Microzonation of ground motion parameters in Xianyang City

Baolai Li¹, Hanliang Zhang¹, Fengwen Ren¹ and Chunfeng Li*¹
¹Shaanxi Earthquake Agency, Xi’an, Province, 710086, China
*Corresponding author’s e-mail: lichunfeng@sxdzj.com.cn

Abstract. In this paper, based on the study about the geology, seismology and conditions of site of seismic microzonation in Xianyang City, the microzonation of ground motion parameters in Xianyang City was finished, which can contribute to the aseismic fortification of the structure of in Xianyang.

1. Introduction
The accuracy of microzonation of ground motion parameters is higher (scale of microzonation of ground motion parameters in Xianyang City is 1:25000), the local site effect is considered, the level of seismic fortification is more (63%, 10%, and 2% probabilities of exceedance in 50 years). In the 1980s, Xianyang city carried out seismic microzonation, but the seismic fortification level and the scope of the target area have changed a lot. In order to adapt to the development of the city and the current seismic fortification requirements, this work adopted the results of the latest ground motion zonation of China [1]. On this basis, the seismology of the target area is thoroughly studied, so as to lay the base for the division of seismic region and seismic belt, and potential source area.

2. Seismic geological environment
The seismic microzonation of Xianyang city mainly involves Ordos platform margin fold belt in the north, Weihe Fault Depression in the middle and Qinling fold belt in the south. The platform margin fold belt in the northern margin of the Yangtze platform and the Bayankala fold belt in the Songpan Ganzi fold system have little influence on the site. There are many geomorphic types in the work area. There are 34 regional main active faults (Figure 2). In the regional, moderate strong seismicity is mainly distributed in Weihe Basin and its vicinity. Within this range, there were 36 earthquakes of magnitude 5 or above, including 6 earthquakes of magnitude 6, 2 earthquakes of magnitude 7 and 1 earthquake of magnitude 8. This area is the most seismically active area in the region (Figure 1).

3. Seismic risk analysis
Based on seismic ground motion zonation of China [1], through the research on the seismology and geology in the target area, seismic region and seismic belt, and potential source area were determined. And the seismic activity parameters of the belt and potential source area are acquired. After determining appropriate attenuation relationship, the seismic risk probability analysis is used to give the parameters of bedrock ground motion under probabilities of exceedance in the site, which provides basic data for seismic response analysis and site seismic parameter determination of the soil layer.

As shown in Figure 2, the region is located at the intersection of Qinghai Tibet earthquake region, North China earthquake region and South China seismic region. The seismic belts in the region and adjacent include Fenwei seismic belt, Ordos seismic belt, belt of middle reaches of Yangtze River, seismic belt of Liupanshan Qilian Mountain, Longmenshan seismic belt and North China Plain.
seismic belt. In 1556 BC, the magnitude 8¼ earthquake in Huaxian is about 100km away from the site.

The analysis adopted the CP SHA method [2]. The seismic risk analysis and calculation are carried out according to the grid points of 0.01°×0.01° within the scope, and the distribution map of bedrock acceleration peak value with 50 year probability of exceedance of 63%, 10% and 2% for each calculation point is obtained (Figure 3). According to the results, the absolute value of the difference in the spatial distribution of the horizontal peak accelerations of the bedrock with a 50 year probability of exceedance of 2% are larger than those of 63% and 10%. Taking the 50 year probability of exceedance of 2% as an example, we divided the peak accelerations into three different areas (such as area a), and elected a bedrock input control point in each area (underlined number in Figure 3).

4. Survey of conditions of the site
Site seismic engineering geological condition investigation is the basis of site seismic response analysis. The purpose and work content of this paper are to probe the thickness of Quaternary loose overburden, the structure of soil layer and its change with depth, and to test the conventional soil mechanics parameters of soil. The seismic engineering geological conditions the site were investigated in accordance with the national standard of the people's Republic of China, Code for investigation of geotechnical engineering (GB 50021-2001)[3]. According to the requirements of Seismic Ground Motion Parameters Zonation Map of China (GB 18306-2015) [4], the drilling holes were arranged on the basis of the preliminary division of engineering geological units. The principle of drilling hole arrangement is:1 km×1 km grid, at least two control holes are arranged in the area of engineering geological unit below 10 km², no less than 4 control holes were arranged in the area of
10~30 km², and when the area is more than 30 km², there are no less than 6 control holes on the surface, and the rest are general holes. The control hole depth is 90m (the drilling depth has to reach the shear wave velocity not less than 500m/s), and the general hole depth is 30~60m. If there were collecting boreholes on or near the 1km×1km grid point, the boreholes on the grid point may not be constructed. On the basis of the collected engineering geological data, 122 boreholes were laid out in a 1km×1km grid pattern according to the site, and shear wave velocity test and dynamic triaxial experiment of typical soil type were carried out on each borehole. According to the survey results, the subdivision of engineering geological units is carried out on the site. (Figure 4).

5. Seismic response of soil layer
Taking Area a as an example, we described the results of seismic response analysis of soil layer in the small site with a 50 year exceedance probability of 2%. The figure below shows the acceleration response spectrum curve of horizontal ground motion peak at the bedrock input control point with a 50 year exceedance probability of 63%, 10% and 2%.

Firstly, the acceleration response spectrum and peak acceleration of bedrock at the control point of Area a are taken as the target, and the time history of ground motion is synthesized by numerical simulation method, which is used as the input value of ground motion for the analysis of soil layer seismic response. In order to consider the influence of phase randomness, the time history samples with different random phases were synthesized for 10% probability level. The interval of synthesized time history is 0.02 seconds, and the number of discrete values is not less than 2048. 75 control points
were selected from the target response spectrum in 0.04-6 seconds to ensure the accuracy of fitting the target response spectrum in synthetic ground motion. In the process of synthesis, the method of approaching target spectrum step by step is used to make the synthesized acceleration time history accurately meet the target peak acceleration and approximately meet the target acceleration response spectrum. The relative error of fitting target acceleration response spectrum is less than 5%. Figure 6 are three groups of time history samples of bedrock ground motion exceedance probabilities of 63%, 10% and 2% in 50 years at control points in block a of the project site.

![Figure 6 The ground motion time history of bedrock in the case of 63%, 10%, and 2% probability of exceedance in 50 years](image)

![Figure 7 The fitting of ground motion of the site bedrock to the target spectrum (50 year exceedance probability)](image)

122 engineering geological drilling holes were provided in the seismic condition investigation of the site. There are 61 additional boreholes collected. All the holes have obtained the layer thickness and shear wave velocity of soil. 207 typical soil samples in the borehole were tested by dynamic triaxial test (and the density and other parameters of the typical undisturbed soil samples were obtained). After the finite element model of each borehole was established to be calculated, the seismic response analysis of soil layer of each borehole can be carried out. According to the requirements of the national standard of the people's Republic of China Evaluation of seismic safety for engineering sites (GB17741-2005) [3], for the 50 year exceedance probability of 10%, the seismic dynamic response analysis of each borehole was carried out by using the time history of ground motion at each control point as input, and the ground motion parameters of each borehole surface are obtained. As shown in Figure 5, the seismic response analysis of the borehole within the area was conducted with the seismic time history of Figure 6 respectively.

6. Determination of ground motion parameters in the site
Based on the results of the seismic response analysis of the soil layer, the ground motion parameters of
the project site are determined (Table 1). A$_{\text{max}}$ is the peak ground motion acceleration, $\beta$ (T) is the response spectrum of ground motion acceleration amplification coefficient, and $\alpha_{\text{max}}$ is the maximum value of earthquake influence coefficient. The parameters should be used according to the national standard of the people's Republic of China code for Code for seismic design of buildings (GB 50011-2010, 2016) (GB17741-2005) [5].

According to the calculation results of horizontal ground motion acceleration response spectrum (5% damping ratio) of 10% of the 50 year exceedance probability of the surface of the engineering site, the fitting curve of horizontal ground motion acceleration response spectrum of the surface at each borehole is obtained (Figure 7). According to the fitting curve of ground motion peak acceleration and response spectrum, and the division results of engineering geological units, the results of microzonation of ground motion in Xianyang city are obtained. Area A is a bedrock site, and its design ground motion parameters are directly given according to the calculation results of seismic risk analysis.

![Ground acceleration response spectrum and site ground motion response spectrum in horizontal direction in Areas A, B and C (10% exceedance probability in 50 years)](image)

The site of Xianyang microzonation of ground motion was divided into three site parameters Areas A, Area B and Area C (Figure 9). The parameter values of the peak ground acceleration and acceleration response spectrum (5% damping ratio) of the three sites with 50 year exceedance probability of 63%, 10% and 2% are shown in Table 1. Formulas 1, 2, 3 and table 1 constitute the results of microzonation of ground motion parameters in Xianyang city. $T_1$ in Table 1 is the inflection point period of the design seismic response spectrum, and $T_g$ is the characteristic period.

![Division of design ground motion parameters in Xianyang city](image)

### Table 1 Parameter values of the ground surface horizontal ground motion peak acceleration and response spectrum (5% damping ratio) of the project site

| Partition | probability of Exceedance | $T_1$ (s) | $T_g$ (s) | $\beta_m$ | $\gamma$ | $A_{\text{max}}$ (gal) | $\alpha_{\text{max}}$ (g) |
|-----------|---------------------------|----------|----------|-----------|---------|---------------------|---------------------|
| Area A    | 50 years 63%              | 0.10     | 0.50     | 2.5       | 0.9     | 70                  | 0.175               |
|           | 50 years 10%              | 0.10     | 0.55     | 2.5       | 0.9     | 210                 | 0.525               |
|           | 50 years 2%               | 0.10     | 0.80     | 2.5       | 0.9     | 375                 | 0.938               |
| Area B    | 50 years 63%              | 0.10     | 0.45     | 2.5       | 0.9     | 80                  | 0.200               |
|           | 50 years 10%              | 0.10     | 0.50     | 2.5       | 0.9     | 235                 | 0.588               |
|           | 50 years 2%               | 0.10     | 0.75     | 2.5       | 0.9     | 415                 | 1.038               |
| Area C    | 50 years 63%              | 0.10     | 0.40     | 2.5       | 0.9     | 80                  | 0.200               |
|                | 50 years 10% |         | 2.5 | 0.9 | 235 | 0.588 |
|----------------|--------------|---------|-----|-----|-----|-------|
| 50 years 2%    | 0.10         | 0.45    | 2.5 | 0.9 | 415 | 1.038 |

7. Conclusion

Based on the study of the geological environment, seismic environment and soil dynamic conditions of site of microzonation of ground motion in Xianyang city, the seismic response of the site was analyzed, and the microzonation of ground motion of the site is carried out, which can provide the basis for the seismic fortification of the general structure of Xianyang microzonation site. Due to the use of the latest research results, the content of this study is substantial and reliable. With the development of economy, the expansion of city scale and the constant updating of basic research data, microzonation in the city is suitable to be carried out again in the future to meet the new requirements of seismic fortification.

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