakes.

The procedure is described in the following paragraphs.

2. DATA

The main information used in the assignment to EMS-92 vulnerability classes of the existing buildings in Catalonia has been the data collected in the buildings census carried out in 1990 by the Catalonian Institute of Statistics. This information is summarized in Table 1, where

buildings are grouped by age, number of stories and location (whether in rural or urban areas). This last parameter (location) is considered since experience shows that buildings in urban areas are, in average, of better quality than those on rural areas.

Table 1. Distribution of buildings in Catalonia by height, construction year, and location.

Construction year		Up to 1950		1951-1970		After 1970		Total
Location		Urban	Rural	Urban	Rural	Urban	Rural	by height
Number	1 - 4	232740	31119	212070	16304	315504	37346	757100
of	5	7065	9	14083	24	11937	22	33140
stories	> 5	12699	2	21963	33	22028	44	56769
Total by age		252504	31130	248116	16361	349697	37605	934992

On the other hand, age has a strong influence on vulnerability due, not only to the deterioration process, but also for the historical evolution of the construction practice.

Finally, height is also of influence, since low rise buildings are strong enough to resist gravitatory loads, while high-rise buildings are working in the range of maximum admissible loads.

Specific bounds for these parameter in the classification, as given in Table 1, give the result of a study conducted on a representative sample of buildings in Catalonia with the aim to estimate their state of preservation.

3. CLASSIFICATION OF BUILDINGS ACCORDING TO EMS-92

With the available information and the help of experts were derived values of the percentage of buildings from each one of the groups in Table 1, to the vulnerability classes A, B, C, and D of the EMS-92. These are represented in Table 2.

Table 2. Distribution of buildings in Catalonia in vulnerability classes according to EMS-92. (Percentages)

Code of Town							
Construction year		Up to 1950		From 1951 to 1970		After 1970	
Location		Urban	Rural	Urban	Rural	Urban	Rural
Height	1 - 4	20A+80B	30A+70B	5A+50B+45C	15A+70B+15C	85C+15D	5A+20B+65C+10D
	5	20A+80B	40A+60B	10A+60B+30C	20A+70B+10C	5A+20B+65C+10D	10A+30B+55C+5D
	> 5	40A+60B	60A+40B	15A+70B+15C	30A+65B+5C	8A+27B+60C+5D	15A+45B+40C

Figure 1 summarizes this distribution for the whole Catalonian territory. It is seen that the majority of buildings corresponds to classes B and C; only a 10% is assigned to class A and about 6% to class D.

The distribution of buildings into vulnerability classes for each Catalonian municipality can also be obtained. As an example, Figure 2 shows the percentage of class B buildings in each municipality.

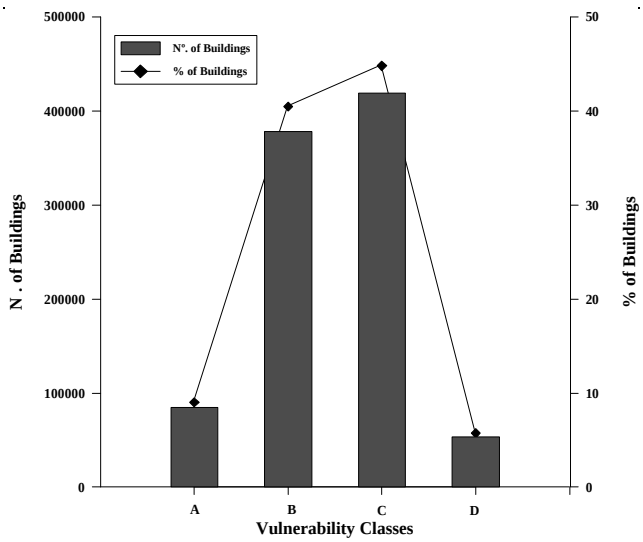

Figure 1. Distribution of buildings in Catalonia in vulnerability classes according to EMS-92.

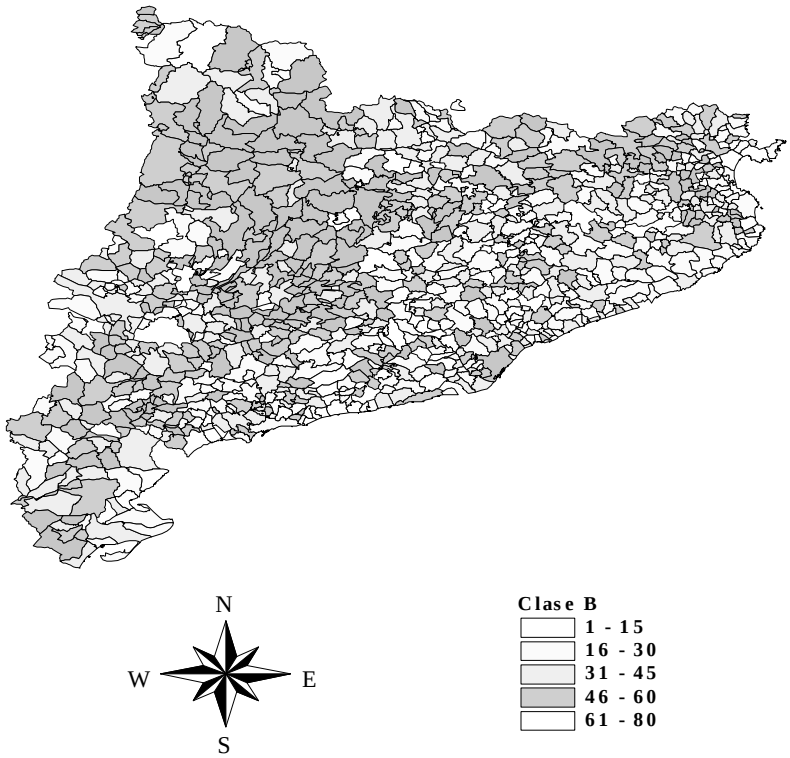

Figure 2. Distribution of vulnerability class B buildings in municipalities of Catalonia.

4. ESTIMATION OF DAMAGE OF BUILDINGS

Once the buildings in Catalonia have been catalogued and distributed in vulnerability classes, the following step should be to derive vulnerability functions for such classes. As there are no damage observations available from recent earthquakes, we have made use of the results obtained by Braga et al. (1982, 1985, 1986) in their study of data from the Irpinia shock of

1980. Their analysis covered 32548 buildings, that were classified in 15 structural typologies, and showed damage which were graded in 8 levels.

For our purpose a reduced classification was derived from the Italian study, to 4 classes (A, B, C, D) of building typologies, and to 5 levels (intensities VI to IX) of the damage. Damage probability matrices were then obtained from them (Chávez et al., 1998). Figure 3 shows these matrices.

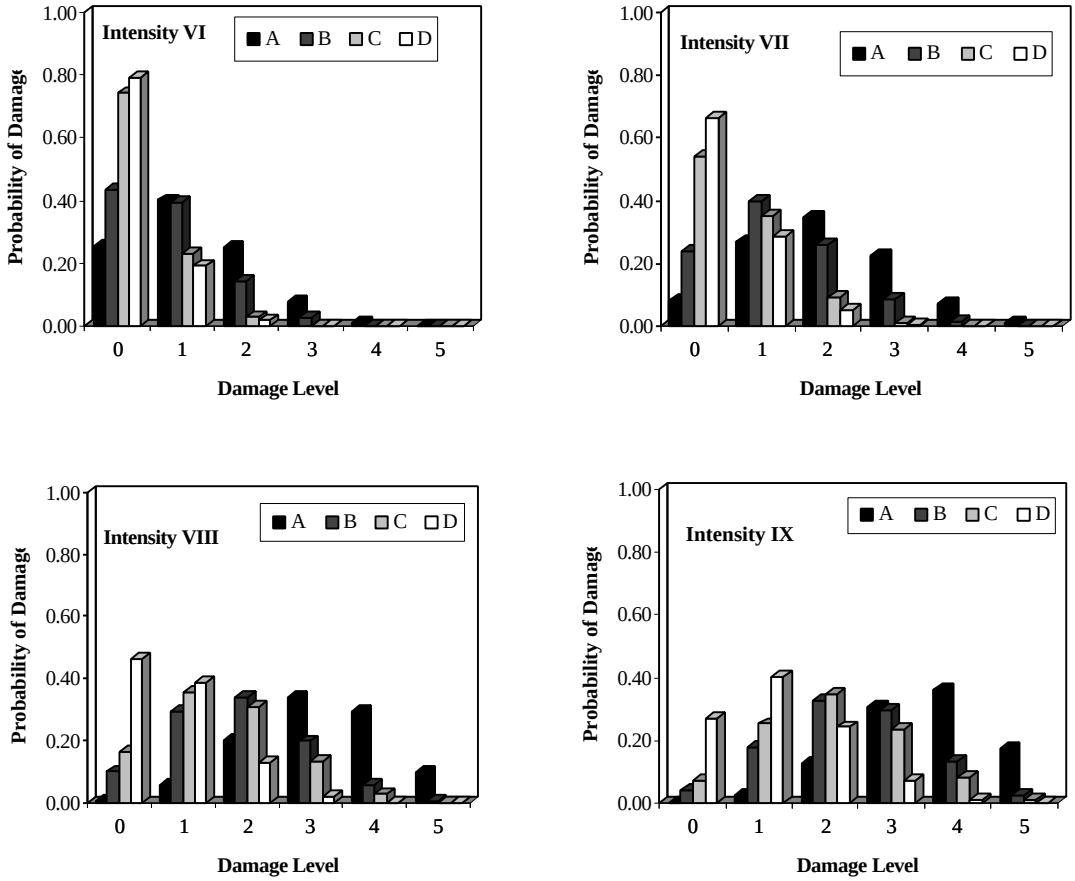

Figure 3. Damage probability matrices for A, B, C and D vulnerability classes according to EMS-92, obtained from Italian damage data.

Finally, the potential damage to buildings of each municipality of Catalonia has been obtained from consideration of the building catalogue, the distribution in vulnerability classes and the damage probability matrices. The computation will be applied to all Catalonian municipalities, considering for them the seismic action given by Spanish seismic Code NCSE-94 (that corresponds to a return period of 500 years) and that resulted in the study made recently by Goula et al. (1997). As an example, Figure 4 shows two scenarios for the city of Barcelona corresponding to intensities VI and VII. Damage levels are taken in this figure according to the definition in the EMS-92; thus, 0 means no damage and 5 total collapse of the building.

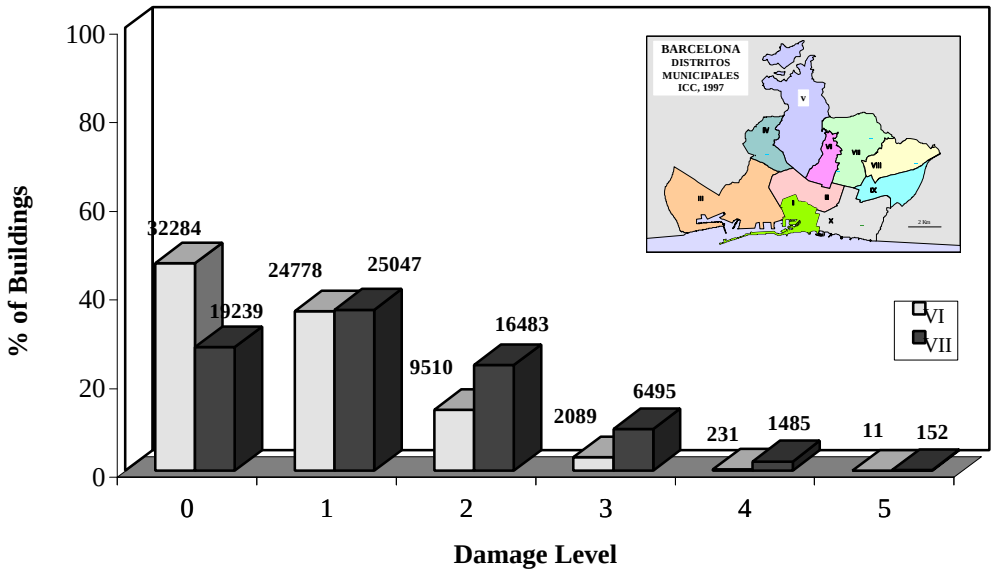

Figure 4. Distribution of damage in buildings of Barcelona city for intensities VI and VII.

5. CONCLUSIONS

It has been presented a methodology for the assessment of vulnerability and damage of buildings at regional scale. A classification of the existing buildings according to the vulnerability classes defined in the EMS-92 is made. Easily available information is used for this approach, its application is very economic. This methodology is specially suitable in those regions where there are not seismic damage data and a complete inventory of buildings. The results, as in this case, can be used for preparing emergency plans for earthquake risk mitigation.

6. ACKNOWLEDGMENTS

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