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CITY SEISMIC MICROZONATION IN CHINA

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SUMMARY

Basic ideas of the current microzonation in China are explained. Two parallel and complementary microzonation methods--site classification and comprehensive microzonation are systematically introduced, the former is suitable for large amounts of urban areas of medium and small size while the latter for big cities and important engineering areas. The site specified peak ground acceleration A and velocity V are suggested as the microzoning indexes. An empirical model for scaling design response spectrum in terms of A and V is presented for use, its deviation from recorded strong motion data is smaller than that of conventional ones . Finally , studies on comparison between various microzoning methods, between actual and predicted earthquake damage distributions and between observed strong motion distribution and ground motion microzoning results in an urban area are stressed in order to lead to more balanced guidelines for seismic microzonation.

INTRODUCTION

Assessment of seismic hazard is the first step to mitigate earthquake disaster, without which seismic countermeasures shall get nowhere. The assessment is usually depicted by a zoning map. Almost every country on seismic belts in the world has now a national zoning map , which delineates its territory into several regions of different hazard levels. A delineated region of a certain hazard level on such a map, commonly has an area larger than several hundred square kilometers, therefore , only an average level of hazard over the area can be provided by the map. However, it is well known from earthquake field investigations and strong motion observations that the hazard level might vary considerably within one square kilometer or less. Consideration of the variance seems to have substantial importance for earthquake resistant design at any particular engineering site. Therefore, a gap exists between the national zonation and the engineering need.

In order to fill the gap, microzonation has been developing in China since the late 1950s (Ref.1). The objective of the microzonation might be specified as estimation of seismic hazard distribution over an urban area , which should provide fundamental data needed for earthquake resistant design and for general hazard mitigation in the area. Microzonation is such a practical task faced by earthquake engineers and city planning makers in vast seismic regions of China that Chinese earthquake engineering circle and local governments have been attaching increasing importance to it. In order to cope with the task, several years ago the Department of Scientific Programming and Earthguake Monitoring, State Seismological Bureau organized a group of Chinese scientists to summarize the experiences which had been acquired in the field and asked the scientists to form a seismic microzonation guide for the practice in China. This effort had led to a draft of the guide in 1984. The guideline specified by the draft was then put in practice for cities, such as Dalian, Guang Ao developing area, Hefei, etc. According to experiences obtained in the practices, the draft has been revised and resulted in "Seismic Microzonation Guide (Tentative)" (Ref.2). The guide has been put in force by all local seismological bureaus and other organizations nationwide since January 1988. It is expected that the guide would be further revised and improved through microzoning practices in the country and developments in engineering seismology worldwide in following years. For helping - users understand the background of the guide and implement it in the practice, a book titled by "Seismic Microzonation" is edited and expected to issue in China this year. The book consists of 20 research reports done by Chinese Seientists in the field recently, in which various basic problems encountered in microzonation are systematically discussed and stress is put on the integrate method to bring it to the practical end. The writer of the paper, as the draftsman of the guide and editor of the book, would like to give a general sketch here on the current methodology of microzonation in China and make a few remarks which are connected with further improvement of the methodology.

THE CURRENT METHODOLOGY OF MICROZONATION IN CHINA

Strong Ground Motion and Ground Failure One of the basic ideas in the current microzonation in China is that direct causes of earthquake damages in urban areas must be distinguished into two general types, strong ground motion and ground failure. The ultimate results provided by microzonation for an urban area are two series of microzoning maps on a scale of 1:10,000--1:50,000 or so. One series, called design earthquake microzonation, include maps of design ground motion parameters; the other series, called ground failure microzonation, include maps delineating sections of various possible ground failures, such as sand soil liquefaction, soft soil settlement, ground rupture caused by active faults, etc.. Importance of the above grouping is that different causes of earthquake damages should be handled by different countermeasures. The damage caused by structure dynamic response to strong ground motion may be mitigated by strengthening structures or reducing its response through earthquake resistant design; while the damage caused by ground failures may be mitigated by site selection or sometimes by foundation soil treatments (Ref.3).

Delineating sections of potential ground failure in an urban area is an important problem, particularly, for making city land use planning (Refs.24, 25 and 26). However, ground failures occur only under rare conditions of engineering geology and topography, and are usually limited to much smaller area than the total damage area. In fact, according to field investigations of destructive earthquakes occurred in China, at least more than 90% of the direct damages were caused by strong ground motion. Therefore, design earthquake microzonation is generally considered as a more substantial problem and will be discussed here.

Two Kinds of Design Earthquake Microzonation The ground motion parameter required by the current earthquake resistant design in China is the acceleration response spectrum SA(T) (Ref.8) or sometimes entire accelerograms consistent with the spectrum (Ref.14 and 15). In order to specify SA(T) at any site within an urban area, two parallel microzonation approaches are used, namely, the site classification microzonation and the comprehensive one. The two approaches are mutually complementary. The former is suitable for large amounts of cities and engineering areas of medium or small size, while the latter is for big cities and important engineering areas.

1. Site Classification Microzonation

The approach is closely connected with the repeated field experience which reveals that earthquake damage on hard soils are generally less than that on soft ones, and thus the site is classified into several classes from hard to soft (Ref.9). The standard design response spectrum in an design code is then specified for each site class according to strong motion data obtained at sites belonging to that class. The original suggestion for the classification is of macro-descriptive type, as shown in table 1 (Ref.4). The classifying method has been changing with development of the design code. For example, in the proposed new code (Ref.5) some quantitative scales are adopted for classifying a site, as shown in table 2. This simplified approach has been widely adopted in China for its being convenient for use and familiar by the civil engineering circle in the country. Based on an established national zonation and an aseismic code, determination of design SA(T) may be summarized as follows:

(1) Determine the seismic intensity according to location of the considered urban area on the national zoning map, and convert the intensity into peak ground acceleration A (Ref.6);

(2) Classify sites within the area according to site data of engineering geology;

(3) Determine the dynamic coefficient $\beta(T)$ in terms of site classification according to an earthquake resistant design code , and the design $SA(T) = A\beta(T)$.

2. Comprehensive Microzonation

The approach has been developing since late 1970s for a more banlanced seismic hazard assessment for important urban areas in China . It is characterized by a unified considertion of seismic environment of a microzoning area and local site conditions within the area, and by putting advanced research results on seismicity, seismogeology and strong motion seismology into the unified consideration. The approach includes four linked steps: determine seismic input, estabish site model, estimate site effects and compile microzoning maps.

(1) Seismic Input The seismic input to a microzoning area is assessed on the basis of a probabilistic hazard analysis following the frame originally set by Cornell (Ref.7) .The assessment includes:

A. Devise probabilistic seismicity models for potential earthquake sources. The models should reflect the time variation of seismic activity on any seismic belt related with the potential sources and possible space distribution of future earthquake location on each belt according to seismicity and seismogeology data and research results connected with long--term earthquake prediction available in the background region (Refs.10,11);

B. Set up empirical models for scaling parameters of strong ground motion on bed rock according to strong motion records and the seismic intensity data in related regions (Refs. 12,13)

C. Determine the uniform risk response spectra on bed rock of the microzoning area for several probability levels (Refs 27,28).

D. Synthesize accelerograms consistent with the bed rock response spectra by means of the empirical approach (Ref.14) or the semi-empirical approach (Ref.15).

(2) Models of Local Sites The models of local sites within a microzoning area is established on the basis of detaited investigations on engineering geological conditions, wave velocity measurement in situ and experiment data on dynamic properties of soil samples in the area (Refs.16,17,23). The models are generally divided into two types : one dimensional model and higher dimensional model. If sites have no considerable lateral variation of soil properties , they are modeled by the former, otherwise , the latter are adopted (Ref.29).

(3) Effects of site conditions on ground motion. For site models of one dimension the conventional approach is used (Ref.18). For site models of higher dimension , a practical computational technique, which incorporates an effective transmitting boundary into the finite element method, has been developed (Refs.19,20,21) and applied to estimating effects of complicated site conditions on ground motion for input SH, P, SV waves of different incident angles and the Rayleigh wave (Refs.21,29,30) .

(4) Microzoning Maps of Design Ground Motion The peak ground acceleration A and velocity V are suggested as the microzoning indexes. The suggestion is based on an empirical model for scaling the design SA(T) in terms of A and V (Ref.22), which will be briefly introduced

in the next section. The final results of design earthquake microzonation are several pairs of microzoning maps for different design probability levels. Each pair includes a map showing design A and the othar showing design V in terms of isolines or subzoning.(Ref, 23).

3. An Empirical Model For Scaling Design SA(T)

The suggested empirical model for scaling design SA(T) in terms of site-specified peak ground acceleration A_i and velocity V_i is given by

$$SA(T) = A_i \beta(T) \tag{1}$$

$$\beta(T) = 1 + b_1(A_i/V_i)\,T \qquad 0 \leqslant T \leqslant T_1$$

$$= b_2 \qquad T_1 \leqslant T \leqslant T_2 \tag{2}$$

$$= b_3(V_i/A_i)\,T^{-r} \qquad T_2 \leqslant T \leqslant T_3$$

where

$$T_1 = [(b_2-1)/b_1]\,(V_i/A_i), \qquad T_2 = \left[(b_3/b_2)(V_i/A_i)\right]^{1/r} \tag{3}$$

The empirical constants of b_1, b_2, b_3 and r, are determined by a minimization of deviation Q, which is defined by

$$Q = \left[\frac{1}{m}\sum_{i=1}^{m}\frac{1}{T_3}\int_0^{T_3}\left[\frac{\beta(T)-\beta_i(T)}{C(T)}\right]^2 dT\right]^{1/r} \tag{4}$$

where m is the total number of recorded accelerograms adopted, $\beta(T)$ is given by Eq.(2), $\beta_i(T)$ is the normalized response spectrum of the i-th recorded accelerogram. Q may be expressed by absolute deviation for C(T)=1 or by relative deviation for $C(T)=\beta(T)$. 216 recorded accelerograms adopted for specifying horizontal design SA(T) in the new proposed code (Ref.5) are used for statistical estimation of the empirical constants of Eq.(2). The resulrs are as follows

$$b = 1, \qquad b = 2.25, \qquad b = 10, \qquad r = 1 \tag{5}$$

The empirical formula of Eq.(2) seems merely a slight modification of the one proposed by Newmark and Hall (Ref.31) for the design period range of T_3=3 sec., the difference is that the corner periods of T_1 and T_2 here are no longer fixed for determining the empirical constants, instead, variances of T_1 and T_2 from one record to another is considered in the minimization of Q. This leads to the deviation Q of the model presented in the paper being considerably smaller than that of the conventional ones, which have been adopted in Chinese design codes (Ref.22).

CONCLUDING REMARKS

Microzonation, as a detailed seismic hazard assessement for urban areas, is a practical and important task faced by earthquake engineers. It is also a complicated problem involving disciplines of geological, geophysical and engineering sciences. Although great effort has been made in the field it still remains at a young stage with a lot of uncertainties. In order to make microzonation more effective in mitigating earthquake disaster in urban areas, studies on fundamental problems in engineering seismology, such as seismicity model, prediction of near field strong ground motion, local site effects, must be strengthened as discussed in Ref.1. However, to meet the present need and to improve methodology of microzonation as a whole, I think, stress should be put on the integrate method balancing various aspects of microzonation through comprehensive comparison studies. The comparison includes,

(1) Comparing various microzoning methods and their various steps in respective analyses

at same urban areas properly chosen;
(2) Comparing results of damage prediction based on various microzonation methods with actual damage distribution for some destructive earthquakes properly selected;
(3) Comparing results of ground motion microzonation with recorded strong ground motion within an urban area (Say, Los Angeles, Ca., USA) where comparatively abundant strong motion data are available.

An example for the second type of comparison study is a China-Japan joint project organized by Shima, E (Japan) and Liao, Z. P. and Yuan, Y. F.(China) for studing the damage distribution of Tangshan earthquake of 1976, which is an on-going project started last year. A project for the other two types of comparison studies were proposed by M. D. Trifunac (USA) and Liao, Z. P.(China) last year, it is now in preparation. We believe that more colleagues from more countries involve in the above comparison studies would be more favorable to lead to a more balanced methodology for the near future microzonation.

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Table 1. Site Soil Classification Specified in the 1964′s Code Draft

Class of Sites	Descriptive Scales
I	Stable rock;
II	Ordinary soil, such as gravel,sand and compact clay;
III	Mellow soil, such as loosening sand, mellow clay, moist loess;
IV	Very soft soil, such as very soft clay, Thick loosening fill

Table 2. Deposit d(m) and Average Shear Velocity Vs(m/sec.) in Site Classification for the Proposed New Code.

Site soil	Vs \ d \ Sites Class	I	II	III	IV
Hard	> 500	--0	--	--	--
Moderate Hard	500--270	0--8	>8	--	--
Moderate Soft	270--140	0--2	2--6	>60	--
Soft & Weak	≤140	0--2	2--8	8--60	>60