5th Canadian Conf. Earthquake Engineering / Ottawa / 1987 / 5ème Conf. Canadienne Génie Sismique

Design ground motion parameters for Xiao Lang Di dam in eastern China

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ABSTRACT: In this paper, based on the analysis results of geoloical tectonics, historical earthquake and seismicity within a radius of 320 KMS from the site, and attenuation laws have been developed from the data of moderate to strong ground motion and observations of historical earthquake intensities in eastern China. The design ground motion parameters for XIAO LANG DI dam in eastern China are obtained by seismic hazard analysis using a fault- rupture model and artificial ground motion are generated for the site using a nonstationary random process model in the site.

1 INTRODUCTION

South bank and north bank of the site of XIAO LANG DI dam is situated in 30 KMS from LUOYANG city, and JIYUAN county, HENAN province respectively. The reservoir has a capacity of $126.5*10^3 M^3$, and it has a dam of 152 M height, reservoir of 140 M depth. It is a large irrigation engineering which will constructe on the mainstream of Yellow River about 130 KMS from SAN MEN gorge.

The regional site is attached by earthquake located in the greater part of SHANXI seismic subarea of north China seismic area, and in part of midle- lower reaches of the YANGTSE River and QIN LING DABA seismic subarea of the south China seismic area. The site of dam is situated at the part of boundary of XUCHANG HUAINAN seismic zone, XINGTAI HEJIAN seismic zone and SHANXI seismic subarea. The major tectonic structure consists of four parts giving active rupture in the NE, NNE, NNW and EW direction within a radius of 320 KMS region around the site, and with three sets repture im the NE, NW and EW direction within a radius of 30 KMS from the site. Two steps were used to determine the design ground motion parameters for XIAO LANG DI dam. First, based on the analysis results of the geological tectonic, seismicity , potential seismic sources and attenuation laws taking into account whether the source was nearby or distant. The probability methed (A. Der. Kiureghian, A H-S Ang, 1977) was used in seismic hazard analysis to determine the peak ground acceleration with an annual probability of exceedance of 10^{-4}, which was chosen as the criterion for the safe earthquake of dam. Site spectra and acceleration time history envelopes were chosen based on each of the major potential seismic sources, taking into consideration the character of the site, whether the sources were nearby or distant and the maximum magnitude and distance from the site. Finally, a nonstationary random process model was used to generate ten acceleration history curves for each set of major source parameters to match the target spectra. These artificial ground motion record were the design ground motion for the dam.

2 IDENTIFICATION OF POTENTIAL SEISMIC SOURCES

Considering a region with a radius of 320 KMS around centre of the site, the active fault, seismicity and correlations between active fault and seismicity were developed to identify the potential seismic sources which are likely to affect the XIAO LANG Di dam site. The records of historical earthquake can be traced back to 288 B. C. since that time up to now, there have occurred 188 destructive earthquakes with magnitude $M_s \geq 4.75$ within the region including 3 earthquakes with magnitude M=8, 4 earthquakes with magnitude $M \geq 7$. Most focal depth of earthquake were in range 15- 20 KMS. The character of the seismicity within the regional site is strong seismicity to the north and weak activity to the south. HUAILAI XIAN seismic zone on northwest of dam is one of most strong seismicity zone in

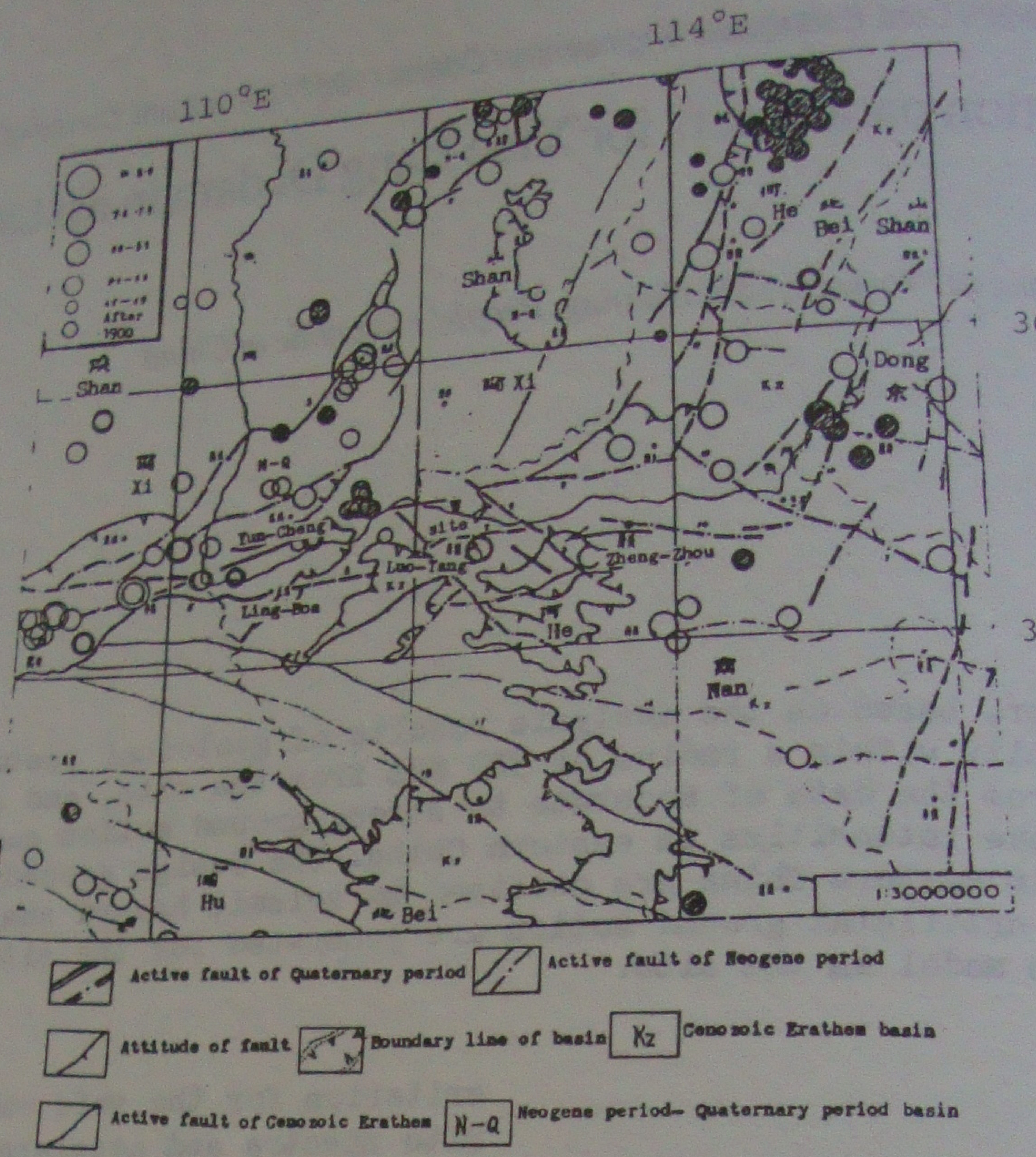

Figure 1: Seismological structure on regional site

China, 3 earthquakes of magnitude M=8 have occurred in the zone. The major structures with NE, NNE, NNW and EW direction rupture play impotant roles as shown in Fig. 1.

According to the analysis results of active fault, seismicity, and correlation between active fault and destructive earthquakes, as well as the character of seismicity at fault basins, the potential seismic sources within the region can be simulated by fifteen idealized seismic sources (Zhang Xue-Liang , 1985) as shown in Fig. 2. No.1 to No.8 are area sources of type II(i. e. a fault with known strike direction , location unknown). and No.9 to No.15 are area sources of type III(fault with locations and strike direction unknown).

3 SEISMICITY PARAMETERS

Within potential seismic sources in the region we assume a law of earthquake occurrence of the form

$$\text{Ln } N(M)=\alpha-\beta M \quad (1)$$

where N(M) is the number of earthquakes with magnitude greater than or equal to M, occurring in any time, α, β are regression constants. considering the correclation between greater earthquakes in same seismic belt, the β value within the same seismic belt are with same value, and also considering the unreliablity of the records of his-

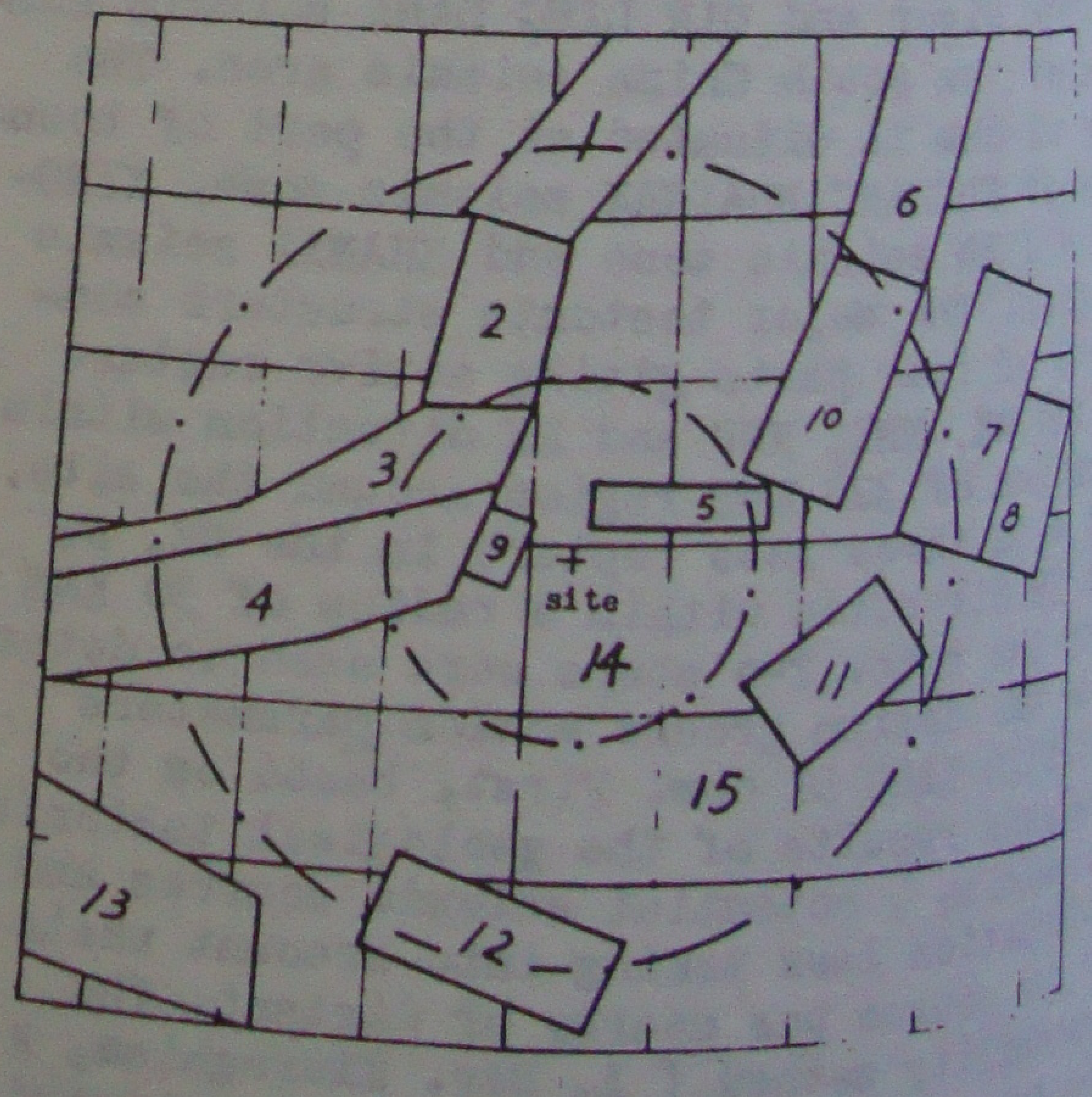

Figure 2: Idealized potential seismic sources

Table 1: Main seismicity parameters of potential seismic sources in regional site

No	Type	Upper M	Value	Occurrence	Node coodinate (X_1,Y_1) (X_2,Y_2) (X_3,Y_3) (X_4,Y_4)
1	II	7.0	1.1263	0.0673	(-13,210) (80,340) (-6, 340) (-88,232)
2	II	8.0	1.1263	0.0096	(-42,101) (-13,210) (-72, 227) (-113, 95)
3	II	7.0	1.1263	0.0192	(-54,61) (-42, 101) (-113, 95)
4	II	8.0	1.2048	0.0673	(-355,-5) (-355, -18) (-104, -30)(-54, 61) (-355, -18) (-355, -106)
5	II	6.5	1.4077	0.0051	(-5,15) (138, 15)(138, 50) (-5, 50)
6	II	7.7	1.4077	0.0356	(238,185) (284, 340) (192, 340) (158,222)
7	II	7.5	1.4077	0.0356	(272, -37) (336,176) (273,194) (209,-7)
8	II	6.5	1.4077	0.0059	(336,-69) (377,84) (315,103) (272, -37)
9	III	6.0	1.2048	0.0102	(-57,-25) (-33,21) (-67,39) (-91,-7)
10	III	8.0	1.4077	0.0178	(187,15) (238,185) (158,222) (107,67)
11	III	6.5	1.2048	0.0255	(152,-143) (247,-84) (205,-21) (112,-76)
12	III	6.0	1.2048	0.0291	(10,-315) (40,-246) (-109, -185)
13	III	6.0	1.2048	0.0153	(-138, -254) (-207,-320) (-207,-235) (-355,-159) (-355, -273)
14	III	6.0	1.2048	0.0102	R= 0— 150
15	III	6.0	1.2048	0.0765	R= 150 — 320

torial earthquake in the earlier days, the time are selected from 1501 up to 1984 for analysis. The lower bound magnitude is usually adopted as 4.0, the maximum magnitude of historical earthquakes in a region of potential seismic sources is increased by 0.5 to give the upper bound magnitude (Zhang Xue-Liang chief editor, 1987), except in region where a maximum magnitude of 8.0 or above has alread been measured, since the accumulation of strain energy has already been released inthese areas. The average value of focal depth of earthquake is obtained as 17 KMS. The seismicity parameters of these potential seismic sources are listed in table 1.

4 ATTENUATION FORMULA

In order to increase reliability in seismic hazard analysis (Zhang Xue- Liang, 1986), both using the data of intensity distribution of historical earthquakes and ground motion in eastern China and vicinity of regional site on soil II type to statistically to obtain the attenuation formulas of minor axis is obtained from 65 data of isoseismal contours of historical earthquakes as follows

$$I=5.6664+1.3771M_s-1.8598Ln(D+20) \qquad (2)$$

$$\sigma_{n-1}=0.5362$$

The peak acceleration attenuation formula is obtained from 32 horizontal acceleration records with $5<M_s\leq7.9$, $2<R\leq422.5$ KMS, $10<H\leq35$ KMS, as follows

$$LnA=4.2175+1.1713M_s-1.7037Ln(D+20) \qquad (3)$$

$$\sigma_{n-1}=0.5015$$

where D is hypocentral distance, R is epicentral distance, H is focal depth of earthquake.

5 RESULTS OF SEISMIC HAZARD ANALYSIS

A probability of exceeding within T years of a specified intensity or peak acceleration level at the site can be expressed as follows (Zhang Xue-Liang chief editor, 1987)

$$P(Y\ y)_T=1-\left[1-\sum_{i=1}^{N}P_i(Y>y/E_i)\ \nu_i\right]^T \qquad (4)$$

where E_i denotes earthquakes with magnitude $M\geq M_0$ occurred in the ith source.

Using the correlation formula (Chen Dash-

$$S=exp\ (1.2918M_s-6.1311)$$

eng, 1984) between fault rupture length S(in KMS) and magnitude and formula (1), (2), (3). A probability of exceeding within T years of a specified intensity or peak acceleration level at the site can be obtained through formula (4) from each source in combination with mean occurrence rate ν_i. The results of uncertain correction for attenuation are obtained using these formulas as follows.

$$P(Y\ y)=\frac{1}{\sqrt{2\pi}\sigma_1}\int_{-3\sigma_1}^{3\sigma_1} P(Y>y-z)\, e^{-\frac{1}{2}\left(\frac{z}{\sigma_1}\right)^2} dz \qquad (5)$$

when using formula (2)

$$P(Y\ y)=\frac{1}{\sqrt{2\pi}\sigma_2}\int_{-3\sigma_2}^{3\sigma_2} P(Y>ye^{-z})\, e^{-\frac{1}{2}\left(\frac{z}{\sigma_2}\right)^2} dz \qquad (6)$$

when using formula (3)

The calculating results are shown in Fig.3, the solid line denotes the results after correction , dotted line denotes uncorrection results, the results after correction is increased 29.6% more than uncorrection. In China, an annual probability of exceeding of 10^{-4} has been adpoted as criterion for safe earthquake of dam. Then, the design peak acceleration 0.2127g or intensity 7.7 can be obtained from Fig.3, it is quite closed by comparing peak acceleration with conversion peak acceleration from intensity using the formula(Liu Hui-Xian ,1980)

$$a(\text{in g})=10^{I\text{Log}2-0.01}$$

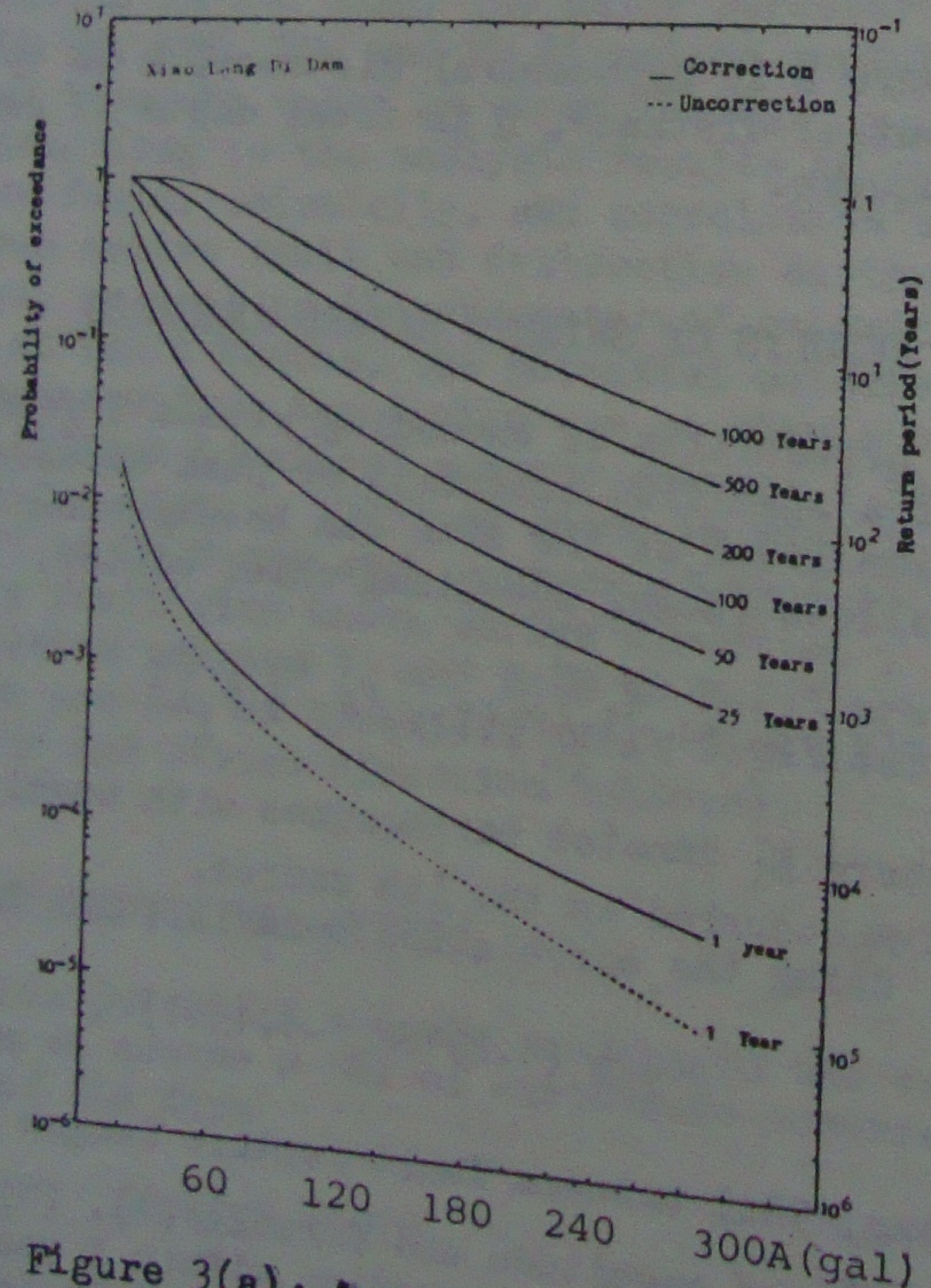

Figure 3(a): Annual probability of exceedance (Peak ground acceleration)

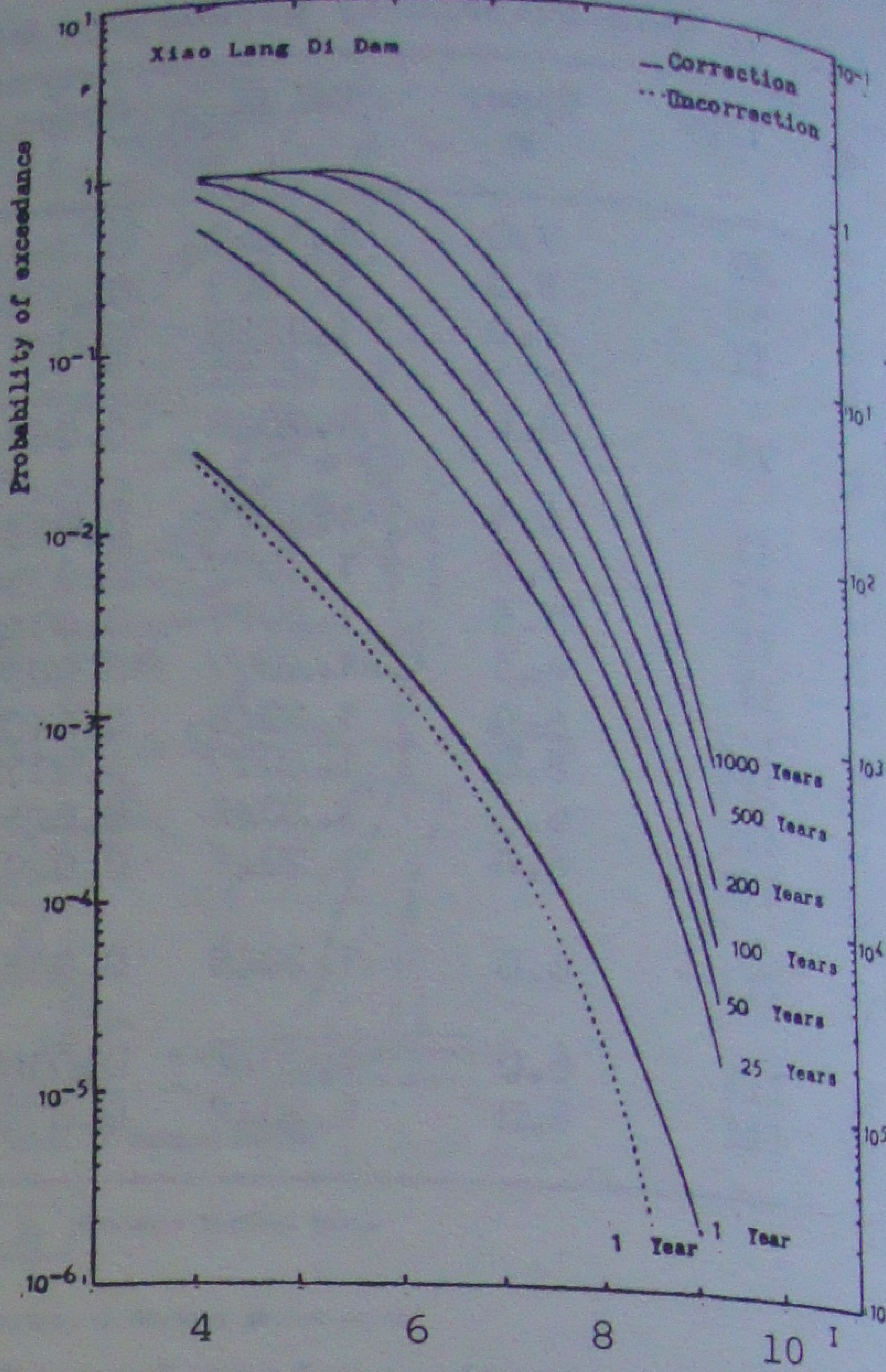

Figure 3(b): Annual probability of exceedance (Intensity)

6 SITE SPECTRA AND SHAPE FUNTION

Site spectra and acceleration time history envelopes (shape funtion) are constructed to consider near-source and far-source motion at regional site. The calculation results indicated that No.2, No.4 and No.5 were major potential seismic sources which obviously affected the site through comparing with other sources at regional site.

According to the major potential seismic sources No.2 and No.4 with maximum magnitude M=8, distance 100 KMS and 80 KMS from the site respectively, No.5 with maximum magnitude M=6.5 , distance 30 KMS from the site, site spectra were constructed as shown in Fig.4. Comparing the far-source with near-source spectra, the spectra values of near-source decrease in region of lower frequency and increase in region of higher frequency. The shape funtion is usually indicated in terms of the foumulas as follows

$$\begin{aligned} \varphi(t) &= (t/t_1)^{\lambda_1} && 0\le t\le t_1 \\ \varphi(t) &= 1 && t_1<t\le t_2 \\ \varphi(t) &= e^{-\lambda_2(t-t_2)} && t_2<t\le t_e \end{aligned} \qquad (7)$$

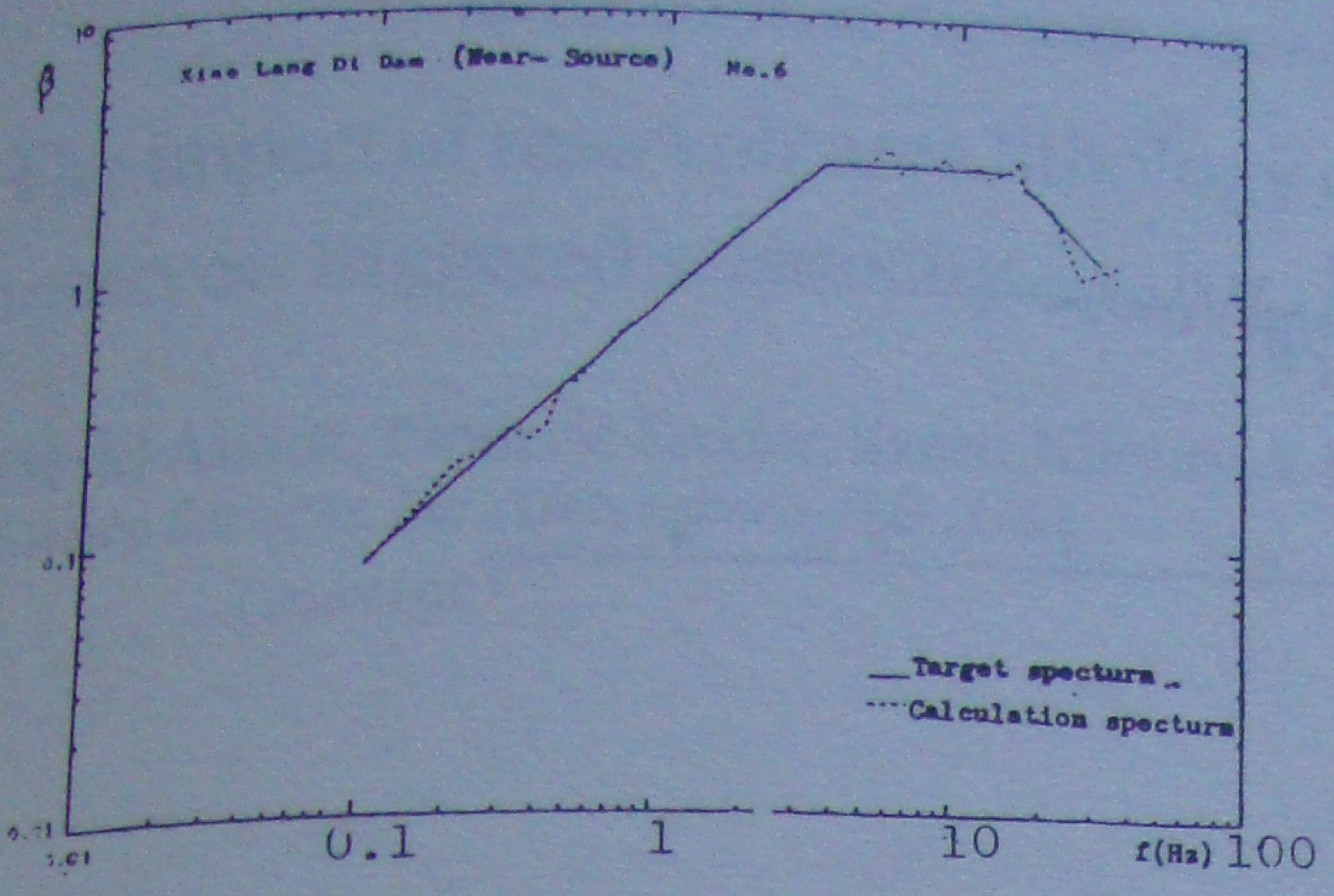

Figure 4(a): Response spectra (Near-source)

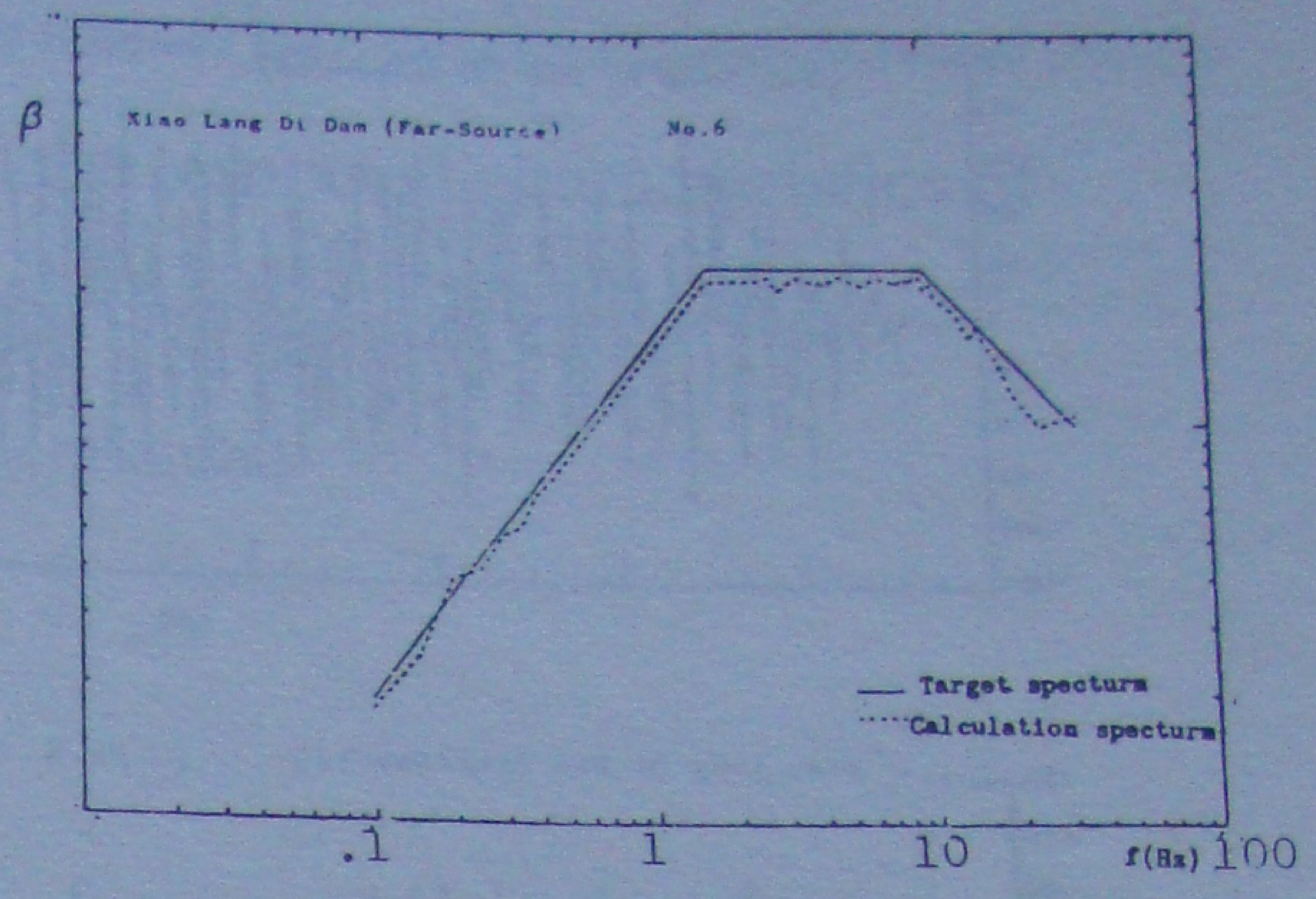

Figure 4(b): Response spectra (Far-source)

where t_1, t_2 and t_e denote rising time, starting descendent time of amplitude and duration of ground motion respectively, λ_1 and λ_2 denote attenuation coefficient.

Near-source

$\lambda_1=2$, $\lambda_2=0.46$, $t_1=2$ sec. $t_2=10$ sec.

$t_e= 15$ sec.

Far- source

$\lambda_1=2$, $\lambda_2=0.13$, $t_1=4$ sec. $t_2=20$ sec.

$t_e= 38$ sec.

7 ARTIFICIAL GROUND MOTION

A nonstationary random model were chosen to generate acceleration history curves, which can be expressed in the form as follows (Zhang Xue- Liang chief editor , 1987)

$$A(t)=\varphi(t)X(t)=\varphi(t)\sum_{i=1}^{N}A_n \operatorname{Cos}\left(\frac{2\pi nt}{T}+\theta_n\right) \tag{8}$$

where $\varphi(t)$ 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 with $X(t)$ Fourier transformation.

For the shape of an artificial acceleration to achieve similitude with natural ground motion, it must satisfy the three main factors of amplitudes, frequencies and duration. It is usually considered as follows

1. Near-source and far-source spectra with 0.05 damping ratio were adopted as goal spectra for the artificial ground motion.

2. Rise time and starting decentent time of amplitudes and duration of ground motion are satisfied for the given shape function of time history of ground motion.

3. The peak acceleration for the generation of the artificial ground motion is adopted as 1000 gal. for convenience. The accelerogram is scaled to the required peak acceleration during the structural dynamic analysis.

Ten artificial time histories of ground motion for each set with near-source and far-source were generated using formula (8) to match target spectra (Zhang Xue-Liang chief editor, 1978, Zhang Xue-Liang, Yan Xin-Yu, 1986). The part of calculation results were shown in Fig. 5.

8 CONCLUSIONS

The calculation analysis indicated that the main earthquake hazard to affect the site of dam is from major potential seismic source No. 4, secondary No.2 and No.5 . Two sets of artificial ground motion can be applied as design ground motion parameters for aseismic design of dam, and according the criteion with an annual probability of exceeding 10^{-4} of the safe earthquake of dam, its peak acceleration value is suggested to adpot 0.215g.

Using two difference attenuation formulas in seismic hazard analysis to be obtained these results were quite closed by comparison in Fig.3. In Fig. 4,it can be also shown that these calculation spectra of each artificial acceleration history curves were very closed to the target spectra expect few point. It could be explained that the provided ground motion parameters were in reliance in aseismic design of XIAO LANG Di dam.

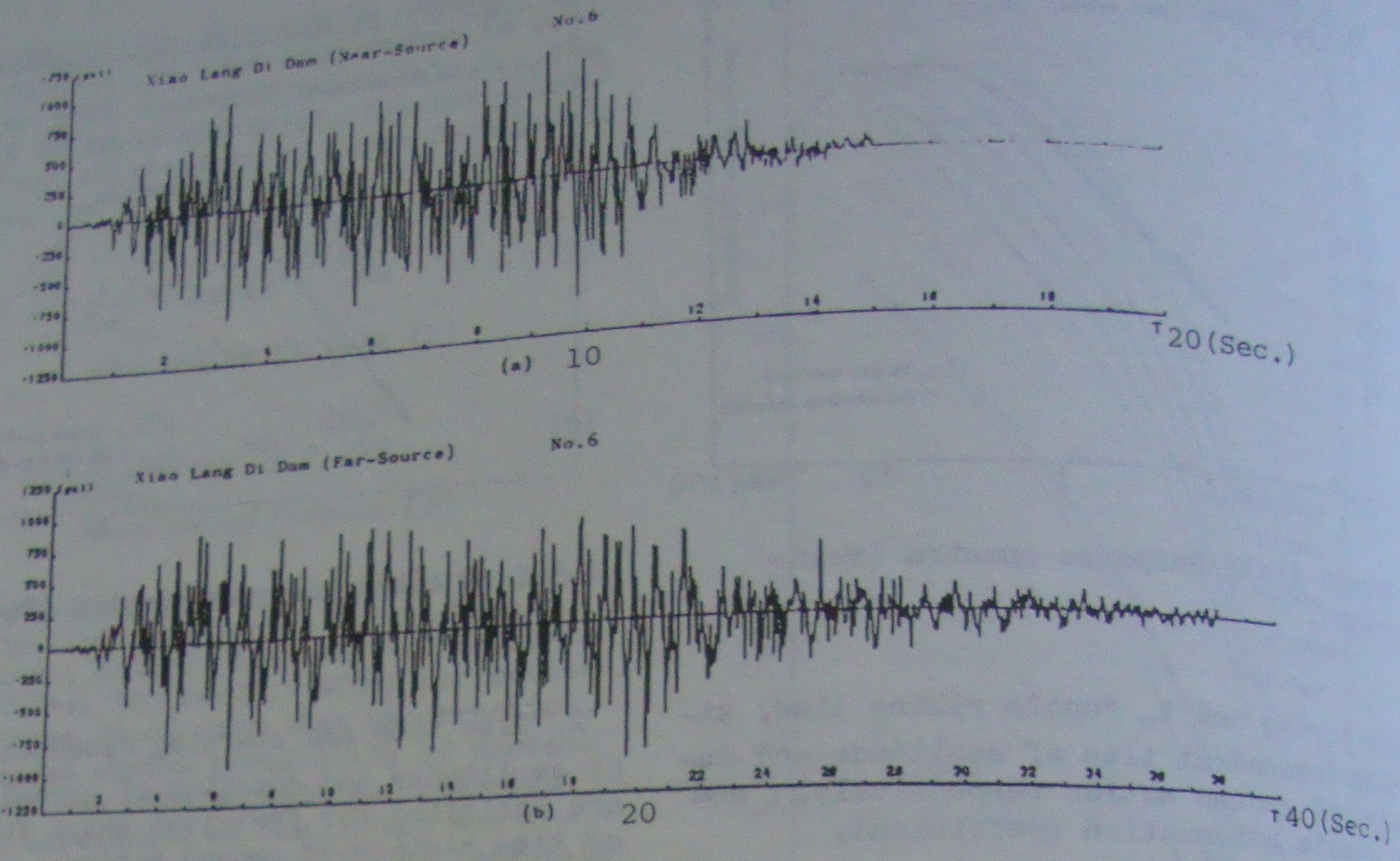

Figure 5: Artificial ground motion (a) Near-Source (b) Far-Source

9 ACKNOWLEDGMENT

The authou wishes to thanks to colleagues of Seismological Bureau of Jiangsu Province and Henan Province for their support. The authou alsowithes to extent their gratitude to prof. HU Yuxian for his useful suggestion.

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