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Historical records, macroseismic scales and seismic hazard

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ABSTRACT: Historical records play an important role in assessing seismic hazard and risk. This paper evidences the need for the collaboration among engineers, seismologists and historians for a better interpretation of historical records, and outlines the main improvements contained in the 1992 version of the MSK intensity scale.

1. HISTORICAL RECORDS

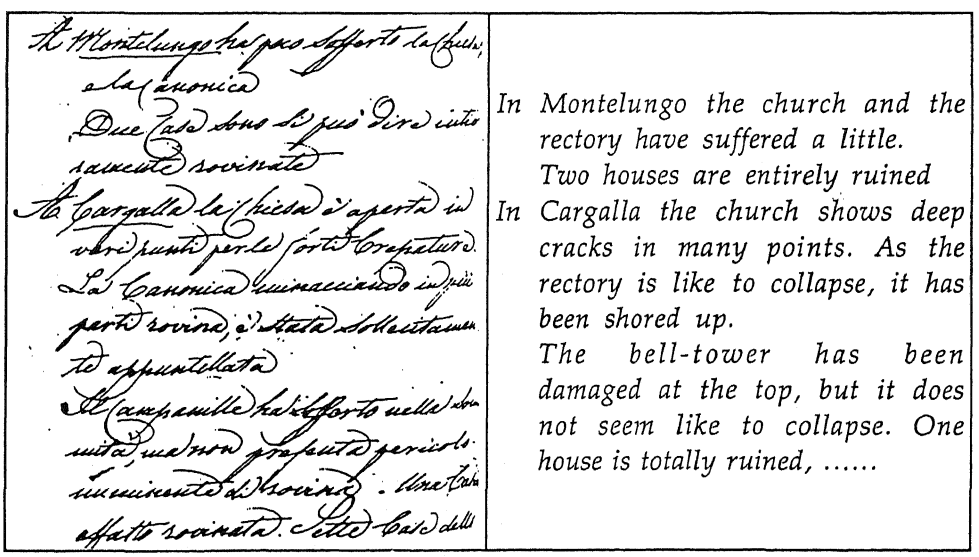
What ?

The term "historical data" is frequently used to mean data on earthquakes obtained from written sources prior to the instrumental period, that is before 1900. It has to be stressed, nevertheless, that important macroseismic data of the same kind are currently available, and used, also for this century, and even for "yesterday" earthquakes. Actually, we should speak of historical records, assuming that these data are "historical" according to their nature (written descriptions) and to the way they are retrieved and interpreted, that is according to historical methods: this will differentiate them from questionnaire-based field surveys.

Historical records can range from a few words, just reporting that an earthquake was felt, to very detailed damage descriptions, such as those found in official damage surveys (Fig. 1).

Why ?

Historical records play an important role in some aspects of engineering seismology and earthquake engineering such as seismic hazard and risk assessment. Actually, they provide data from a time-window more or less wide, but in general fairly wider than instrumental data. In many cases it is well known that the seismicity of the XX century is not fully representative of the real seismicity of an area. Furthermore, historical records are useful because they supply direct data on damage.



In Montelungo the church and the rectory have suffered a little. Two houses are entirely ruined
In Cargalla the church shows deep cracks in many points. As the rectory is like to collapse, it has been shored up.
The bell-tower has been damaged at the top, but it does not seem like to collapse. One house is totally ruined, ...

Figure 1. Excerpt from a damage survey report for the earthquake of 1834 in the Apennines (Italy) (ASPi, 1834).

How ?

Historical records are usually processed according to the following steps (Fig. 2):

- sources are investigated through archives and libraries, and earthquake records are retrieved;
- records of the same earthquake are assembled;
- macroseismic intensity is assessed at each locality for which some records are available;
- isoseismals are drawn (when possible) and focal parameters are evaluated.

In this way historical records contribute:

- to compile earthquake catalogues in the same way of instrumental data and to calibrate attenuation laws;
- to assess seismic hazard.

Retrieving and processing historical records on earthquakes require care and expertise and it is turning out as a specific branch of seismology, which can be called historical seismology (updated references can be found in Stucchi & Albini, 1992). In particular, the investigator who processes historical records must be aware that the earthquake records have been compiled by someone else, and arrived at him often after a long and complicated itinerary. It is therefore necessary, first of all, to consider them as far as possible into their historical, geographical and source context, paying special attention to:

- value of the source, motivation and context for which it has been produced, sensitivity to earthquakes and other natural events;
- context of the source in which the earthquake record is situated (records are not to be "cut out" from the source like stamps from the envelope), wording aspects ("translation" to nowadays language can require care), and so on;
- time/space location of the information. Incorrect handling with respect to this can lead to well known duplications and uncareful assembly of data related to more earthquakes.

Processing historical records can point out uncertainties, which are to be evidenced on maps and catalogues and are to be taken into account when assessing seismic hazard (see also Margottini, 1992). It can be stressed, nevertheless, that such uncertainties are by no means higher than those affecting instrumental data, as many believe. For instance, catalogues are full of epicentres or magnitudes determined by one or two station data only: the reliability of these data is also very low.

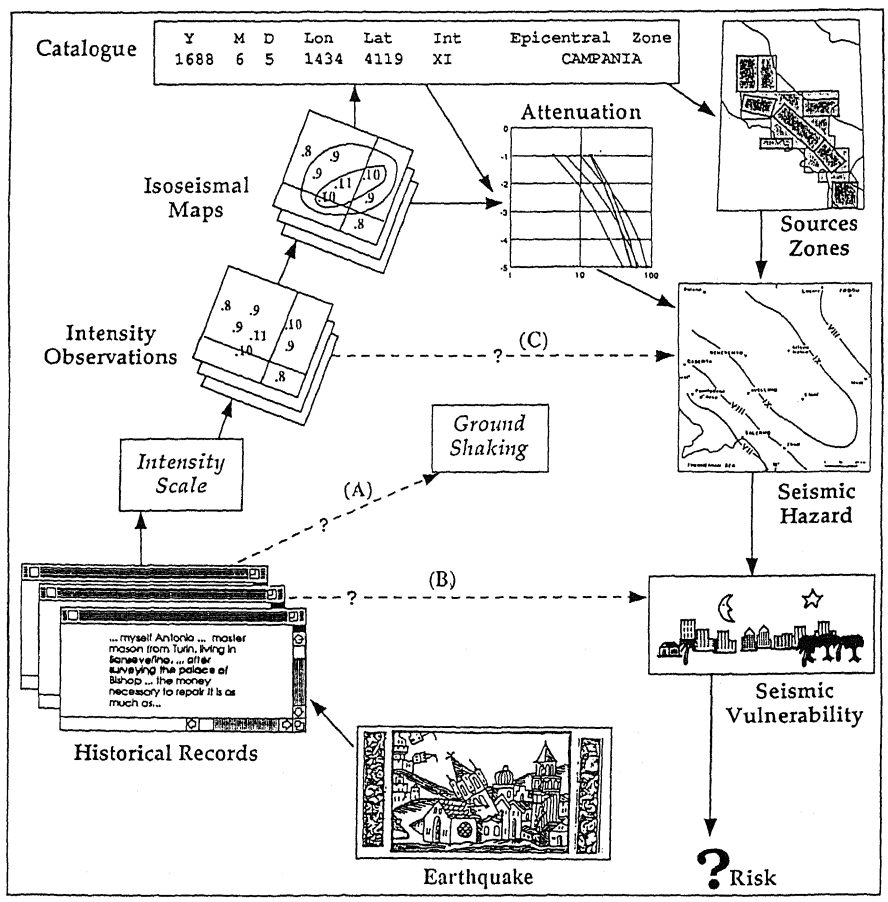


Figure 2. Processing and use of historical records. Dotted lines indicate possible alternatives.

2. BUILDINGS AND HISTORICAL RECORDS

The role of buildings

One of the most important factors in the processing of historical records are the buildings, as they play a major role in the frame of the intensity scales. In order to understand and interpret the records correctly, the main characteristics of the buildings should be known, because of two main reasons:

- historical records account mostly for what happened to buildings;
- the building behaviour strongly influences also the human response.

Very little is known with respect to buildings in the case of historical records. Very often damage is assessed by seismologists having no idea of which types of structures the records account for; however, in many cases, there is no way to know more about the buildings the records are dealing with. This topic needs strong collaboration between engineers and seismologists, with special reference to the aspects described below, which are necessary for assessing macroseismic intensity.

Types of structure

Historical records report frequently detailed damage to special, monumental buildings (castles, palaces, towers, pillars, churches, mosques, pagodas and so on) and less frequently effects to ordinary buildings, which are the only ones which can be used in the frame of intensity scales. The first kind of data will be discussed below: as for the second ones, it has to be stressed that, in principle, traditional, ordinary buildings may range from A to B, even to C, with reference to MSK intensity scale, and to D, C, B, with reference to MM scale.

Very little is known from the literature with respect to historical buildings typologies. This is definitely true for Europe up to XVII century, except the obvious fact that people used the materials they had at nearest, and that the more the owner was rich, the more his house was well-built and in a good state. But in the Middle Ages many houses, in many parts of Europe, were made by wood, and the transition to brick or stone was long, sometimes not definite.

Total number of buildings

The traditional historical investigation on earthquakes privileges records which describe earthquake effects.

The sources where such records are found account, in some cases, also for the number of damaged buildings, but do not systematically carry information on the total number of them. These data can be obtained, with some success, investigating other kind of sources, such as demographic sources, overall descriptions of localities and areas, cadastres and census of various kind. In some cases, reliable figures are found without problems: in some others - more frequently - they have to be extrapolated from data on population, by making use of assumptions and correlations. These figures will carry some uncertainties which are to be taken into account when assessing intensity.

A special problem which has to be carefully considered is that sometimes such figures can be related to an area instead of a locality - for instance the territory surrounding a small town, including some villages or hamlets and many rural houses - even if the wording used by the documents suggests that they could be related to the main town. The situation can be complicated by the fact that the descriptions of damage can suffer from the same problem, too.

Data from monumental buildings

This is the most frequent case, for two reasons:

- special, monumental buildings are more important for the compilers of documents and reports, because of their social, economic and symbolic value;
- their structural and non-structural complexity is such that they are generally more like to be damaged, despite the fact that in many cases they are better built than ordinary buildings.

So, in some cases, some breaks in the walls, or the fall of some decorative components, would probably not appear in ordinary buildings at the same shaking level, and they should not be overweighted.

Furthermore, special buildings exist in few units: the information related to them cannot therefore be used in a statistical way, as the intensity scales require. Nevertheless, it is worth considering whether a specialist could derive, from a rich damage description to a well known monumental building, ground shaking parameters, instead of trying for intensity.

3. INTENSITY AND SCALES

A scale of what ?

Intensity has represented sofar the only bridge between historical records and users. But, what is macroseismic intensity ? What does it represent ?

Asking these questions to scientists always provide strange feelings: "measure of effects"; "not a measure, an estimate"; "estimate of shaking". Someone is more pragmatic: "intensity is what you assess through an intensity scale".

It took about one afternoon in the first meeting of the Working Group "Macroseismic Scales" of the European Seismological Commission to come to a working definition, which is now adopted (Grünthal, 1992):

"the macroseismic intensity is a class (of the severity) of the ground shaking on the basis of observed effects in a limited area" .

Actually, intensity scales and the concept of intensity itself have been evolving through this century. In a very rough way we can say that, from a scope of pure, hierarchical classification of effects, it has been tried, more and more, to develop a rough instrument for measuring the shaking; or, simply, intensity has been used in this sense. But this trend didn't develop

uniformly: the present situation is a sort of compromise between the two philosophies. For instance, the intensity scales have incorporated differentiation of the "sensors" (A, B, C for the MSK; D, C, B, A for the MM), supposed to respond to the shaking in different ways; at the same time they still carry literary definitions (few, many, most), which are not like to come from experimental calibration.

A compromise is not a bad thing, provided that everybody knows it is and uses it properly. So, let's assume that, according to the working definition, we want to assess something which has to do with the shaking. Not necessarily something which can be easily transformed into the ordinary shaking parameters (a, v, and so on): but something which doesn't depend (too much) on what is shaken. We need, therefore, a measuring instrument.

The "measuring instrument"

It is widely accepted that the "measuring instrument" is a combination of sensors: humans, objects and nature, buildings. As the response function of these sensors is hard to be defined analytically, it is agreed that the instrument will be composed by many sensors, the response of which will be considered statistically. Also, it is (more or less) agreed that the measured "shaking" must be the real one; that is, we don't want to correct it according to soil conditions.

Scales (the instruments and their response functions), have been defined empirically sofar. Effects have been put together in the same degrees following the field observations of the authors (unfortunately, the original data and the way they have been processed are not available). Some further adjustments in the definitions may have been added for practical uses. In this way, from reading the former scales, it has to be understood that, for instance, the effects describing degree VIII are used to be observed together. Most recent scales, such as MSK and MM, have tried to consider the different response of some sensors, in order to get near the real shaking. Though this attempt has been performed on an empirical basis, some progress can still be achieved.

Improving the MSK intensity scale

Let's consider the response of buildings. If we examine the most important degrees, V to XI, which are defined in the 1981 version by combinations of:

types of structure	*(A, B, C)*
grades of damage	*(1 to 5)*
quantities	*(few, many, most, all)*

some questions arise:

- *Do the types A, B, C represent fully separated classes of vulnerability ?* The answer is: no. The vulnerability distributions of the buildings included in the 3 classes (whatever criteria one adopts to assess vulnerability) seem to overlap partially.
- *Do damage grades 1 to 5 reflect linearly increasing shaking ?* In some way, yes. But the definition of the five grades seem to correspond more likely to classes of damage which can be more easily distinguished by the operator.
- *Do quantities few, many, most, all, reflect linearly increasing shaking ?* Not so much.
- *Are the combination of types, damage grades, quantities, as suggested by the scale, found experimentally in case of earthquake ?* In many cases, not. It can be noticed that the data from 41 localities damaged by the Irpinia, 1980 earthquake, where overall damage surveys have been carried out, don't fit in the distributions described by the MSK 81 scale (Braga et al., 1992).

Therefore we get some problems. If we want to improve the use of intensity as a measure of shaking, we must have a better calibration of the degrees. This could lead to a scale which may considerably differ from the existing one, causing problems to the use of the existing intensity data. If we want to keep the scale more or less as it is, we can remain far from measuring the shaking.

The Working Group of the European Seismological Commission had another commitment: to introduce in the MSK scale the buildings incorporating antiseismic design. The discussion on this has been long, but very fruitful, leading to reconsider also the definition of A, B, C types. Types of buildings are now plotted in a table versus their vulnerability (Fig. 3), in such a way that each type shows a range of vulnerability and a most probable class (something like a modal value). This table has been compiled on the basis of general considerations, but it is now open for calibration.

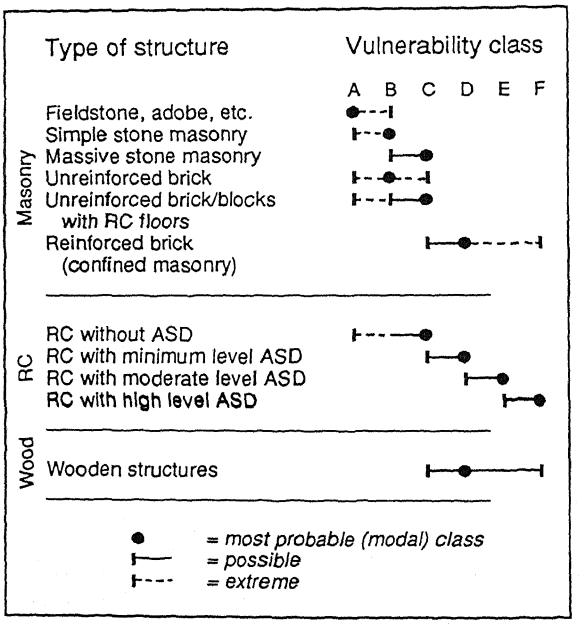


Figure 3. Types of structure vs vulnerability in the 1992 version of the MSK scale (Draft, from Grünthal, 1992).

Calibrating a scale ?

Calibrating a scale would require:
- to select the "sensors" and to define their response to shaking;
- to put together, in some classes, the effects caused by the same ranges of shaking;
- to test the consistency of the model experimentally.

How far are we from this? Still far. But the enormous increase of earthquake data suggests that we can have enough data to provide good calibration for a model.

4. SEISMIC HAZARD ASSESSMENT

Standard procedures

As remembered above, after the historical records have been interpreted in terms of intensity, they contribute to the compilation of isoseismal maps and to the calibration of attenuation laws: further, they contribute to the compilation of earthquake catalogues. In this way they become part of a standard process which allows users to handle them together with instrumental data, in order to assess seismic hazard and risk (Fig. 2).

These procedures are well known, as well as the problems which are connected with them: therefore they will not be discussed here. It is important to stress, nevertheless, that the assimilation of historical data to instrumental data is not always successful, despite the fact that they have been converted into numbers.

Alternatives

Standard procedures are very useful, but there is a general feeling that historical records loose in such a way a part of their potential. Could not they contribute in other ways? Yes, in many ways (Fig. 2, dotted lines).

An example has already been mentioned (Fig. 2, A). When we have a description of damage to a pillar, or to a pagoda, why should we assess intensity from this information - it would be definitely outside the philosophy of intensity scales - rather than trying and deriving a ground shaking parameter directly? Would it not be even easier if the pillar still exists, and if detailed design descriptions are available?

Other roads can be explored. For instance, one may guess whether some historical damage descriptions can contribute to evaluate the vulnerability of buildings which still exist (Fig. 2, B). On the other side, many attempts of using intensity datapoints directly for assessing seismic hazard have been performed (Fig. 2, C).

5. CONCLUSIONS

The need for a strong collaboration among engineers, seismologists and historians for a better interpretation and full utilisation of historical records has been evidenced. In particular, very little is known about the ordinary buildings of which the historical records account for, what leads to significant uncertainties in damage and intensity assessment.

Historical records are generally processed in terms of macroseismic intensity. In order to improve the use of intensity as an indirect measure of shaking, a 1992 version of MSK scale has been prepared in the frame of the ESC. In this version, a new arrangement of types of buildings with respect to vulnerability has been proposed.

Further roads to explore the potential of historical records, in order to provide useful data for assessing seismic hazard, are open to the collaboration of different expertises.

REFERENCES

Archivio di Stato di Pisa (ASPi) 1834. Camera di Sovrintendenza Comunitativa, f. 491. *Pontremoli, corrispondenza ministeriale. Relazione dei Terremoti sentiti in Pontremoli dal 14 Febbraio 1834*, Pontremoli, 12 marzo 1834.

Braga, F., M. Dolce & D. Liberatore 1982. A Statistical Study on Damaged Buildings and an Ensuing Review of the MSK-76 Scale, *Proc. 7th ECEE*. Athens.

Grünthal, G. (ed.) 1992. MSK-92 Macroseismic intensity scale. *Cahiers du Centre Européen de Geodynamique et de Séismologie*, in press.

Margottini, C. 1992. On the uncertainties of historical data and their effects in seismic hazard assessment. *Proc. 10th WCEE*, 1: 405-410. Madrid.

Stucchi, M. & P. Albini 1992. New develepments in macroseismic investigation, *Proc. Mexico-EC Workshop "Seismology and Earthquake Engineering"*. Mexico City, in press.