Earthquake Engineering, Tenth World Conference © 1992 Balkema, Rotterdam. ISBN 90 5410 060 5

On the uncertainties of historical data and their effects in seismic hazard assessment

C. Margottini
ENEA, Italian Commission for New Technologies, Energy and Environment, Rome, Italy

ABSTRACT: Aim of this paper is to show some Italian experiences in evaluating the uncertainties affecting the historical seismic data as well as the related effects in seismic hazard assessment. That is because very often sophisticated calculation may be produced, even analyzing the errors arising from the process, but neglecting almost completely the inaccuracy of starting seismological data; the uncertainties on the reconstruction of the historical context where the earthquake occurred, as well as the way to produce the pieces of information and the translation into an intensity value may affect the final result much more than the statistical process itself.

1 INTRODUCTION

Seismic hazard analysis is mainly based on the postulate that the effect of past earthquakes may repeat in the same area in a defined span of time. In the mean time, effects of past earthquakes are, in ancient cultural regions like Italy but also in other part of the world, described by intensity, while forecast effects of next events may have the "dimension" of either intensity or vibratory ground motion (P.G.A., P.G.V., duration, etc.). Ground motion prediction should also take into consideration a large number of geological, geophysical, seismological and geothecnical parameters. These parameters are physically related to the earthquake occurrence, earthquake source, the wave propagation path, and the local ground response.

With respect to the historical intensity data that are of basically importance in defying occurrence rate and source, seismic hazard analysis shows several uncertainty levels; the first one is due to the missing of information on social, political and historical context hit by the quake, the second concerns the characteristic of buildings damaged by the earthquake, the third is related to the intrinsic uncertainties of a macroseismic scale as it is defined and used, while the fourth depends from the utilization of intensity data and than to the application at modern world, of parameters determined in past social and historical context. In the mean time, the huge diffusion of sophisticated computer equipments is changing the use of intensity that instead of describing the effect of earthquakes is getting an important seismological parameter, suitable of very complex manipulations.

2 SEISMIC HAZARD ANALYSIS TODAY

Producing sound estimates of earthquake hazard is a complex endeavor, which involves the use of information from geology, geophysics, seismology and geotechnical engineering, as well as probabilistic modeling and statistical analysis (Veneziano & Van Dick, 1985). Seismic hazard procedures based on notion Poisson earthquake sources were first developed in the late 1960's (Cornell, 1968; Cornell, 1971) and are now used routinely with only slight modifications (Mc Guire, 1976; Der Kiureghian & Ang, 1977). The main differences among various earthquake-source (or seismogenic-province) methods are in the representation of the source as either lines or regions on the geographical plane and in the definition of distance from the earthquake to the site as epicentral distance, focal distance, or distance to the rupture zone.

Method of a different type, called historical, have also been proposed, e.g. by Milne and Davenport (1969), Lomnitz (1969), Veneziano (1982). The distinguish feature of these methods is that they replace the theoretical model of Poisson earthquake source with the catalogue of historical events. An attenuation relationship is still necessary to calculate earthquake hazard at the site.

Experience with seismic hazard procedures has demonstrated that critical to the final results is the quality of the input, which include the configuration of sources and their activity rates (seismogenic-province methods only), the form and parameters of the attenuation relationship, and the treatment of local effects (Veneziano & Van Dick, 1985). In other words, the methodology of seismic hazard calculation is not as critical as the specification of input parameters. With the objective of improving the estimation of these parameters, new statistical techniques have been recently developed for the problem of magnitude conversion, earthquake clustering, catalogue incompleteness, recurrence rate, and attenuation (Veneziano & Van Dick, 1985). Also, in order to quantify uncertainty on the hazard function, it is now common practice to specify several seismicity and attenuation models, express uncertainty on the correct models through judgmental probabilities, and propagate this uncertainty through the analysis. The final product of the analysis is in this case not a single hazard curve but a set of curves, each with an associated probability (Veneziano & Van Dick, 1985).

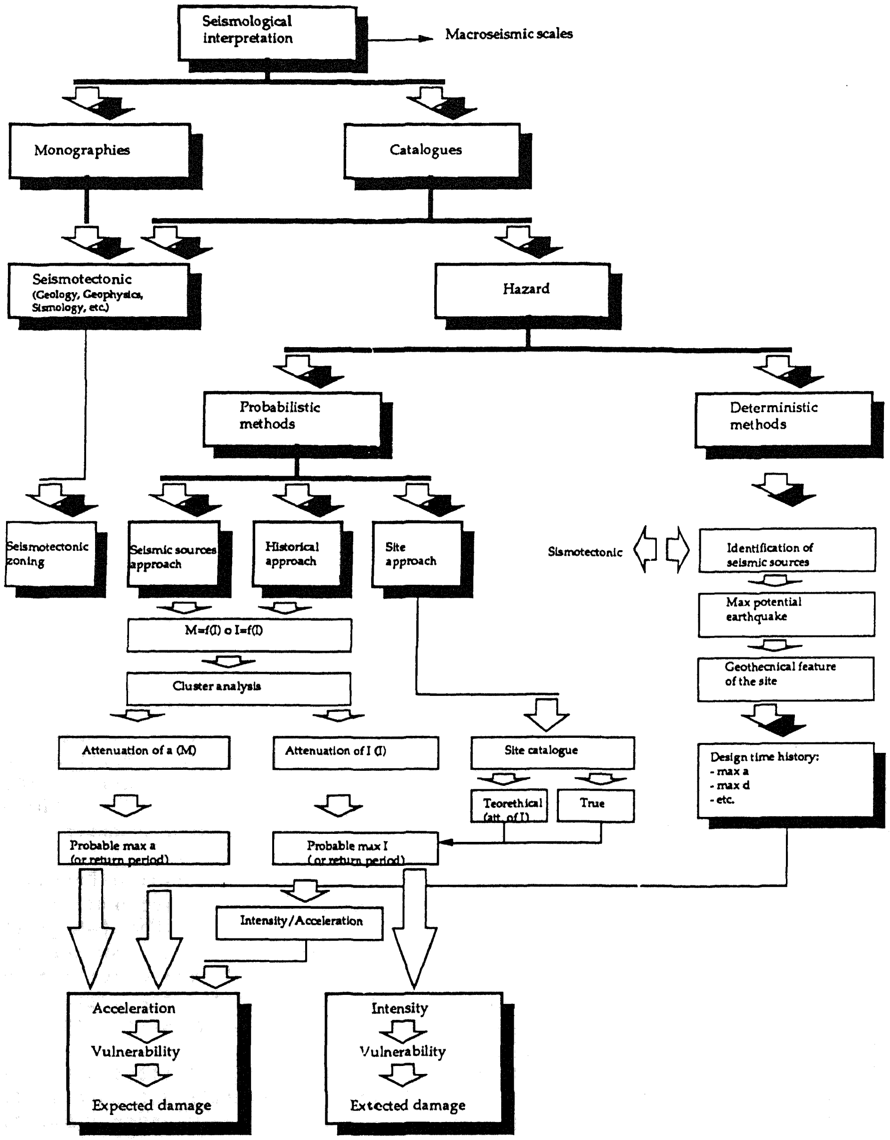

Fig. 1 - Flow chart for seismic hazard analysis.

In figure 1 an overview of the most common approaches for seismic hazard assessment is reported. These methodologies are, in countries like Italy with a long written history and civilization, mainly based on the elaboration and interpretation of the historical information on past earthquakes. From this figure it is possible to recover that, depending from the chosen approach, several combination and correlation among the historical data and others kind of parameters have to be performed during the process. The more common are Intensity vs. Magnitude and Intensity vs. Vibratory Ground Motion (Peak Ground Acceleration, Peak Ground Velocity, Displacement, Arias Intensity, Duration, etc.). This kind of correlations are not physically correct even if their use is today a normal practice. The process of fig. 1 shows also other "weak points" related to the translation of a naturalistic and ordinal parameter (intensity) into an engineering and continuous one, that are: cluster analysis and recurrence rate depending from catalogue incompleteness, attenuation, and seismic (or seismotectonic) zoning, especially when based on the historical seismic activity. All these lasts are strictly depending to the time and geographical distribution of shocks; in other words, the level of knowledge on past earthquakes is function of the capability of historical context to have produced, stored, and preserved the contemporary information as well as to the capability of today researches to find out data and to interpret them correctly.

3 HISTORICAL DATA IN SEISMIC HAZARD ASSESSMENT

In countries like the Mediterranean ones, seismic hazard is mainly performed on the base of seismic history catalogue. This can get back in time up to 1000 years or even more, depending from the energy level of the event. In fact, we can today asses the occurrence of an earthquake in the past if:
•) we can at present recognize the permanent geological effects induced by the vibratory ground motion;
•) we can at present identify the effect of the vibratory ground motion in the at that time man-made structures;
•) we can today read the description of the effect caused by the event, performed by contemporary or posterior writers.
Because of the almost systematic production of detailed reports on the events, it is well known that the best resolution of historical catalogues is since the invention of printing. In tab. 1 (Gurpinar, 1991, modified) a general view of different approaches to collect seismic data is reported, function of time period and classes of energy. It is quite evident that the best compromise between time covered and lower energy threshold is

Table 1
Data base for seismic hazard assessment (from Gurpinar, 1991; modified)

TYPE OF DATA	APPROX. TIME FRAME IN YEARS	DETECTED MAGNITUDE
Microearthquake	10 E 1	> 0
Insturmental seismicity	10 E 2	> 4
Historical seismicity	10 E 3	> 3 - 6
Archaelogical evidence	10 E 4	> 6
Paleoseismicity	10 E 5	> 7
Neotectonics	10 E 6	

related to the utilization of written sources.
In order to better understand the uncertainties affecting historical data it is advisable to follow the process starting from the occurrence of the earthquake till the seismological interpretation of written information (fig. 2). When an earthquake occurs, in fact, a certain type of damage can affect different kinds of buildings; in the mean time chronicles, newspapers, religious and civil administrative documents describing the effects of the events are producing.
The documentary sources on the earthquakes were generally stored in depositories, close or far from the origin region. The knowledge of historical, social and political context, as well as the way of collecting and storing political, cultural, religious, and admistrative documents in tha past it is of basically importance to lead the today researches in recovering the contemporary sources. As examples can be mentioned the small church or local administrative archives spreaded in all over Europe and, as other extreme, the example of the Record Office of Venice, named Frari's Archive, containing sources for the study of the Balcan peninsula, referred to the time of the Venice domination in that region (Albini, Daltri, 1991; Guidoboni, Margottini, 1988).
As the documents are recovered, they have to be critically interpreted from an historical point of view; this is to avoid duplication of shocks due to chronology, to allow the identification of places on the base of contemporary geographical reconstruction, to define the

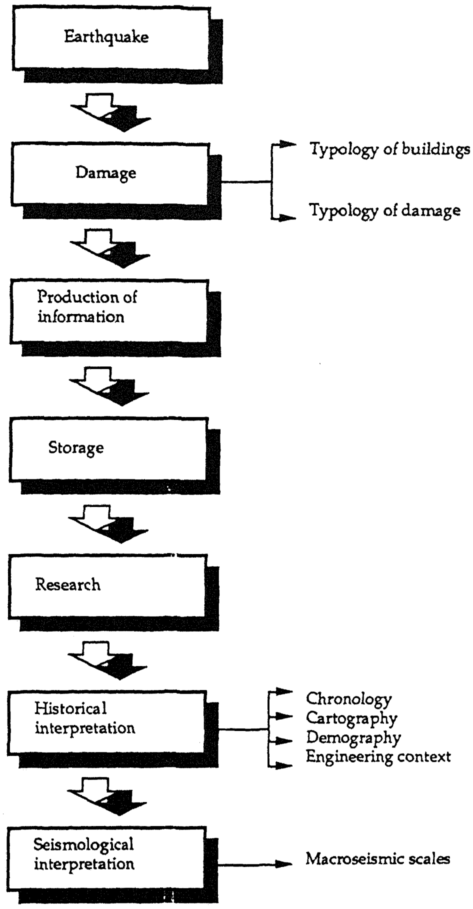

Fig. 2 - Flow chart showing phases since the occurrence of an earthquake in the past until the present time seismological interpretation.

human and engineering context hit by the quake. This step is very important in order to avoid, as sometime occur, seismic catalogues prepared uncarefully on the basis of other catalogues without checking the original data, catalogues often referred to "secondary hand" sources, and catalogues not showing the way primary information has been synthesized.
All the above mentioned steps are of basically importance for understanding the background (or "dark side") of historical data, before the seismological interpretation; they represent a first level of uncertainty. Recent studies on historical earthquakes (Ambraseys and Melville, 1982. Guidoboni, 1990; and others) as well as international project supported by the CEC (Stucchi, 1988) or IAEA (Gurpinar, Margottini, 1991) demonstrated very well the useful contribution of detailed historical researches in this topics. Unfortunately, in common practice not high attention was devoted, up to now to the detailed reconstruction, even in Italy, of typology and number of buildings, number of living people, and typology of damage for each village.This is much more evident especially for common houses of the past that should represent, on the

Fig. 3 - Individual buildings with detailed descrptions, damaged during the September 1349 earthquake in Viterbo (Central Italy), superimposed in a 1595 historical map.

other hand, the link with the today situation. In fact, if we go in very detail into the reports describing damage sustained by a village during an earthquake, we can see that the historical descriptions refer mainly to the damage of churches, castles and/or other relevant official buildings (fig. 3). What above said it means that we have production of information mainly for category of buildings remarkables from a religious and political point of view, but not standard with respect to the contemporary common houses for which, roughly speaking, only general descriptions are available. In the mean time it is very difficult to reconstruct the engineering context hit by the quake, for which "ad hoc" researches should be performed. The knowledge of typology of buildings are in fact, of basically importance to calibrate the "transfer function" at modern time of the damage (and than of the vibratory ground motion, speaking in terms of hazard) occurred in the past.
An other point of uncertainty in Seismic Hazard analysis is the utilization of data and the application, at modern world, of parameters determined in past social and historical contexts. In figure 4 is reported the development of common buildings and population in Italy since 1900. At first sight it is possible to recognize that intensities of Italian catalogue (Postpischl, 1985; time period 1000-1980) before XXth century are mainly based on effects determined up to 20 % of the building existing today, with characteristics that, likely, have been changing in time. The same results can be obtained considering the population that today is more than two times with respect to the beginning of this century. Apart from concrete buildings, these statements mean that we have to be very careful to the application, without criticism, at today structures of effects determined in past engineering contexts.
An other level of uncertainty is related to the seismological interpretation of historical data and to the subsequent translation into an "intensity". Macroseismic scales were born in XVII century but the huge diffusion was at the end of the last century (fig. 5). They were

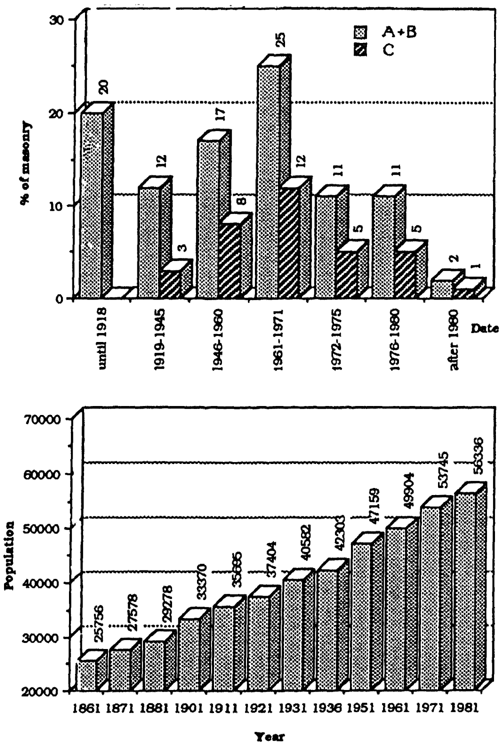

Fig. 4 - Percentage increasing of buildings in Italy (A + B types and C type of MSK-64) with respect to present time situation, and increasing of population (below).

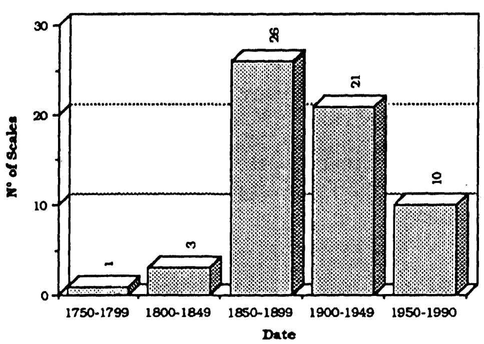

Fig. 5 - Distribution of macroseismic scales, function of date of presentation.

adopted to describe the effects of the earthquakes in different places, to allow a quantification and classification of severity of different quakes. A general definition of intensity can be state as a measure of the effect of an earthquake upon environment, artificial structures and human observers in a given locality (Eiby, 1965). Anyway not evident statements to define the rulers for application of the scales has ever published.
From the above definition of intensity it is quite evident that the macroseismic scale is a combination of three different groups of markers each one of them can be

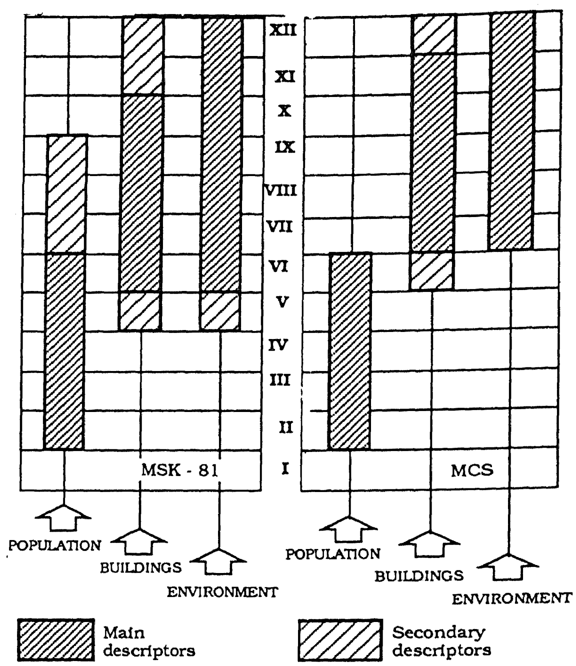

Fig. 6 - Effects on population, buildings, and environment as reported in the MSK-64 and MCS macroseismic scales.

considered as a separate scale (fig. 6). Consequences are several limitations in the use of intensity as it is conventionally defined and used. Apart from not representative of the seismic energy released in the affected locality, these limitations of macroseismic scales include non linearity of the scale, ambiguous terms which require subjective interpretation, incompatibility of the lower, middle and upper sections of the scale in terms of effects, limitation in the range of intensity when engineering concerns are pertinent and presence, in the same degree, of effect not directly related to the same vibratory ground motion (USGS, 1977).
In the mean time, the huge diffusion of sophisticated computer equipments is changing the use of intensity that instead of describing the effects of earthquakes is getting an important seismological parameter suitable of very complex manipulation. The main effect is the use of intensity as a physical parameters, continuous and representative of the strength of the earthquake.
The results of what above said is that seismic hazard, with respect to the intensity data, is a function of the historical context were the earthquake occurred, of the possibility to transfer the effects of a certain historical engineering heritage to the today situation, of the difficulties to fit the damage data with the intensity scale, and, finally, of the use of intensity data in sophisticated computer programs. The following table 2 is synthetically reporting the effect on seismic hazard analysis due to the uncertainties in historical data.

Table 2
Effect on Seismic Hazard Assessment due to uncertinties in historical data.

UNCERTAINTIES ON HISTORICAL DATA	EFFECTS ON SEISMIC HAZARD ASSESSMENT
missing of knowledge on historical, social, and political context where the earthquake occurred	catalogue uncompletness
determination of historical heritage and present day engineering situation	uncorrect definition of the "transfer function" from past damage to hazard of future damage
interpretation of damage trough a macroseismic scales	not correct representativity of damage
use of intensity data	uncorrect treatment of data as "physical parameters

4 CONCLUSIONS

The data and comments above reported may lead to three main impressions:

• the study of an historical earthquake cannot be separated by the collection of comprehensive information on the historical context hit by the shock;

• it seems that the intensity, defined in modern terms, about 100 years ago, were useful, at that time, to allow a sort of roughly comparison among the energy content of different quakes in the same place, or in different places;

• the increasing of computer equipments is leading to a mathematical use of intensities in very complex computer programs in which this parameter is loosing the original concept.

The results of what above said is that a big effort is now required to underline new way and solution to interpret historical data. In fact, it is quite evident that the uncertainties affecting historical data, even if not defined from a mathematical point of view, are substantials and from their accuracy the final estimate of seismic hazard is depending (Veneziano & Van Dick, 1985).

Finally, it has to be emphasized that the above reported considerations are coming mainly from the Italian experience where there is a huge amount of documentary sources. In other Countries with shorter and less detailed written history deep approach on historical data will be rather problematic.

REFERENCES

Albini, P., Daltri, A. 1991. The Serenissima Republic of Venice and the earthquakes. *Proceedings of Third international workshop "Historical earthquakes in Europe", Liblice by Prague, 4-6 April 1990*, Prague

Ambraseys, N.N., Melville, C.P. 1982. A history of Persian earthquakes. Cambridge earth science.

Cornell, C.A. 1968. Engineering seismic risk analysis. *BSSA*, 54(5): 1583-1606.

Cornell, C.A. 1971. Probabilistic analysis of damage to structures under seismic loads. *In Howells D.A., Haigh I.P., Taylor C. (ed) "Dynamic waves in Civil Engineering"*. Wiley-Interscience.

Der Kiureghian, A., Ang, A. 1977. A fault rupture model for seismic risk analysis. *BSSA*, 67 (4): 1173-1194.

Eiby, G. A. 1965. The assessment of earthquake felt intensities. *Proc. 3rd World Conference on Earth. Eng. Paper III/E/10.*

Guidoboni, E. (editor) 1990. I terremoti prima del mille in Italia e nel bacino del Mediterraneo. Bologna.

Guidoboni, E., Margottini, C. 1988. The 6th April 1667 Dalmatian earthquakes in the Italian historical sources. *In C. Margottini, L. Serva (editors), Proceeding of the "workshop on historical seismicity of Central Eastern Mediterranean region", Rome 27-29 October 1987,*. Rome.

Gurpinar, A. 1991. Importance of historical earthquake research in the siting of nuclear facilities. *Proceedings "Historical seismicity and seismotectonic of Mediterranean region"*, Istanbul 10-12 October 1990.

Gurpinar, A., Margottini, C. 1991. The IAEA project on the historical seismicity of the mediterranean region "Seismic Data for Nuclear Power Plant Siting". *Proceedings of Third international workshop "Historical earthquakes in Europe", Liblice by Prague, 4-6 April 1990*, Prague.

Lomnitz, C. 1969. An earthquake risk map of Chile. *Proc. 4th World Conf. on Earth. Eng.*, 1:161-184.

Mc Guire, R.K. 1976. FORTRAN computer program for seismic risk analysis. *USGS Open File Report 76-67.*

Milne, W.G., Davenport, A.G. 1969. Distribution of earthquake risk in Canada. *BSSA*, 59 (2): 729-754.

Postpischl, D. 1985.

Stucchi, M. 1988. The CEC Project "Review of historical seismicity.*In C. Margottini, L. Serva (editors), Proceeding of the "workshop on historical seismicity of Central Eastern Mediterranean region", Rome 27-29 October 1987,*. Rome.

USGS, 1977. *Report of conference on intensity scales.* Denver.

Veneziano, D. 1982. Historic methods. *Sec. 3 of supplemental Seismic Probabilistic Study*, Yankee Atomic Electric Company, Rowe, Massachusetts, Report YAEC-1331, Yankee Atomic Electric Company, Framingham, Massachusetts.

Veneziano, D., Van Dick, 1985. Seismic hazard analysis for the Friuli region. *ENEA Consulting report*, part I.