INTRODUCTION OF SEISMIC ZONING MAP OF CHINA (1999)

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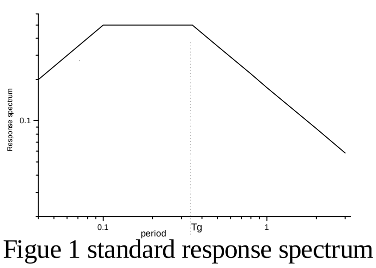
SUMMARY

The seismic zoning map of China (1999) is a new generation of the hazard map of the country. The project was start in 1996. Hundred scientists were involved in this project. The new data and results achieved in about ten years enrich the database of the seismic zoning. The parameters of standard response spectrum of acceleration, A and T_g, were used as the zoning parameters. The probabilistic approach was adopted in this project. The seismicity parameters such as annual occurrence rates and b value are determined in a large region called seismic provinces. The annual occurrence rates of the potential source are evaluated from relative spatial distribution of the earthquakes with different magnitude. The logic tree is used to treat the uncertainty in the delineation of the potential. Three groups of scientists with different background provided their own potential sources of the country. The attenuation of the parameters was regressed from the data of the western United States. The curves were modified through the comparison of the attenuation of intensity in both countries. The country was zoned by A and T_g. There are frequent interaction with the users and local people. We emphasis the engineering application of the zoning map.

INTRODUCTION

The fundamental objective of the new generation of seismic hazard zoning map is to provide a design base for ordinary civil structures. The new map will be made on the more scientific foundation and easy to be used in engineering design. The new zoning map try to collect the new results and new data obtained in the last decade. In order to reflect the temporal and spatial imhomogeneity of the seismicity in the assessment of seismic hazard, the new tectonic model and seismicity model were adopted. The local seismologists and geologists were involved in this project. The ideas and new results from the local people were reflected in the results. The attenuation of ground motion is the crucial input. Due to the lack of the records of strong ground motion, we use the data from the western United States and modify it by the comparison of intensity attenuation of the two countries. We use two parameters to character the standard response spectrum for design (Department of Construction and Environmental Reservation, 1989): A and T_g. A is the mean value of the platform of the spectrum divided by 2.5, which comparable with the peak acceleration in the mean of statistics, and the corner period where the spectrum begins to decrease. The probabilistic approach was adopted in the seismic hazard assessment (A. Cornell, 1968). The logic tree method was used to treat the uncertainties in the seismicity model.



Figue 1 standard response spectrum

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Study on engineering application was emphasised in this project. Engineers from different filed including the code drafter were invited in the discussion.

The new data and results of seismicity and tectonics are carefully studied. The database include:

1. Catalogue of disaster earthquakes (780BC-1996) in china and adjacent region, Epicentre map for this catalogue (scale: 1:2,500,000)

2. Catalogue of instrumental earthquakes (1970-1996) in china and adjacent region, Epicentre map for this catalogue (scale: 1:2,500,000)

3. Map of Quaternary active basins (scale: 1:2,500,000)

4. Synthetic intensity seism (scale: 1:4,000,000)

5. Map of seismo-tectonics of China (scale: 1:2,500,000)

6. Neo-tectonic map of China (scale: 1:2,500,000)

7. Active tectonics from satellite image of China (scale: 1:4,000,000)

8. Map of tectonic stress field of China (scale: 1:4,000,000)

9. Continental crust deformation map of China (scale: 1:4,000,000)

10. Map of the high conductivity layer in upper-mantle of the China Continental (scale: 1:6,000,000)

11. Map of the high conductivity layer in crust of the China Continental (scale: 1:6,000,000)

12. Map of distribution of Moho depth in the China Continental (scale: 1:6,000,000)

13. Map of the gravity anomaly in the China Continental (scale: 1:6,000,000)

These maps are the results of this project.

SEISMICITY AND POTENTIAL SOURCES

The Poison type model was used in the project but some modification was made. The country is divided into different regions with uniform seismicity (the same annual occurrence rate and b value). Such kinds of regions are called seismic provinces. The seismic potential sources are delineated in every seismic province. Then annual rates for potential l sources with magnitude *mj* can be written as:

$$\nu_{l,m_j} = \frac{2\nu_4 \exp(-\beta(m_j - m_0) sh(\tfrac{1}{2}\beta\Delta m)}{1-\exp(-\beta(m_{uz} - m_0)} f_{l,m_j} \qquad (1)$$

Where ν_4 is the annual rate of the seismic province, f_{l,m_j} is the spatial distribution function (Gao, 1993), $\beta = b\ln 10$, m0 and M_{uz} are the minimum and maximum magnitude of the seismic province. Both historical catalogue and instrumental recorded catalogue are emphasised in the evaluation of b and ν_4. We also pay attention to the completeness and uncertainty of the data.

The delineation of potential sources is most important in this project. There is large uncertainty in the delineation of potential sources. We use logic tree method to due with the problem. Geologists and seismologists were organised into three groups. Group A includes scientists who are familiar with the tectonics in the institutes. These scientists mainly carry on studies on active faults in China in recent years. Group B includes Geologists who are familiar with tectonics and seismology. Group the scientists mainly from local seismological bureau form C. Then we get potential source distribution of the whole country from three sources. We also choice potential sources for the current used zoning map (1990) as an optional choice.

Seismicity pattern repeat and tectonics analogy is taken as the principle. The followings were considered when used the tectonics analogy:

1. The analogy is only correct is the same province;

2. Only consider the similarity of neo-tectonics, active tectonic structure and stress field.

The following are indexes for the delineation of potential sources:

1. Where damage earthquake occurred in history;

2. Density distribution of small and moderate earthquakes;

3. Cross-section of neo-tectonics and other tectonic trends;

4. Rupture zone of Paleoearthquake;

5. Active tectonic structure;

6. Quaternary faults before late Pleistocene with moderate seismicity;

7. High activity rate segment of the active faults. Maximum magnitude can be evaluated from the rates.

8. Special section of the active faults. These sections are indexes of the potential sources with great earthquake.

GIS were used in the delineation of the seismic potential sources. It is very convenient to compare the results with the basic data. The accuracy of the location enables us to determine the boundary of the potential sources more reasonable.

There are about 900 potential sources in every delineation approach. The shape of the potential sources is different in eastern china and western China. The neo-tectonic movement is very strong in western China. There are many results about these faults. The main faults are limited in narrow zones and activity is very high. In this region, the potential source is easy to recognise and the potential sources are in narrow shape. Whereas in the eastern part of the country, active faults are not very clear in surface. Only a few active faults are well investigated. The return period of the large earthquake in eastern part is very long. There is large uncertainty in the delineation of potential sources.

ATTENUATION OF GROUND MOTION

The trend of the seismic zoning is to provide parameters of design response spectrum directly. In the National Seismic-Hazard Maps of United States (A. Frankel, 1996), the response spectrum of acceleration with period 0.2s and 1.0s are provided as design base. It is actually the standard response spectrum. Our goal of this project is also to provide such standard response spectrum of acceleration. It is crucial to provide the related attenuation law of the parameters. The attenuation law can be made from the strong ground motion record. Unfortunately, there is rare database of such records as in many countries. We have to use records from other country where strong ground motion data are abundant. Then we modify the attenuation curve by the comparison of character of attenuation of intensity in both countries. The records in western United State are used in our analysis. The soil condition of the site is rock.

We use two parameters A and T_g to character the zoning map. These two parameters are from response spectrum of the strong ground motion records. Firstly, we calculate the acceleration response spectrum and get the value of the platform of the spectrum S_a. Secondly, we calculate the peso- velocity response spectrum and get the value of the platform of the spectrum S_v. Then the two parameters of zoning can be written as:

$$A = \frac{Sa}{2.5} \tag{2}$$

$$V = \frac{Sv}{2.5} \tag{3}$$

$$T_g = 2\pi \frac{V}{A} \tag{4}$$

We can get A and V from every record, then we regress the attenuation relationship for A and V for the western United States. We translate attenuation to China by the comparison of intensity attenuation of both countries. There are differences for the attenuation of intensity for western China and eastern China. The attenuation type we Choice is:

$$\ln Y = c_1 + c_2 m - c_3 \ln(r + c_4 e^{c_5 m}) \tag{5}$$

Where *Y* is *A* or *V*. σ is the standard deviation.

We provide attenuation relationships of *A* and *V* for the two regions:

Table 1. Attenuation relationships of *A* in China

	c_1	c_2	c_3	c_4	c_5	σ
Western China	5.304005	1.719594	2.59029	2.789	0.451	0.546
	2.726514	1.346759	1.76361	1.046	0.451	0.546
Eastern China	5.912025	1.836588	2.84658	3.400	0.451	0.546
	2.509012	1.360759	1.79151	1.046	0.451	0.546

Table 2. Attenuation relationships of *V* in China

	c_1	c_2	c_3	c_4	c_5	σ
Western China	0.02894	1.82582	2.21231	2.789	0.451	0.753
	-2.17246	1.50735	1.50616	1.046	0.451	0.753
Eastern China	0.47621	1.90802	2.40817	3.269	0.451	0.753
	-2.30650	1.52113	1.55031	1.046	0.451	0.753

ZONING RESULTS AND ENGINEERING APPLICATION

The whole country was divided into 40,000 grids with 0.2×0.2 in longitude and latitude direction. Seismic hazard assessment for every grid for A and V in rock site with probability of exceedance 10% in 50 years was calculated. The logic tree was used to treat the uncertainty. According to relation of ground motion of rock site and soil type B (Department of Construction and Environmental Reservation, 1989), the results of grid value for site type B were determined. The zoning of soil type is the soil type B.

The zoning parameters *A* and T_g of every grid then can be evaluated. According to these values, two zoning maps were made.

1. Zoning map of *A*

The country is divided into different zones with *A* value.

Zone 0: *A*<=0.05g

Zone 1: *A*=0.05g

Zone 2: *A*=0.10g

Zone 3: *A*=0.15g

Zone 4: *A*=0.20g

Zone 5: *A*=0.30g

Zone 6: *A*=0.40g

2. Zoning map of T_g

The country is divided into different zones with A value.

Zone 1: T_g =0.30s

Zone 2: T_g =0.35s

Zone 3: T_g =0.40s

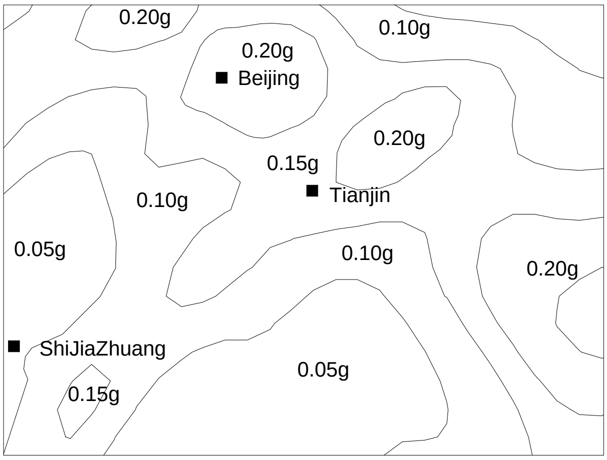

Figure 2. Illustration of zoning map of A near Capital Region

The zoning values are coincident to the revise of the currently used building code (Department of Construction and environmental Reservation, 1989) .

The zoning map of *A* together with the zoning map of T_g is called “Seismic Zoning Map of China (1999)”. There are series discussions with the users and the local people. The zoning map was slightly change within the uncertainty. This map will replace the currently used zoning map with intensity as the zoning parameter. Compared with the current used map, there are some advantages in the new zoning map then the currently used version:

The standard response spectrum was provided directly. In the intensity map, the response spectrum was made by the code from intensity value. This is unreasonable.

The database for the compilation of the new map is more abundant than that of the previous map. In the eastern China, the instrumental data is more than doubled. There are more investigations on active faults in western China and some regions in eastern China.

Spatial smoothing method (A. Frankel, 1995; Xu, G., 1998) for weak and moderate seismicity region and characteristic earthquake model are tried in some main active faults with clear trace of Paleo-earthquakes (Dong R., Ran, H., Ren G., 1998). They provided a background of analysis of the results.

The seismic hazard assessment for nuclear plants, long span bridges, oil pipelines, and high dams provide more detailed study results on active faults.

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