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SUGGESTED NORMALIZED SPECTRAL ACCELERATIONS FOR SEISMIC MARGIN ASSESSMENTS OF NUCLEAR POWER PLANTS

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ABSTRACT

Strong-motion inputs characterized by normalized spectral accelerations are needed in seismic margin assessments of nuclear power plants in China, which are mainly located in coastal regions with weak seismicity. Based on statistics of 350 strong-motion acceleration records on bedrock in Next Generation Attenuation(NGA) database and 14 strong-motion acceleration records on bedrock in Wenchuan *M*w7.9 earthquake and Lushan *M*w6.6 earthquake, normalized horizontal spectral accelerations on bedrock for seismic margin assessments of nuclear power plants in China were suggested. The influences of earthquake magnitude on frequency contents of strong-motions were adequately taken into account in these suggested spectral accelerations, which could help evaluate the influences of different seismic tectonic environments on normalized spectral acceleration inputs in different nuclear power plant sites. In comparison to the normalized spectral accelerations suggested in RG1.60, this suggested spectral accelerations could reflect the high frequency contents of strong-motions induced by diffuse seismicity in near field more reliably.

Keywords: Spectral acceleration; strong-motion input; seismic margin assessment; nuclear power plant; acceleration record

1. INTRODUCTION

Normalized spectral accelerations scaled by Peak Ground Acceleration (PGA) are used as fundamental earthquake inputs to evaluate the seismic margins of structures, systems and components in nuclear power plants. At present, several normalized spectral accelerations with significant differences are used, which might lead to different analysis results for seismic margins of nuclear power plants. It is of significant importance to find a kind of normalized spectral accelerations that is applicative for the seismic margin assessments of nuclear power plants in China.

In the US and then in the European Union, two methods of seismic margin assessment are recommended in the file of ‘ASME-ANS RA-Sa-2009: Add to RA-S-2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications L1’ (ASME/ANS, 2009) and in the file of ‘EUR 16245 EN: Seismic re-evaluation of operating nuclear power plants in European countries Comparative study on national practices (European Commission nuclear science and technology)’. One is suggested by Electric Power Research Institute, hereinafter referred to as EPRI method. The other is suggested by U.S. Nuclear Regulatory Commission, hereinafter referred to as NRC method.

Variant normalized spectral accelerations are suggested. The normalized spectral accelerations

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published in the file of Regulatory Guide 1.60 (U.S. Nuclear Regulatory Commission, 1973), which is a statistics result by Newmark, et al., gives horizontal spectrum and vertical spectrum for 0.5%, 2%, 5%, 7%, 10% damping. The normalized spectral accelerations published in the file of NUREG/CR-0098 (Newmark and Hall, 1978) are suitable for areas with sufficient low seismic activities as Central and Eastern of the US, for it is a statistics result based on strong motion records mostly located at soil sites with an epicentral distance greater than 20km. The files of Regulatory Guide 1.65(U.S. Nuclear Regulatory Commission, 1997) and Regulatory Guide 1.208 (U.S. Nuclear Regulatory Commission, 2007) suggest the probabilistic seismic hazard analysis as one way to obtain normalized spectral accelerations.

In China, the normalized spectral accelerations suggested in Regulatory Guide 1.60 are currently used as seismic input in seismic margin assessments of nuclear power plants. Meanwhile, the seismotectonic environments in China are more complex than in California, and an updating Chinese seismic regulations for seismic margin assessments of nuclear power plants are required based on new strong-motion data and local seismotectonic environments.

2. DATA SOURSES

350 acceleration records on bedrock observed at worldwide stations from Next Generation Attenuation database are used in the statistics, all of which the moment magnitude are no less than 6.0 and the PGA are no less than75 cm/s^2. Another 14 acceleration records on bedrock observed in Wenchuan *M*w7.9 earthquake and Lushan *M*w6.6 earthquake are also included. The magnitude-distance distribution of all the 364 acceleration records are illustrated as in Figure 1, in which the definition of Joyner-Boore distance is used.

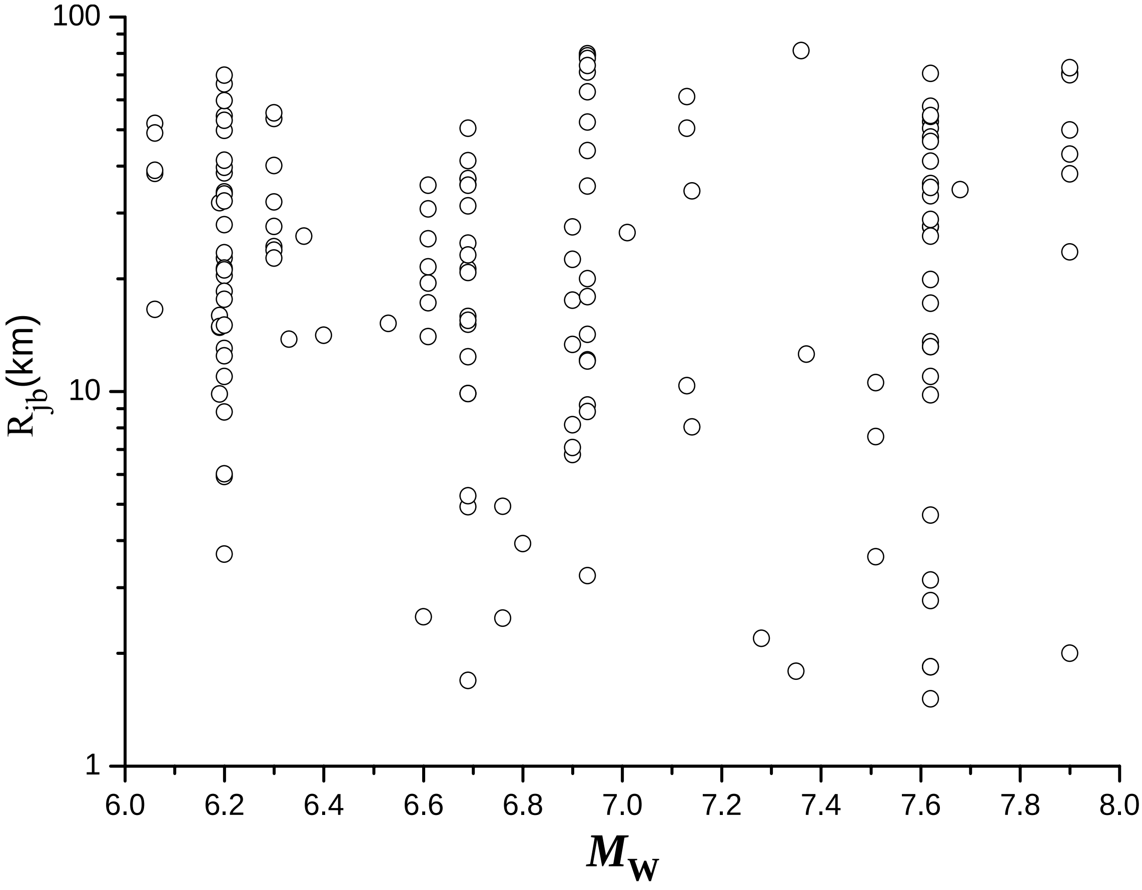

Figure 1. Magnitude-distance distribution of data

3. NORMALIZED SPECTRAL ACCELERATION STATISTICS

The spectral accelerations with damping ratio 5% were calculated from each horizontal acceleration component, and then they were normalized by its PGA. The average normalized spectral accelerations for acceleration records obtained in earthquakes of magnitude 6.0-6.5, 6.5-7.0, 7.0-7.5, 7.5-8.0 are shown in Figure 2, which indicated that the shape of normalized spectral accelerations are significantly dependent on the earthquake magnitude, as larger magnitude gives higher spectra at long periods.

The average normalized spectral accelerations for acceleration records obtained at stations of R_{jb} distances 0-10 km, 10-20 km, 20-40 km, 40-80 km are shown in Figure 3, which indicated that the shape of normalized spectral accelerations are independent on the earthquake magnitude. The average normalized spectral accelerations for R_{jb} distances 40-80 km at long periods are higher than the average normalized spectral accelerations for R_{jb} distances 10-20 km and 20-40 km those, but the reason for this phenomena can be attributed to the predominant proportion of acceleration records obtained in earthquake of larger magnitude. Meanwhile, the average normalized spectral accelerations for R_{jb} distances 0-10 km at long periods are so high that it is comparable with the average normalized spectral accelerations for R_{jb} distances 40-80 km.

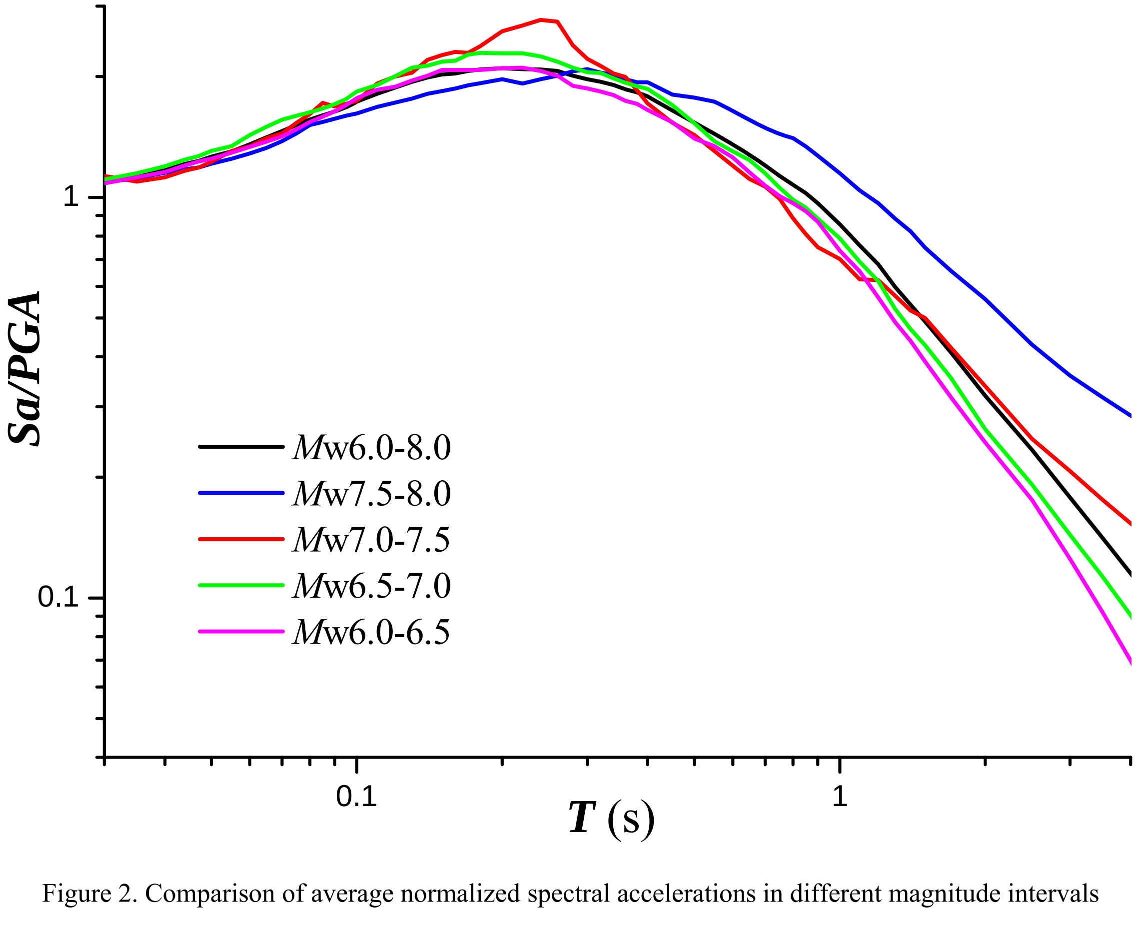

Figure 2. Comparison of average normalized spectral accelerations in different magnitude intervals

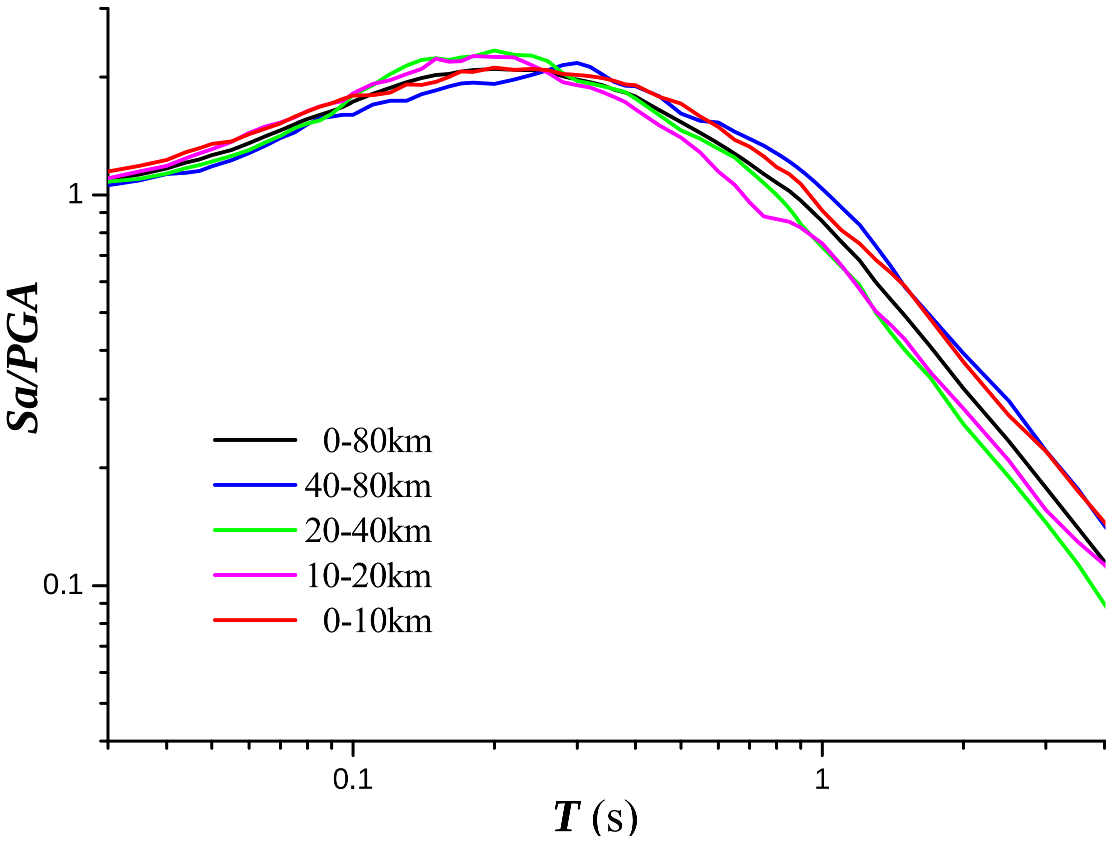

Figure 3. Comparison of average normalized spectral accelerations in different distance intervals

The statistical normalized spectral accelerations on bedrock are given in EQ. 1,

$$\lg(Sa(T)) = a(T) + b(T) * M_W \pm \delta \quad 6.0 \leq M_W \leq 8.0 \tag{1}$$

where *a, b* are regression coefficients given in Table 3, δ is the standard deviation.

Table 1. Coefficients of spectral accelerations on bedrock

T(s)	*a*	*b*	δ	*T*(s)	*a*	*b*	δ
0.000	0.000	0.0000	0.126	0.280	0.096	0.0305	0.152
0.030	0.052	-0.0016	0.158	0.300	0.021	0.0401	0.142
0.035	0.108	-0.008	0.165	0.320	-0.019	0.0447	0.140
0.040	0.138	-0.0102	0.178	0.340	-0.048	0.0476	0.139
0.044	0.197	-0.0166	0.186	0.360	-0.091	0.0524	0.146
0.047	0.235	-0.0208	0.191	0.380	-0.139	0.0576	0.149
0.050	0.247	-0.0211	0.195	0.400	-0.186	0.0628	0.150
0.055	0.279	-0.0237	0.199	0.450	-0.311	0.0763	0.156
0.060	0.321	-0.0274	0.208	0.500	-0.442	0.0911	0.172

T(s)	a	b	δ	T(s)	a	b	δ
0.065	0.333	-0.0265	0.215	0.550	-0.551	0.103	0.182
0.070	0.347	-0.0264	0.220	0.600	-0.628	0.1103	0.190
0.075	0.353	-0.025	0.220	0.650	-0.721	0.1199	0.200
0.080	0.351	-0.0228	0.224	0.700	-0.847	0.1345	0.209
0.085	0.368	-0.0238	0.225	0.750	-0.942	0.1445	0.217
0.090	0.408	-0.0282	0.221	0.800	-1.002	0.1499	0.224
0.095	0.451	-0.0327	0.221	0.850	-1.022	0.1497	0.227
0.100	0.518	-0.0406	0.222	0.900	-1.092	0.1563	0.229
0.110	0.534	-0.0399	0.226	1.000	-1.31	0.1803	0.228
0.120	0.504	-0.0334	0.225	1.100	-1.399	0.1856	0.236
0.130	0.564	-0.0399	0.226	1.200	-1.598	0.2075	0.235
0.140	0.577	-0.0403	0.227	1.300	-1.805	0.2296	0.235
0.150	0.549	-0.0350	0.222	1.400	-1.921	0.2399	0.237
0.160	0.528	-0.0319	0.214	1.500	-2.09	0.2562	0.234
0.170	0.494	-0.0258	0.206	1.700	-2.422	0.2935	0.235
0.180	0.453	-0.0193	0.199	2.000	-2.845	0.3376	0.252
0.200	0.433	-0.0158	0.187	2.500	-3.312	0.3866	0.263
0.220	0.398	-0.0105	0.170	3.000	-3.782	0.436	0.273
0.240	0.318	0.0006	0.167	3.500	-4.139	0.4738	0.286
0.260	0.186	0.0183	0.162	4.000	-4.435	0.5047	0.301

4. APPLICATION

The spectral accelerations for seismic margin analysis at a nuclear power plant on bedrock site in southeast coast of China are shown as blue polygonal line in Figure 4. The strong motion prediction equations for PGA used are from Yu and Wang, 2006. Figure 4 indicated that the ground motion at this site is mainly controlled by near-field earthquake, and the known active faults in far field only influenced the spectral acceleration at long periods, i.e., T>1 second. comparing to spectral accelerations suggested in RG1.60 shown as black polygonal line in Figure 4, spectral accelerations calculated by EQ. 1 give a more reasonable and more realisable ground motions at long periods, which is more significant in areas of low seismic activities as in Southeast China.

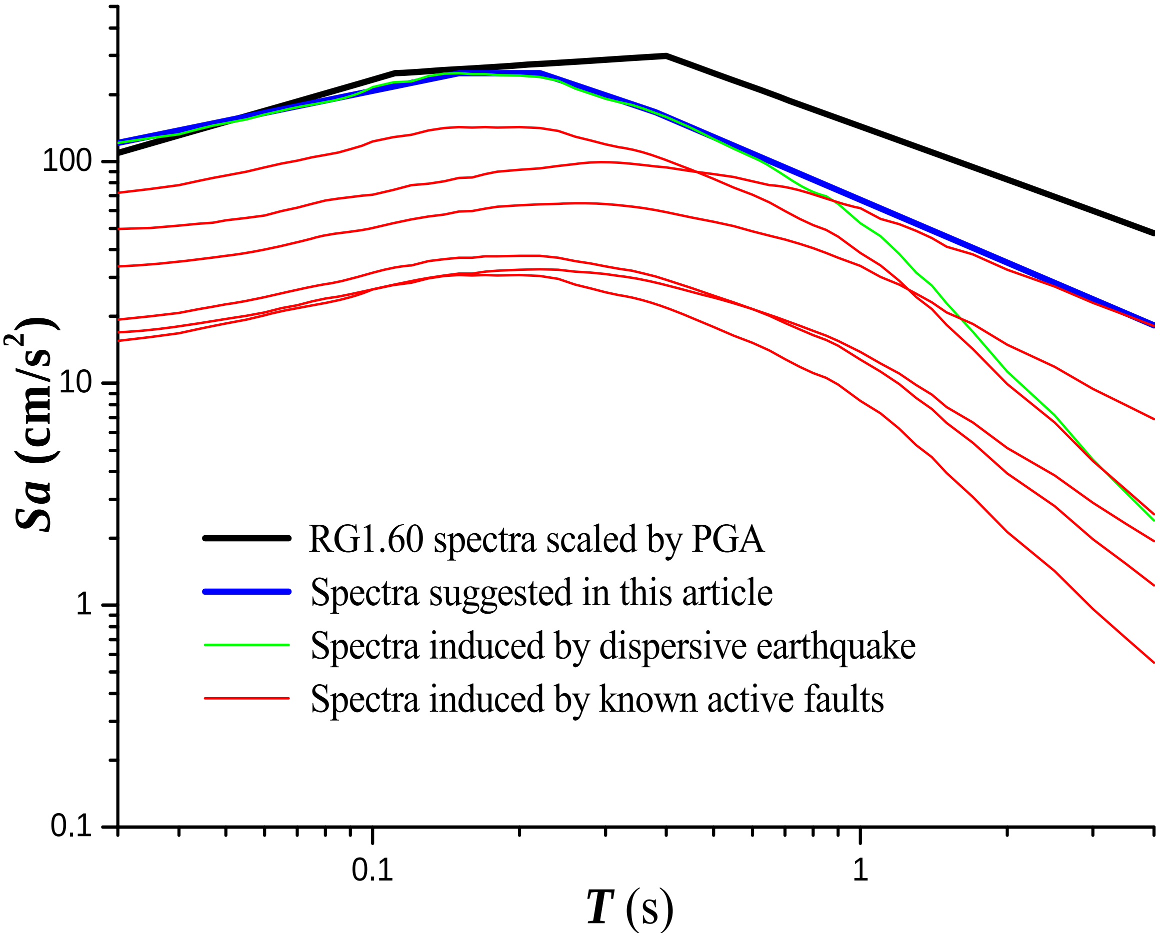

Figure 4 Spectral accelerations for seismic margin analysis at a nuclear power plant on bedrock site

5. CONCLUSION

A method of determining normalized spectral accelerations on bedrock sites for seismic margin assessments of nuclear power plants was suggested. The influences of seismotectonic environments on normalized spectral accelerations were considered in this method, which made it more applicable than spectral accelerations suggested in RG1.60 in areas of low seismic activities as in Southeast China.

6. AKCNOWLEDGEMENT

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