Earthquake Engineering, Tenth World Conference © 1994 Balkema, Rotterdam. ISBN 90 5410 060 5

Statistical models of damage to buildings and the MSK scale

D. Liberatore
Università degli Studi della Basilicata, Potenza, Italy

ABSTRACT: The review of the MSK scale is now in progress. In this paper, results coming from statistical analyses of large Italian databases on damage to buildings are presented. They permitted to set up a statistical model of the relationships between earthquake intensity, type of building and damage, which give useful information for the review of the MSK scale.

The logical link between statistical models of damage to buildings and the MSK scale is provided by the concept of Damage Probability Matrices (DPM's). The DPM of a given building type is the set of the probability distributions of damage for different earthquake intensities. DPM's are a convenient way to define the seismic vulnerability of building types.

It is well known that the MSK scale defines three classes of buildings (A, B, C) with decreasing vulnerability; for each class and each intensity degree between V and X, the number of buildings which show certain damage levels are expressed by three quantifications: single≅5%, many≅50%, most≅75%. This is a semi-quantitative representation of the probability distributions of damage, that is of the DPM's.

A set of questionnaire-based surveys of damage to buildings were carried out soon after some Italian earthquakes, primarily the Southern Italy earthquake, 1980 [1], and the Middle Italy earthquakes, 1984 [2], involving 36,000 and 15,000 buildings, respectively. Most part of the surveyed buildings has masonry structures of different types, and some thousands a r.c. structure. A first elaboration of the collected data showed two important discrepancies with respect to the MSK scale: the frequency distributions of damage were significantly more scattered and the correlations between damage levels of different classes were no longer verified.

For these reasons, a statistical method of analysis was purposely set up [1]; it is based on maximum likelihood estimation and provides the intensity degree occurred at each isoseismic area, the classification of building types into three vulnerability classes and the relevant DPM's. A set of constraints was imposed on the probability distributions of damage in order to respect the quantifications of the MSK scale, at least in a statistical sense (e.g. the quantification "many" was interpreted as "mode of distribution"). The classification of building types and the DPM's resulting from the analyses represent a statistical model of a modified MSK scale.

Now (July 1992) the Working Group Macroseismic Scales of the European Seismological Commission is carrying out a review of the MSK scale. The author, together with other researchers from the area of structural engineering, is collaborating informally with the Italian members of the working group (seismologists) as far as engineering aspects are concerned. Some remarks and proposals based on the statistical model coming from the Italian databases are reported in the following.

One of the most important problems in the review process is the re-classification of building types into vulnerability classes. As it is well-known, the original classification is based on the type of vertical structure. However, it is commonly recognized by engineers that a key role in seismic behaviour is played by the stiffness and the strength of horizontal structure, particularly when dealing with masonry buildings. This is confirmed by the statistical model whose classification is almost exclusively based upon the type of horizontal structure.

The following proposal for masonry buildings classification includes also the type of horizontal structure:

Class A: buildings with walls of fieldstone, rubble masonry, adobe and clay; horizontal structure made of vaults, arches or wooden floors. Building vulnerable because of decay, bad mortar, bad state of repair, thin cavity brick walls, etc.;

Class B: buildings with walls of simple stone or unreinforced brick masonry with horizontal steel beams;

Class C: buildings with walls of unreinforced brick masonry with r.c. floors.

Three pre-requisites were taken into account when formulating this proposal:

1) the categories of horizontal structure should be easily detectable during a damage survey and easily retrievable from historical data;
2) it is desirable that no conflicts arise between vertical and horizontal structure;
3) the modification should be gradual.

As for the first pre-requisite, it is noted that the type of horizontal structure (vaults, wooden floors, steel beams or r.c. floors) can be easily detected by field survey even by non-engineers after a minimum amount of training. In historical data retrieving, the data about horizontal structure is often not available; in this case, however, the location, the age of construction and the purpose of the building can be used since in general they are correlated with the type of horizontal structure.

As for the second and the third pre-requisite, it is noted that the classification retains the type of vertical structure in order to assure a gradual transition from the original to the modified formulation, but taking into account both vertical and horizontal structure can lead, generally speaking, to conflict situations. However, it should be noted that many conflicts are unrealistic or unlikely (e.g. walls made of fieldstone and floors made of r.c.); in any case, if a serious conflict situation arises, it appears preferable, when classifying a building, to attribute an higher priority to the type of horizontal structure.

A "probabilistic" classification of building types was recently proposed. This classification comes evidently from the necessity to mediate experiences of many researchers in different countries. According to this classification, any building type may belong to a typical, a possible and, in some cases, an extreme class (e.g. buildings with walls of fieldstone, originally belonging to class A, according to this classification belong typically to class A and possibly to class B). With regard to this, it should be pointed out that the classification based upon horizontal structure, coming from statistical analyses, is extremely stable, even when varying the hypotheses on the shape of probability distributions (binomial or non-parametric) and on the size of isoseismic areas (commune or village) [3]. It appears therefore preferable to avoid an uncertainty-based classification, since this can result in a loss of information. Moreover, it is believed that the statistical distributions, calculated on the basis of the surveyed data, are scattered enough to cover large discrepancies between individual buildings and the typical behaviour of the class.

Another important item is the classification of r.c. buildings. Statistical analyses showed for r.c. buildings without anti-seismic design (ASD) a behaviour similar to that of masonry buildings with r.c. floors (or a little better); it appears therefore correct to classify them in class C.

An important improvement is to take into account r.c. buidings with ASD. For these types of buildings three new classes have been created: D, E and F, corresponding to minimum, medium and high ASD level, respectively.

It is the opinion of the author that this extension of the MSK classification, besides to be "natural" because of the high number of anti-seismic buildings now existing, opens a set of new interesting research possibilities. R.c. buildings are more reliable "sensors" of the ground shaking if compared to, say, masonry buildings: mathematical models of mechanical behaviour are by far more refined for r.c. buildings and large monitoring projects are now in progress. Moreover, r.c. buildings present an higher level of standardization among various countries. For all this reasons they could be used in the future in order to establish more reliable relations between ground shaking parameters and damage.

A provisional quantification of ASD level was as follows: "minimum" corresponds to a capacity to carry horizontal loads equal to 2÷3% of vertical loads, medium 6÷7%, high 10÷12%. It is noted that a minimum capacity to carry horizontal loads is possessed also by buildings without ASD, since they are able to resist wind action, so it appears preferable to classify r.c. buildings in the following way:

Class C: r.c. buildings without ASD (horizontal load capacity = 2÷3% of vertical load);

Class D: r.c. buildings with moderate ASD (horizontal load capacity = 6÷7% of vertical loads);

Class E: r.c. with high ASD (horizontal load capacity =10÷12% of vertical loads).

As a final remark, the author would like to point out that the review process of the MSK scale represented a valuable opportunity of information interchange between engineers, seismologists and historians, with considerable benefits of all the involved researchers, and this is perhaps the most important result of this cooperation.

REFERENCES

[1] Braga, F., Dolce, M., Liberatore, D. 1982. A Statistical Study on Damaged Buildings and an Ensuing Review of the M.S.K.-76 Scale, *Proc. of the VII ECEE*, Athens.

[2] Braga, F., Dolce, M., Liberatore, D. 1986. Assessment of the Relationships between Macroseismic Intensity, Type of Building and Damage, Based on the Recent Italy Earthquake Data, *Proc. of the VIII ECEE*, Lisbon.

[3] Braga, F., Dolce, M., Liberatore, D. 1983. Influence of Different Assumptions on the Maximum Likelihood Estimation of the Macroseismic Intensities, *Proc. of the IV ICASP*, Florence.