

Ground motion parameters for building aseismic design of Nanjing city in China

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ABSTRACT: In this paper, within a radius of 320 KM and emphasis on 30 KM around centre of Nanjing city, seismological sitting, geophysical field character and seismicity are investigated to identify the potential seismic sources which are likely to affect the regional site of Nanjing city. The rock peak accelerations with 50 years exceedance probability 0.63, 0.10 and 0.03 is given using probability method of seismic hazard analysis in which seismicity in spatial nonuniform and time nonstationarity and attenuation relation with regional site character are considered. Considering geomorphic feature, geohydrological data, quaternary alluvium distribution and dynamic behaviour of soil layers in the regional site of Nanjing city, the seismic response of soil layers are obtained by wave motion analysis for 366 boring in the city site. Finally three probability level design ground motion parameters of seven subareas in Nanjing city are obtained for building aseismic design.

1 INTRODUCTION

The ground motion parameters for building aseismic design in the city is usually to adopt the value which are provided from seismic zoning map or aseismic design code. It is well known that it can be used as estimating seismic hazard on regional area, but it can not reflect the character of local site conditions such as foundation failure and the variable value of ground motion parameters around the city induced local geological conditions of the site. In order to increasing reliability with practical value and city building aseismic design, a improved the usual probability model has been proposed to determine the design ground motion parameters for building aseismic design based on seismic microzonation of city in which the seismicity parameters in spatial nonuniform and time nonstationary are important factors to affect the evaluation of seismic hazard to be considered in the seismic hazard analysis (Zhang Xue-Liang, Yan Xin-Yu, 1987). It comprises a series of steps. First, based on the analysis results of geological tectonics, historical earthquakes and seismicity within a radius of 320 KM from the central city are used to identify possible potential seismic sources and to determine its seismicity parameters which are likely to affect the city. The rock peak acceleration of ground motion of three probability level of 50 years exceeding probability

0.63, 0.1 and 0.03 have been obtained using probability method of seismic hazard analysis in which the attenuation relation with regional site character are also considered. Then a nonstationary random model is chosen to generate rock acceleration history curves which is as input at the base rock surface, the ground motion parameters of seismic response of soil layers can be obtained by shearing wave model using test data of dynamic behaviour of soil layers in the city area (Zhang Xue-Liang chief editor, 1987). Finally the design ground motion parameters of three probability level is given to use these average values of calculating results at surface of every boring for various parameters such as acceleration, velocity in the city area. The provided design ground motion parameters can be used for building aseismic design and also used for territorial programme, and drawing up programme of seismic resistance and precautionary earthquake damage. It is also convenience with microzonation for aseismic design of engineering structures and predicting earthquake damage of city etc. It will also be saved a lot of investment of engineering construction.

2 SEISMOLOGICAL SETTING

Nanjing city is situated in southwest part of Jiangsu Province of China. It has developed industry, commerce, traffic and dense

population city. Hence determination design ground motion parameters for city building aseismic design with reasonableness and reliability is very important project for economical aseismic design and city planning.

Considering a region with a radius of 320 KM around the centre of the city, the active fault and its age, correlation between basins structure and destructive earthquakes, active faults of near field etc. were found to denote that the region belongs to three first order, and six second order geological structure unit respectively. The major active reapture parts are given in WE or WNW and EN, EEN direction. There are four sets of major reapture in the EN, ENN, WN and WE direction within a radius of 30 KM from the centre of the city. The records of historical earthquakes can be traced back to 283. A.D. Since that time up to now, there have been three hundred records to narrate the earthquake damage of Nanjing city. Two among these earthquakes were occurred in vicinal Nanjing city on August 4,499 and on October 27, 548 with magnitude $M_S=4.75$, and $M_S=5.25$ and epicentral intensity 6 and 7 respectively, the building in Nanjing city are damaged during those earthquakes. The most strong earthquake occurred on July 25, 1668 at Tan-Lu with magnitude $M_S=8.5$ and affected the Nanjing city with 7 intensity. There have occurred 26 small earthquakes with magnitude $1.9 < M_S < 3$ from 1950 to 1988. The analytical results have shown that the character of seismicity within the region is strong seismicity to the north and in the sea, weak activity to the south and on the land. Most focal depths of the earthquakes were in range from 15 to 20 KM. As discussed above, it is shown that Nanjing city is located at the joint position of several sets of reapture in EN, NNE, WN and WE direction and it also had occurred destructive earthquake. Therefore, it has seismogeological setting of occurred destructive earthquake within regional site.

3 IDENTIFICATION OF POTENTIAL SEISMIC SOURCES

According to the geological tectonics marks of possible occurrence of earthquakes with magnitude $M_S=6$ and active faults, large deep reapture, seismicity given by the distribution of historical earthquakes and correlation between active faults and destructive earthquakes as well as the character of seismicity at fault basins, the potential seismic sources within the region can be identified by twenty-three idealized seismic sources as shown in

Fig 1 and the maximum magnitude of potential seismic sources can be also estimated as shown in table 1.

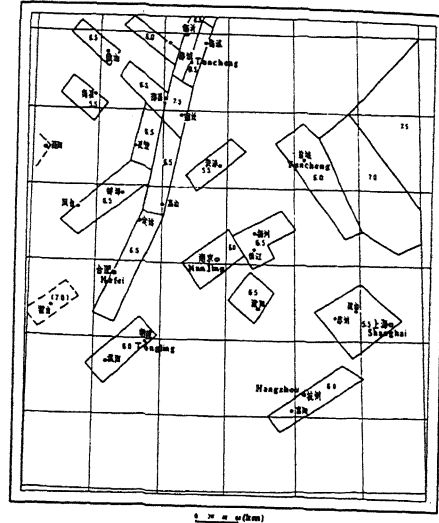


Fig. 1 Idealized potential seismic sources

Seismic sources Table 1

No.	M_S	No.	M_S	No.	M_S
1	6.5	9	6.0	17	6.0
2	8.5	10	6.5	18	7.0
					(7.5)
3	6.0	11	6.5	19	7.5
4	6.5	12	6.0	20	6.5
5	6.5	13	6.0	21	6.0
6	7.5	14	5.5	22	5.5
7	6.5	15	6.0	23	6.0
8	6.5	16	6.5		

4 SEISMIC HAZARD ANALYSIS

The seismicity is considered in spatial nonuniform and in time nonstationary which is simplified to dispose as uniform and stationary as following steps.

First, the degree of seismicity is changed with time in the statistical range of earthquakes and used the seismicity tendency within one hundred years to determine the b value, annual average occurrence rate and maximum magnitude M.

Second, according to probability density function of earthquake space for each potential seismic sources of magnitude grade, the annual average occurrence rate of each earthquake magnitude grade can be obtained

within each earthquake statistical area to be determined potential seismic sources and its maximum magnitude. Probability density function of earthquake space distribution of potential seismic sources of magnitude grade f_i, m_i , can be determined using synthesis identification method of many factors. These factors have with seismic pattern recognition, and structure gap, decreasing effect of large earthquake, background earthquake and small earthquakes activity, the area of seismic source and earthquake prediction etc. The magnitude grade is sum of 6 degree, i.e. <4, 4~5.5, 5.5~6, 6.5~7, 7~7.5, >7.5. The weight function of earthquake space distribution is denoted by $Q_i=f_i, m_j.S_i$ in each statistical area, which S_i is area of the i th seismic source. The statistical area and seismicity parameters are shown in table 2.

Seismicity Parameters of Statistical Region Table 2

Region	Parameters				
	M	M_0	b		
Yangtse River-South Yellow Sea Seismic Zone	7.5	4.0	0.62	1.43	0.73
Tan-Lu Seismic Zone	8.5	4.0	0.58	1.34	0.56

Third, contribution of seismic hazard analysis for every point of site can be obtained in each statistical area using segment poisson model. According to segment poisson distribution model and full probability theory, the probability of exceeding a specified intensity or peak acceleration level at the site can be expressed as follows:

$$P(Y>y) = 1 - \exp \left[- \frac{2v}{\beta} \sum_{i=1}^n \int \int \int_{j=1}^{j_m} P(Y>y|E_i) \cdot \text{sh}[(1/2)\beta \Delta_m] \cdot f(\theta) \cdot f_{i,m} dx dy d\theta \right] \quad (1)$$

in which, $P(Y>y|E_i)$ denotes the i th sources exceeding probability at the site when magnitude is $m_j + (\frac{1}{2})\Delta_m$, $f(\theta)$ denotes tendency probability of fault rupture direction. The probability of exceeding a specified value at the site can be expressed in statistical area as follows:

$$P = 1 - \prod_{n=1}^N (1 - P_n) \quad (n=1, 2, 3, \dots, N) \quad (2)$$

in which, P_n is exceeding probability at the site of the n th statistical area.

4.1 Attenuation relation

In order to increase reliability in seismic hazard analysis, both using the intensity and ground motion (Zhang Xue-Liang, 1986; Zhang Xue-Liang, Yan Xin-Yu, 1990) the intensity attenuation formula is obtained from 61 data of isoseismal contours of intensity 5 of historical earthquake in eastern China from 1961 to 1990 as follows:

Major axis

$$I_a = 5.526 + 1.266M - 1.626L_n(R+15) \quad \sigma_a = 0.456 \quad (3)$$

Minor axis

$$I_b = 4.942 + 1.245M - 1.595L_n(R+10) \quad \sigma_b = 0.534$$

using equal distance method and the ground motion data in western America, the attenuation formula is obtained as follows:

Major axis

$$I_{NA} = 6.592 + 0.6785M - 1.5979L_n(R+15) \quad S_a = 0.244 \quad (4)$$

Minor axis

$$I_{NB} = 6.0727 + 0.6672M - 1.5462L_n(R+10) \quad S_b = 0.286$$

4.2 Results of seismic hazard analysis

Using the formula (1), (2) and uncertain correction, for 0.1 exceeding probability the intensity value of 50 years can be obtained for Nanjing city which is 6.7 degree, and for five suburb of Nanjing which are 6.6, 6.7 and 6.8 degree respectively. 50 years 0.63, 0.1 and 0.03 exceeding probability of rock ground motion acceleration value for Nanjing city are 0.0306G, 0.0976G and 0.134G respectively. According to the calculation results, the intensity 7 is suggested as earthquake protection standard for Nanjing city and suburb.

4.3 Artificial rock ground motion

A nonstationary random model was chosen to generate acceleration history curves, which can be expressed as follows:

$$A(t) = \psi(t)X(t) = \psi(t) \sum_{n=1}^N A_n \cos(2\pi n t / T + \theta_n) \quad (5)$$

in which, $\psi(t)$ denotes shape function of ground motion, θ_n denotes starting phase angle, T denotes computed time of ground motion process. A_n denotes the correlation coefficient at $X(t)$ fourier transformation. According to major potential seismic sources with maximum magnitude and distance from the site, the shape function can be obtained as follows (Zhang Xue-Liang, 1987):

50 years 0.1 and 0.63 exceeding probability

$$\lambda_1=2, \lambda_2=0.5$$

$$t_1=2\text{sec}, t_2=10\text{sec}, t_e=16\text{sec}$$

50 years 0.03 exceeding probability

$$\lambda_1=2, \lambda_2=0.5$$

$$t_1=2\text{sec}, t_2=11\text{sec}, t_e=18\text{sec}$$

Using rock spectra in eastern China, the rock acceleration spectra with 50 years 0.63, 0.1 and 0.03 probability level can be obtained in the seismic hazard analysis as target spectra as shown in table 3. The target spectra with 0.05 damping ratio were adopted for the artificial ground motion. A artificial time histories of rock ground motion of 50 years 0.1, 0.63 and 0.03 exceeding probability level were generated using formula (5) to match target spectra.

Target spectra Table 3

Period T Sec	0.63 (50 years)	0.10	0.03
0.04	1	1	1
0.1	2.3	2.4	2.45
0.32(3.0)	(2.3)	2.4	2.45
3	0.46	0.48	0.49

5 DESIGN GROUND MOTION PARAMETERS

The seismic responses of soil layers can be obtained by shearing wave model using the data of dynamic behaviour of soil layers in the regional site. The design ground motion parameters (including peak acceleration, velocity, displacement, acceleration historical curves and spectra with 0.05 damping ratio) at the ground surface for every boring in the 366 boring of city site may be obtained from the average

values of calculating results of the seismic responses of soil layers.

The design ground motion parameters of seven subareas in Nanjing city are got to draw isoline through the calculating average values for boring in which the peak accelerations of 50 years exceedance probability 0.63 and 0.03 of seven subareas are 0.042G, 0.050G, 0.033G, 0.043G, 0.033G, 0.034G, 0.047G and 0.189G, 0.209G, 0.159G, 0.189G, 0.153G, 0.162G, 0.204G, corresponding design seismic spectra values are 2.30, 2.25, 2.32, 2.30, 2.32, 2.32, 2.26 and 2.38, 2.25, 2.45, 2.38, 2.45, 2.45, 2.25 character periods of seismic spectra are 0.32, 0.46, 0.32, 0.42, 0.32, 0.32, 0.42 sec. and 0.36, 0.51, 0.36, 0.46, 0.36, 0.36, 0.46 sec. The maximum seismic influence coefficient are 0.097, 0.113, 0.077, 0.099, 0.077, 0.079, 0.106 and 0.45, 0.47, 0.39, 0.45, 0.375, 0.239, 0.459 etc. respectively. The peak accelerations of ground motion of 50 years exceedance probability 0.63 and 0.03 are provided for strength and deformation design of structural component respectively.

6 CONCLUSION

The proposed method is considered the seismicity in spatial nonuniform and in time nonstationary to determine the design ground motion parameters for city building aseismic design. It is with reasonableness and reliability than using usual method, and it is also convenience to be used for aseismic design of city construction and city planning. It will also be saved a lot of investment of engineering constructions.

7 ACKNOWLEDGMENT

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