

To what degree can historical seismicity records assist in seismic microzonation?

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Received 7 November 2005; received in revised form 21 April 2006; accepted 28 April 2006

Available online 7 July 2006

Abstract

It is well known that historical data of seismic effects in urban areas can be useful in seismic microzonation, but we must consider how to make the most of available documentary sources and assess to what degree historical information can help us.

From this starting point, this paper deals in a more objective manner with the potential contribution of macroseismic site data, suggesting the compilation of an *ad hoc* questionnaire. In this way, the two main aims of this paper can be achieved: to make the most of available documentary sources, and to quantify the usefulness of macroseismic information for microzonation analysis via a 'Site Normalised Utility and Reliability Parameter' (SNURP). This second aim resolves, for example, the question of priority in resource allocation for microzonation site surveys. On the whole, the proposed approach will provide an easily used tool to deal with historical accounts, especially for professionals in the engineering geology field.

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Keywords: Seismic microzonation; Historical seismology; Damage pattern

1. Introduction

Seismic microzonation concerns *the identification and mapping at local or site scales of areas having different potentials for hazardous earthquake effects, such as ground-shaking intensity, liquefaction, or landslide potential* (Lee et al., 2003).

Indeed, it is known that during an earthquake the damage to buildings with comparable features can differ enormously between points separated by as little as several hundreds of metres. This phenomenon is generally due to the effects of surface geology or topography on ground motion (e.g.: Sanchez-Sesma, 1985; Aki, 1988;

Geli et al., 1988; Pedersen et al., 1994; Chavez-Garcia et al., 1997).

Historical sources sometimes refer to differential seismic effects, especially sources that document Italian quakes, where the observed differential damage is interpreted from a geological point of view probably for the first time in the second half of the 18th Century following the 1783 Calabria (Me=6.9) seismic event (e.g.: Lallement, 1785). Several descriptions of the influence of territorial features on damage patterns are also recorded in the following centuries, including Pilla (1846) and Baratta (1910). On the whole, these works, when considered with observations of other earthquakes all over the world, can be considered as a sort of preliminary study of microzonation. Therefore, it is evident that documentary sources concerning

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urban historical damage can provide useful information in view of the seismic microzonation. Indeed, a microzonation procedure based only on *in situ* surveys will supply an indication of those urban sub-areas where potential high levels of damage *may occur* as a consequence of an earthquake. In contrast, microzonation analysis also leads with a historical approach enables us to identify the urban areas where relatively high levels of damage *have already occurred* in previous earthquakes. The written accounts also sometimes provide information concerning the reasons for higher levels of damage in certain areas.

In this context, at least two problems rise. How do we make the most of available documentary sources, and to what degree can historical information help us? Up to now, the approach to historical sources has only been qualitative, and no codified criteria were available. For a better approach to historical data, we suggest the compilation of a questionnaire for each earthquake that affects a chosen town where sufficient information exists.

The proposed questionnaire has two main purposes: to make the most of available documentary sources by expert questions, and to quantify by 'Site Normalised Utility and Reliability Parameter' (SNURP) the usefulness of the whole macroseismic data set. The SNURP parameter will resolve, for example, the question of priority in resource allocation for *in situ* surveys when a campaign of microzonation concerns several towns.

It must be emphasised that this approach to historical investigations of microzonation analysis is also due to the ambiguous interpretation of certain *in situ* analysis. For example, the site-effect inferred from the horizontal-to-vertical spectral ratio H/V of microtremors, the well-known Nakamura technique (Nakamura, 1989), is contradicted by various authors (*e.g.*: Bonilla et al., 1996; Lachet et al., 1996; Seekins et al., 1996).

On the whole, the proposed approach will be useful for professionals in the field of engineering geology because the proposed scheme provides a quick and easy interpretation of acquired data. However, details of the proposed method will be tested by three case studies in Italian towns.

2. The questionnaire

To make use of historical data for the purpose of microzonation analysis, it is necessary to set up a procedure to *retrieve* and *evaluate* the information.

With regards to the procedure to retrieve the information, a key point will be the acquisition of the national catalogue of earthquakes. The information

both about features of national catalogues and state-of-the-art historical earthquake research in several states can be found, for example, in Stucchi (1998) and Albini et al. (2004). The national catalogues are usually compiled for seismic hazard purposes, and therefore provide only parametric data, such as Latitude and Longitude of the epicenter, epicentral intensity, and magnitude. However, attached to the catalogue are bibliographic references used to compile the list of seismic events. Therefore, by a search based on earthquakes or localities it is possible to gather the list of bibliography relevant to the site of interest, including primary sources, that is written accounts contemporary to the seismic event produced by reliable and authoritative eyewitnesses geographically close to the analysed event (*e.g.*: sources pertaining to memoir writing, literary sources, archive documentations and scientific accounts) and secondary sources such as studies of history of the town and historical earthquake compilations assembled from scientists and literary men with naturalistic interests. Some catalogues also report the original text of the written sources.

It is obvious that the temporal and spatial resolution of these written accounts is limited to the general goal of the catalogue. Therefore, these basic data will be supplemented with deeper research, especially with regard to relatively recent earthquakes for which there will be detailed damage descriptions and analysis of the causes of damage (*e.g.* archive sources in public institutions active in the post-earthquake stage, newspapers, scientific reports, and local historiography). However, for a reliable examination of the basic data, both the analysis and interpretation criteria of the sources should be identified in several references (*e.g.*: Albini and Moroni, 1994; Stucchi, 1998; Boschi et al., 2000).

Once the information on seismic effects has been collected it is necessary to examine it, that is to analyse the procedure to evaluate the information. This involves standardizing and optimizing the criterion to gather as much information as possible from the selected written records.

To achieve this goal we propose a questionnaire that must be compiled for each important and well-documented earthquake recorded for the site of interest. The proposed questionnaire is drawn from the analysis of several historical descriptions of urban damage in Italian towns. However, it can be considered as an open structure adaptable, if necessary, to various national contexts.

The questionnaire (Tables 1 and 2) is composed of two main parts that contain ten questions (3 in *Damage* field and 7 in *Damage causes* field). On the whole, the

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