Subdivision of Ground Motion Parameters in Ankang City

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Abstract. On the basis of studying the geological environment, seismic environment and geodynamic conditions of the site of Ankang Seismic Zoning Project, this paper divides the seismic statistical area and potential seismic source area, determines the seismicity parameters of the seismic statistical area and potential seismic source area, determines the attenuation relationship of the ground motion of the bedrock in the study area, calculates the seismic risk analysis, and calculates the bedrock. The calculation model of site seismic response analysis is established, the site seismic response analysis is carried out, and the design earthquake ground motion zoning of the site is carried out, which provides a basis for the seismic fortification of the general structure of the site in Ankang seismic zoning.

1. Introduction
National seismic parameter zoning is to divide the land into different seismic parameters zoning (exceeding probability of 10% in 50 years), which is used for seismic fortification of general structures. Compared with the national seismic parameter zoning (scale 1:4 million), the accuracy of seismic parameter zoning is higher (the scale of Ankang seismic parameter zoning is 1:25,000). Considering the local site effect, the design level is more (63%, 10%, 2% in 50 years), which can better meet the needs of seismic fortification of general structures. Historically, Ankang City has never carried out seismic microzoning. This work adopts the latest results of “China's Seismic Ground Motion Parameters Zoning Map” (GB 18306-2015, 2015). On this basis, the seismic geological environment of the zoning site is further studied, thus laying a foundation for the division of seismic statistical areas and potential seismic source areas. The flow chart of this work is shown in Figure 1.
2. Seismological environment
The regional scope of Ankang seismic zoning mainly covers the southern margin of Ordos platform margin fold belt and Weihe fault depression belt in the north, the Qinling fold belt in the middle, and the northern margin of Sichuan platform Syncline in the south. From north to south, there are many geomorphic types, such as Weihe Basin, Qinling Mountains, Dabashan Mountains, Hanzhong Basin and Sichuan Basin. There are 34 main active faults in the region, such as Yuehe fault (Figure 2). The Yuehe fault in the Late Pleistocene (Lin Zhuo, 2018) was investigated in detail in this work. Seventy-seven destructive earthquakes occurred in the region, mainly in the Weihe Basin (Figure 2).
3. Seismic risk analysis
On the basis of the National Standard of the People's Republic of China (GB18306-2015), and on the basis of the study of the seismic geological environment of the site, the seismic statistical area and the potential seismic source area are divided, and the seismicity parameters of the seismic statistical area and the potential seismic source area are obtained. After determining the attenuation relationship of bedrock ground motions suitable for this area and engineering characteristics, the parameters of bedrock ground motions at different transcendental probability levels within the scope of the engineering site are given through the probability analysis of seismic risk, which provides basic data for the analysis of soil seismic response and the determination of design ground motion parameters.

As shown in Figure 3, there are mainly four seismic statistical areas and 30 potential source areas in the region. The zoning site is located in the Ankang potential earthquake source area of the seismic statistical zoning in the middle reaches of the Yangtze River. The upper limit of magnitude in the potential source area of Ankang is 6.5. The potential focal area is mainly affected by near-field moderate-strong earthquakes. The magnitude 6 earthquake in 788 B.C. northwest Fangxian County, Hubei Province, and the magnitude 5 earthquake in Ankang, Shaanxi Province, on September 28, 1559, within the site of the subdivision, all have a magnitude 6 impact on the site of the subdivision.

The CPSHA method was used in the probability analysis of seismic risk in this subdivision (Panhu et al., 2013). In the range of 0.01°x0.01° grid points are used for seismic hazard analysis and calculation. The 50-year exceedance probability of each point is 63%, 10% and 2% of the peak acceleration distribution maps of bedrock (Figure 4). According to the calculation results, the peak acceleration of bedrock is divided into two different zones (e.g. Area a1). Each zone is selected as the input control point of bedrock (the underlined figure in Figure 4).

![Figure 3. Division of Seismic Statistical Area and Potential Source Area.](image-url)
4. Survey of Seismic Engineering Geological Conditions in Small Zoning Sites

Seismic Engineering Geological Conditions Survey of Small Zoning Site is the basis of site seismic response analysis. Its purpose and content are to detect the thickness of Quaternary loose overburden, the structure of soil layer and its variation with depth, and to test the conventional soil mechanics parameters of soil. According to the requirements of the National Standard of the People's Republic of China "Seismic Safety Assessment of Engineering Sites" (GB17741-2005, 2015), 102 boreholes were laid out in a grid shape of 1 km *1 km according to the plotted site, and shear wave velocity tests were carried out for each borehole and dynamic triaxial tests of typical soils were carried out. According to the survey results, the engineering geological units of the plotted site are divided (Figure 6).
5. Seismic Response of Soil Layer in Small Zoning Site

This part takes the case of exceeding probability 10% in 50 years as an example to describe the results of seismic response analysis of soil layers in plotted sites. Firstly, the response spectrum and peak acceleration of bedrock acceleration at the control points of Area a2 and Area b2 are taken as the target, and the time history of ground motion is synthesized by numerical simulation method. As the input value of ground motion for the analysis of ground motion response, the ground motion response is analyzed. In order to consider the influence of phase randomness, the seismic time history samples with different random phases are synthesized at 10% probability level. The synthesized time intervals are 0.02 seconds, and the number of discrete values is not less than 2048. Seventy-five control points are selected from the target response spectrum within 0.04-6 seconds to ensure the accuracy of fitting the target response spectrum in synthetic ground motion. In the synthesis process, the method of approaching the target spectrum step by step is used to make the synthesized acceleration time history meet the target peak acceleration accurately and approximate the target acceleration response spectrum. The relative error of fitting target acceleration response spectrum is less than 5%. Sequence 7a and 7b are seismic time history samples of bedrock ground motions at control points of Area a2 and Area b2 of small zoning engineering sites with 50-year exceedance probability of 10%.
102 engineering geological boreholes were provided in this site engineering seismic condition investigation. There were also 24 collecting boreholes. All boreholes obtained the soil layer thickness and shear wave velocity. Dynamic triaxial tests were carried out on 184 typical soil samples in boreholes (and the density and other parameters of typical undisturbed soil samples were obtained at the same time). After establishing the finite element model of each drilling site, the seismic response of soil layer can be analyzed. In accordance with the requirements of the national standard of the People's Republic of China "Seismic Safety Assessment of Engineering Sites" (GB17741-2005), the seismic time history of the control points of Area a2 and Area b2 is used as input to analyze the seismic response of the soil layer in each borehole in 50 years when the probability exceeds 10%. The ground motion parameters of each borehole are obtained. As shown in Figure 6, the seismic time histories of Figure 7a and Figure 7b are used as input for drilling holes in Area a2 A and Area b2, respectively.

6. Determination of Design Earthquake motion

On the basis of the calculated results of the seismic response analysis of the site soil layer, the design seismic parameters of the engineering site are determined. The seismic acceleration response spectra of engineering site design are as follows:

\[ S_a(T) = A_{\text{max}} \beta(T) \]  
\[ \alpha_{\text{max}} = A_{\text{max}} \beta_{\alpha} / 1000 \]  

Among them, \( A_{\text{max}} \) is the peak acceleration of ground motion, \( \beta(T) \) is the response spectrum of the amplification factor of ground motion acceleration, and \( \alpha_{\text{max}} \) is the maximum of the earthquake impact factor. According to the National Standard of the People's Republic of China, "Code for Seismic Design of Buildings" (GB50011-2010, 2016 edition), there are:

\[ \alpha(T) = \begin{cases} 
\alpha_{ss} + \frac{\alpha_{\text{max}} - \alpha_{ss}}{0.1} T, & 0 \leq T < 0.1 \\
\alpha_{ss}, & 0.1 \leq T < T_g \\
\frac{T_g}{T}, & T_g \leq T < 5T_g \\
0.2^{\frac{T_g - 0.02(T - 5T_g)\Delta T_{\text{max}}}{T_g}}, & 5T_g \leq T \leq 6.0(s)
\end{cases} \]  

According to the calculation results of horizontal ground motion acceleration response spectrum (5% damping ratio) calculated by 10% of the 50-year surpassing probability of the surface of the engineering site, the fitting curves of surface water horizontal ground motion acceleration response spectrum at each borehole are obtained (Figure 8). According to the fitting curve of peak acceleration and response spectrum of ground motion and the result of division of engineering geological units, the...
result of subdivision of ground motion parameters in Ankang City is obtained. Area a is a bedrock site, and its design ground motion parameters are given directly according to the calculation results of seismic hazard analysis.

Ankang Seismic Zoning Site is divided into five design earthquake ground motion zones A, B, C, D and E (Figure 8). The parameters of the peak acceleration and acceleration response spectra (5% damping ratio) of the five design earthquake ground motion zones with a 50-year exceedance probability of 10% are shown in Table 1.

Formulas 1, 2, 3 and 1 constitute the results of the zoning of calculated ground motion parameters for Ankang seismic zoning. The T1 in Table 1 is the inflection period of the design seismic response spectrum and the Tg is the characteristic period.

![Figure 8. Acceleration response spectra of horizontal ground motion and design ground motion in area D (exceeding probability 10% in 50 years).](image)

![Figure 9. A Brief Map of Seismic District Division in Ankang City.](image)
Table 1. Parameters of peak acceleration and response spectrum (5% damping ratio) of surface water horizontal design ground motion in engineering site.

| Partition | Transcendental probability value | $T_1$ (s) | $T_g$ (s) | $\beta_m$ | $\gamma$ | $A_{max}$ (cm/s$^2$) | $\alpha_{max}$ (g) |
|-----------|----------------------------------|----------|----------|----------|--------|-----------------|-------------|
| Area A    | 50 years 10%                     | 0.10     | 0.35     | 2.5      | 0.9    | 80              | 0.200       |
| Area B    | 50 years 10%                     | 0.10     | 0.40     | 2.5      | 0.9    | 100             | 0.250       |
| Area C    | 50 years 10%                     | 0.10     | 0.45     | 2.5      | 0.9    | 105             | 0.263       |
| Area D    | 50 years 10%                     | 0.10     | 0.45     | 2.5      | 0.9    | 105             | 0.263       |
| Area E    | 50 years 10%                     | 0.10     | 0.45     | 2.5      | 0.9    | 100             | 0.250       |

7. Conclusion
On the basis of studying the geological environment, seismic environment and geodynamic conditions of the site of Ankang Seismic Zoning Project, the seismic response of the site is analyzed, and the design seismic zoning of the site is carried out, which provides a basis for the seismic fortification of the general structure of the site of Ankang Seismic Zoning Project. Because of the latest research results, the content of this study is substantial and reliable. With the development of economy, the enlargement of city scale and the continuous updating of basic research data, it is suitable for Ankang seismic zoning in the future to meet the requirements of new seismic fortification.

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