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Seismic Hazard of Hong Kong

J.W. Pappin[1], R.C.H. Koo[1] & M.W. Free[1], H.H. Tsang[2]
Ove Arup and Partners Hong Kong Ltd, Hong Kong[1]
Department of Civil Engineering, University of Hong Kong, Hong Kong, Email: tsanghh@hku.hk[2]

ABSTRACT: This paper reviews the probabilistic seismic hazard assessment studies undertaken in recent years to estimate the potential seismic ground motion levels on bedrock in Hong Kong. A detailed catalogue of historical and recent seismicity within the South China region has been compiled. A suite of published empirical and stochastic attenuation relationships have been used with alternative source models and source parameters in a logic tree hazard analysis. Uniform hazard bedrock ground-motion spectra having various probabilities of being exceeded in 50 years have been calculated. The results have been de-aggregated to investigate what earthquake magnitude and distance combinations have contributed most to the hazard levels for the different probabilities and structural periods. The obtained uniform hazard spectra have been compared to the study using an alternative assessment approach developed by the University of Hong Kong. Recent recorded earthquake ground motions in Hong Kong are also presented with the uniform hazard spectra.

Keywords: Seismic hazard, earthquake, ground motion, attenuation, response spectra, Hong Kong

1 INTRODUCTION

The Hong Kong Special Administrative Region is located in an area of low to moderate seismicity. The current codes of practice for building design do not require any seismic considerations. This paper reviews the assessments of the potential seismic ground motion levels on rock in Hong Kong. The evaluation of the potential site response effects in Hong Kong are described in a companion paper in Pappin et al. (2008).

2 GEOLOGY AND TECTONICS OF THE HONG KONG REGION

2.1 *Regional Geology and Tectonic Setting*

Hong Kong is situated in Southeast China near the south-eastern margin of the Eurasian Continental Plate in a stable continental intraplate region about 700 km from the nearest plate boundary, which underlies Taiwan and trends south to the Philippines and northeast to Japan [Sewell et al. (2000) and Fyfe et al. (2000)]. The regional tectonic setting is shown in Figure 1. Two major, regional northeast trending fault zones are interpreted to lie along the Southeast China coast. The Changle-Nanao Fault Zone, runs along the coast and is offshore northeast of Hong Kong. The Lianhuashan Fault Zone, runs inland, parallel to the coast from Shanghai to Hong Kong.

Most of the tectonic deformation that is evident in the rocks of Hong Kong today was caused by events that occurred during the Late Jurassic to Late Cretaceous periods (160 to 90Ma) during what is referred to as the Yanshanian Orogeny (Sewell et al. 2000). Sewell et al. (2000) state that there is no direct evidence of fault displacements in either the offshore or onshore Quaternary age (less than 2Ma) superficial deposits. They state that no fault displacements have been identified in the immediate vicinity of Hong Kong from many hundreds of kilometres of offshore seismic lines of Quaternary age offshore alluvium and marine sequences. In recent years, thermoluminescence (TL) dating has been used for the dating of fault gouge in southeast China, Ding & Lai (1997), with possible peaks in fault activity identified at 270,000, 190,000 and 100,000 years before present. Lee et al. (1998) state that, based upon TL dating, the last major fault activity in Hong Kong can be interpreted to have occurred between 80,000 to 100,000 years ago.

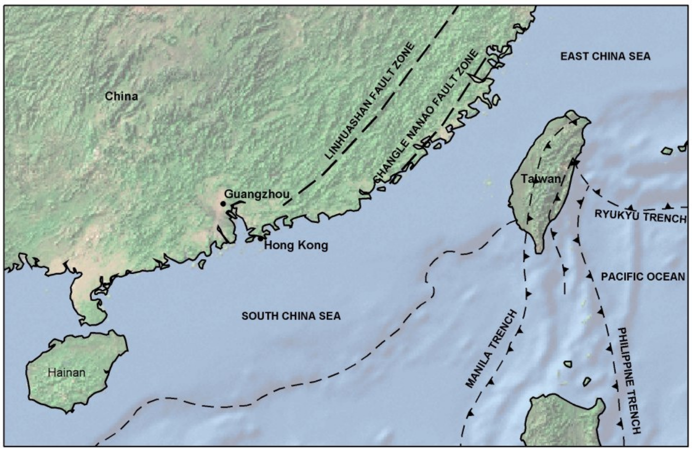


Figure 1. Tectonic setting of Hong Kong

2.2 *Geology of Hong Kong*

The geology of Hong Kong is described by Sewell et al. (2000) and Fyfe et al. (2000). More than three-quarters of the land area of Hong Kong is underlain by igneous rocks predominantly volcanic tuffs and granites of Late Jurassic to Early Cretaceous age (140 to 120Ma). Older, Late Paleozoic (420 to 240Ma) sedimentary rocks and younger Late Mesozoic to Tertiary (140 to 2Ma) sedimentary rocks underlie the majority of the remaining land area. Superficial deposits comprising Quaternary (less than 2Ma) alluvium and other unconsolidated deposits are also present throughout the territory. Large areas of reclamation have been formed around the coastal areas of the territory.

3 SEISMIC HAZARD ASSESSMENT

3.1 *Seismic Hazard Assessment Methodology*

The conventional probabilistic seismic hazard assessment (PSHA) methodology, e.g. Cornell (1968), McGuire (1993), has been applied using *Oasys* SISMIC, the in-house PSHA program of Arup. The PSHA methodology used the following steps:

- Potential seismic sources have been defined on the basis of regional geology and seismicity,
- Seismicity parameters defining the rate of earthquake activity have been derived for each of the potential seismic sources,
- Ground motion attenuation relationships, considered to be appropriate for the region, have been defined, and
- The frequency of specified ground motion levels being exceeded has been derived by first determining the likelihood that the ground motion will be exceeded if an earthquake of a certain magnitude at a certain distance occurs and multiplying this likelihood by the annual frequency of such an event occurring in any of the source zones. By summing the annual frequencies of the ground motion level being exceeded from all specified earthquake distances and magnitudes the overall frequency is established.

The use of this seismic hazard assessment methodology to estimate the potential seismic ground motion levels on bedrock in Hong Kong has been previously published in Free et al. (2004).

An alternative methodology, namely the direct amplitude-based approach, has been developed in the University of Hong Kong (HKU) to assess seismic hazard. This approach has been shown to be consistent with the results using conventional approach in Tsang and Chandler (2006). Also, “site-specific” and “event-specific” ground motion model can be adopted.

Epistemic uncertainty arising from differences in expert opinion on a range of modelling assumptions has been addressed through the use of a logic tree [Kulkarni et al. (1984), Coppersmith and Youngs (1986), National Research Council (1988)]. Aleatory uncertainty, arising from natural physical variability, has been addressed by allowing for the normal variation, represented by its standard deviation “sigma”, of the ground motion attenuation relationships in the hazard computation.

3.2 *Seismological Data for the Hong Kong Region*

Historical earthquake data for the Southeast China region (Guangdong Province of China) has been obtained from a range of sources. The Directory of Earthquakes in China (BC 1831 to AD 1969) as listed in Gu et al. (1983) and the Guangdong Seismological Bureau (1991) database provide the most extensive catalogues of historical earthquake data for the region. These have been supplemented by the data from the Geotechnical Control Office (1991). For historical earthquakes, where there is no instrumental records, the event magnitude has been determined by Gu et al. (1983) using an empirical formula, $M = 0.58\ I_O + 1.5$, where I_O is the intensity at the epicentre of the event. The historical dataset comprises 199 events between 1067 and 1970. For a number of the larger historical events, the magnitudes defined by Johnston (1996a, 1996b) have been used.

A set of 3-component, long period seismographs, was established at the Hong Kong Observatory in 1921. The first felt earthquake recorded by these instruments occurred on the 10th January 1924. During World War II, the original seismographs were lost and no local observations were made between 1941 and 1950. Recording resumed in 1951. The GSB has maintained a database of earthquakes within the Guangdong Province with magnitude, $M_L \geq 2.0$ since 1970. A subset of this data, for the region within 500 km of Hong Kong, was obtained for this study.

For the PSHA, all events are required to be statistically independent and therefore foreshocks and aftershocks have been removed from the catalogue using the methodology of Gardener and Knopoff (1974). Man-induced events have also been identified and removed from the catalogue. A reservoir induced earthquake swarm commenced in 1962 during the filling of the Xinfengjiang Reservoir. The mainshock of the swarm had a local magnitude M_L = 6.1. The earthquake events in the catalogue have been compiled from a range of sources and a range of magnitude scales have been used in the original sources (M_L, mb and M_S). The moment magnitude scale has been adopted for this study and the relationships of Johnston (1996a, 1996b) have been used to define a moment magnitude value for each event.

3.3 *Seismic Source Zones and Parameters*

Southeast China is located within a stable continental intraplate region and the association of earthquakes. A number of previous studies have defined seismic source zone models for Southeast China (Pun & Ambraseys 1992, Wong et al. 1998 and Lee et al. 1998) and these models have been included in this study using the logic tree described below. In addition, the source zone model shown in Figure 2 has been developed and is incorporated into the logic tree with higher weighting. The model extends out to a distance of 500km from Hong Kong. A more distant seismic source zone was also included for the region of Taiwan (not shown on Figure 2). The seismic activity parameters for the model shown in Figure 2 are summarised in Table 1.

The earthquake catalogue for the Hong Kong region includes three earthquakes with magnitudes greater than M = 7. Earthquakes with magnitudes M = 7.5 occurred in 1604 and 1605 and a magnitude M = 7.4 event occurred in 1918. An earthquake with a magnitude M = 7 would be associated with a surface rupture length in the order of 45 km, and a magnitude M = 7.5 with a surface rupture in the order of 125km. There are a large number of certain and inferred faults in the Southeast China Region. The inferred lengths of these faults are typically in the order of 40 to 50km although greater lengths on less well defined faults are also evident.

Table 1: Seismic activity rates for Hong Kong region seismic source zone model

Source	Location	Area	Annual Activity M>4	
		km^2	Number	Density (per 10^6 km²)
Zone 1	Onshore northeast of Hong Kong	108,303	1.28	11.80
Zone 2	Onshore surrounding Hong Kong	143,938	0.71	4.96
Zone 3	Onshore southwest of Hong Kong	108,606	1.09	10.04
Zone 4	Onshore north of Hong Kong	128,196	0.12	0.97
Zone 5	Off-shore east of Hong Kong	69,037	1.69	24.50
Zone 6	Off-shore southeast of Hong Kong	188,860	0.34	1.79
Zone 7	Off-shore southwest of Hong Kong	69,003	0.56	8.17
Taiwan	Taiwan region	146,000	24.22	165.00

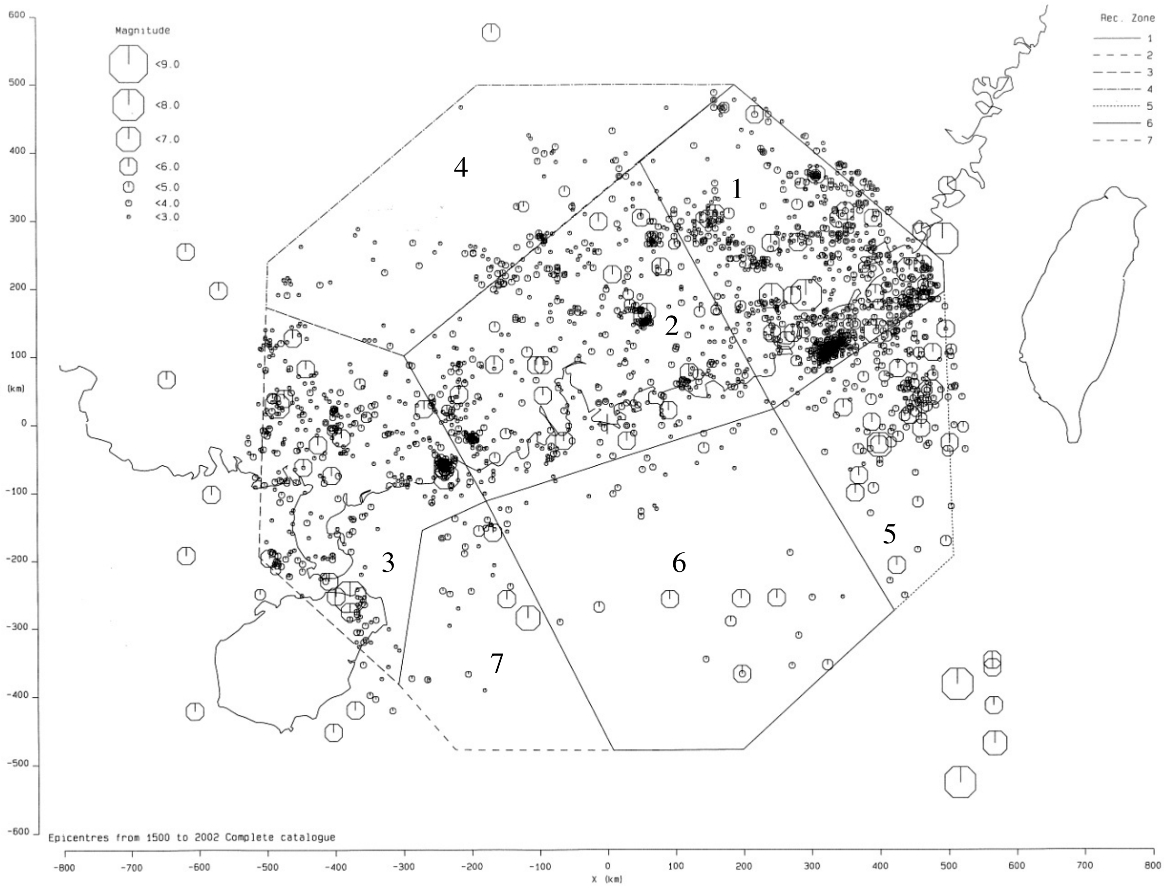


Figure 2: Source zone model for Hong Kong regio

To account for uncertainty in the assessment of the maximum magnitude, three values were considered with weights applied to the high, middle and low estimates. A minimum magnitude of M = 5 was used.

The Weichert (1980) maximum likelihood approach was used to determine the activity rates summarised in Table 1. In order to determine the recurrence parameters, it is necessary to define the magnitude and time ranges over which the earthquake catalogue is complete. For the onshore and near-shore seismic source zones three completeness ranges have been defined (1500 to 2001 for M≥7.0, 1870 to 2001 for M≥5.0, 1971 to 2001 for M≥2.5). For the offshore seismic source zones two completeness ranges have been defined (1920 to 2001 for M≥5.5 and 1971 to 2001 for M≥4.5).

The b-value, the gradient of the magnitude-recurrence relationship, has been found to be consistent in all source zones, which is equal to 0.95. An example of the magnitude-recurrence relationship for Zone 2 is shown in Figure 3. It is noted that the uncertainty in estimating the source parameters (i.e. activity rate and b-value) may significantly influence the hazard results. Hence, the uncertainty has been considered by a logic tree approach (Section 3.5).

3.4 *Attenuation Relationships*

Very few strong motion records have been recorded in the Southeast China region and consequently it is not possible to derive empirical attenuation equations for the region. Relationships have been derived for macroseismic intensity in Southeast China, Lee et al. (1998), and these show that isoseismal areas and attenuation of macroseismic intensity generally fall between those for Western and Eastern North America.

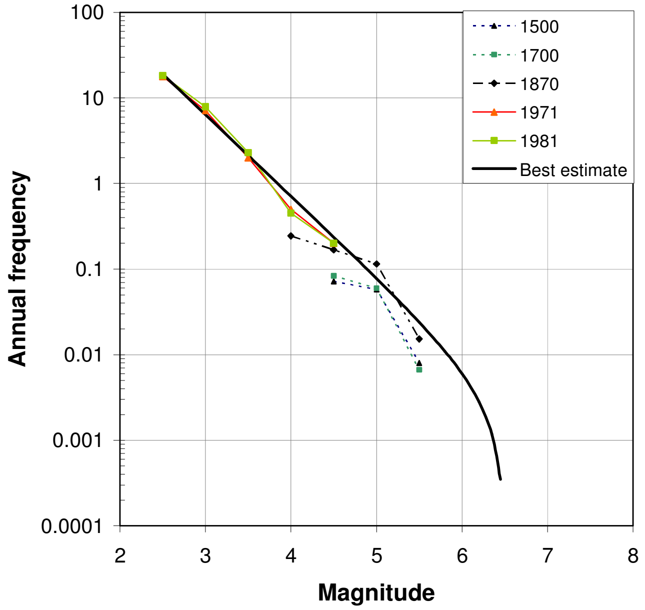


Figure 3. The magnitude-recurrence relationship for Zone 2.

Attenuation relationships for Southeast China for peak ground acceleration and response spectral values have been derived for the seismic hazard studies conducted by Free et al. (2004) and Tsang (2006) based on stochastic simulations of the seismological models developed by Lam et al. (2000a, 2000b) and Chandler et al. (2006a, 2006b) respectively. The seismological model, based originally on Boore (1983) and Atkinson & Boore (1995), used the input parameters shown in Table 2. The uncertainty of the relationships was allowed for by using a log-normal variability with a standard deviation on the natural logarithm of 0.55 (Free et al. 2004) and 0.69 (Tsang 2006) respectively.

In order to account for the epistemic uncertainty in the attenuation relationships appropriate for the region, a number of relationships have been used in Free et al. (2004) and have been incorporated into the logic tree with different weightings. The attenuation relationships for Western North America, Boore et al. (1993), for Eastern North America, Atkinson & Boore (1995), and for Southeast China, Wong et al. (2002), Lam et al. (2000a, 2000b) and Chandler et al. (2002), have been used (refer Figure 4 for comparison).

The attenuation model used in the direct amplitude-based approach of HKU [Tsang (2006)] was based on a series of latest studies on the crustal structure of the South China region and its corresponding attenuation properties. Mak et al. (2004) determined the seismological quality (Q_0) factor for the part of the South China region surrounding Hong Kong, which characterises the energy absorption of the earth's crust. The study obtained a mean Q_0 value of 256 for the regions within 200km of Hong Kong and higher values of whole path Q_0 (in the range of 350-450) for more distant between 200km to 800km including Taiwan.

On the other hand, the seismic wave amplitudes can be significantly modified within the upper 4km (say) of the earth's crust, commonly referred to as upper crustal modification mechanisms. The energy dissipation mechanism within the upper crust is commonly characterised by the upper crustal attenuation parameters κ. However, it is generally difficult to measure in regions of low to moderate seismicity. Hence, empirical correlations for predicting this important parameter have been developed (Chandler et al. 2005; Chandler et al. 2006a) using global information.

The validity of employing stochastic simulation of the seismological model has been shown by a series of calibration studies. A calibration study was undertaken by Chandler et al. (2006b) for the Hong Kong region involving macro intensity data. Similar calibration studies were also conducted for Melbourne, Australia (Lam et al., 2006), and Tehran, Iran (Sabegh and Lam, 2008). Representative seismicity parameters adopted for Arup study and HKU study are summarized in Table 2.

3.5 *Logic Tree*

The logic tree that was developed for Arup study is shown in Figure 5.

4 SEISMIC HAZARD ASSESSMENT RESULTS

4.1 *Peak Horizontal Ground Acceleration on Rock*

The calculated hazard levels, in terms of peak horizontal ground acceleration on rock, at the three probabilities of being exceeded, are summarised in Table 3.

4.2 *Uniform Hazard Response Spectra (UHRS) on Rock*

The calculated hazard levels, in terms of horizontal response spectral acceleration (for 5% damping) on rock, at the three probabilities of being exceeded, are summarised in Table 3. The assessment has been undertaken for periods of 0.1, 0.2, 0.5, 1.0, 2.0 and 5.0 seconds. The uniform hazard response spectra (acceleration, velocity and displacement) at each probability of being exceeded are shown in Figures 6, 7 and 8. It is noted that Figure 8 is plotted in a different format of acceleration-displacement response spectra (ADRS). The horizontal velocity UHRS obtained by adopting HKU attenuation relationship in both the conventional Cornell's approach and the alternative HKU approach (Tsang 2006, Tsang et al. 2007) have also been plotted on Figure 7. The results are found to be in reasonable agreement generally.

Table 2. Input parameters for Southeast China stochastic model

Seismological Parameters		Arup (Free et al. 2004)	HKU (Tsang 2006)
Source Model		CENA model, Atkinson (1993) , S(M,f) M is the moment magnitude and f is frequency.	
Geometrical Spreading		$30 / R$ ($R \leq 45$km) 0.667 ($45\text{km} < R \leq 75$km) $5.77 / R^{0.5}$ ($R > 75$km) where R is hypocentral distance in km, Lam et al. (2000)	
Anelastic Attenuation		(i) Western North America, Boore et al. (1993): $Q = 204f^{0.56}$ (ii) Eastern North America, Atkinson & Boore (1995): $Q = 680f^{0.36}$ (iii) Southeast China, Wong et al. (2002): $Q = 481.5f^{0.31}$ (iv) Southeast China, Lam et al. (2000a, 2000b): $Q = 592f^{0.36}$ for Southeast China $Q = 250f^{0.54}$ for Taiwan where Q is the wave transmission quality factor and f is frequency and the weighting of the attenuation refer to the logic tree in Figure 5.	(i) Southeast China, Tsang (2006): $Q = 256f^{0.7}$ for $R < 200$ km $Q = 348f^{0.54}$ for $200 < R < 500$ km $Q = 384f^{0.51}$ for $R > 500$km where Q is the wave transmission quality factor and f is frequency
Crustal Effect	Mid-Crust	$\beta = 3.5$km/s where β is the average shear wave velocity at mid-crust (~10km depth), Lam et al. (2000)	
	Upper-crust	$\kappa = 0.01$ and $v_{30} = 2{,}000$m/s where κ is kappa value and v_{30} is the average shear wave velocity within the upper 30m, Lam et al. (2000)	$\kappa = 0.03$ and $v_{30} = 2{,}000$m/s where κ is kappa value and v_{30} is the average shear wave velocity within the upper 30m, Chandler et al. (2006a, 2006b)

Table 3. Seismic hazard assessment results

Probability of Being Exceeded	Peak Acceleration (m/s²)	Spectral Acceleration (m/s²)					
		Period (s)					
		0.1	0.2	0.5	1.0	2.0	5.0
50% in 50 years	0.48	1.00	0.82	0.40	0.16	0.07	0.02
10% in 50 years	1.50	3.09	2.24	1.01	0.41	0.15	0.05
2% in 50 years	3.41	6.82	4.66	2.01	0.81	0.30	0.08

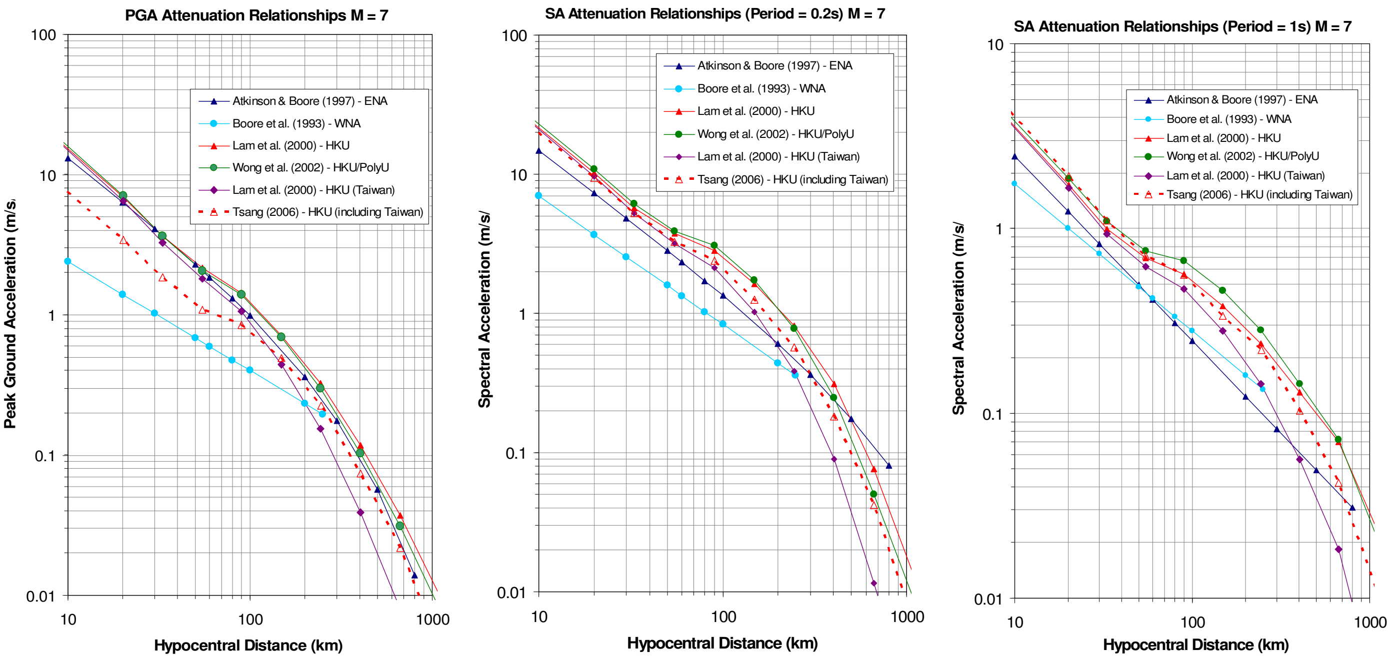
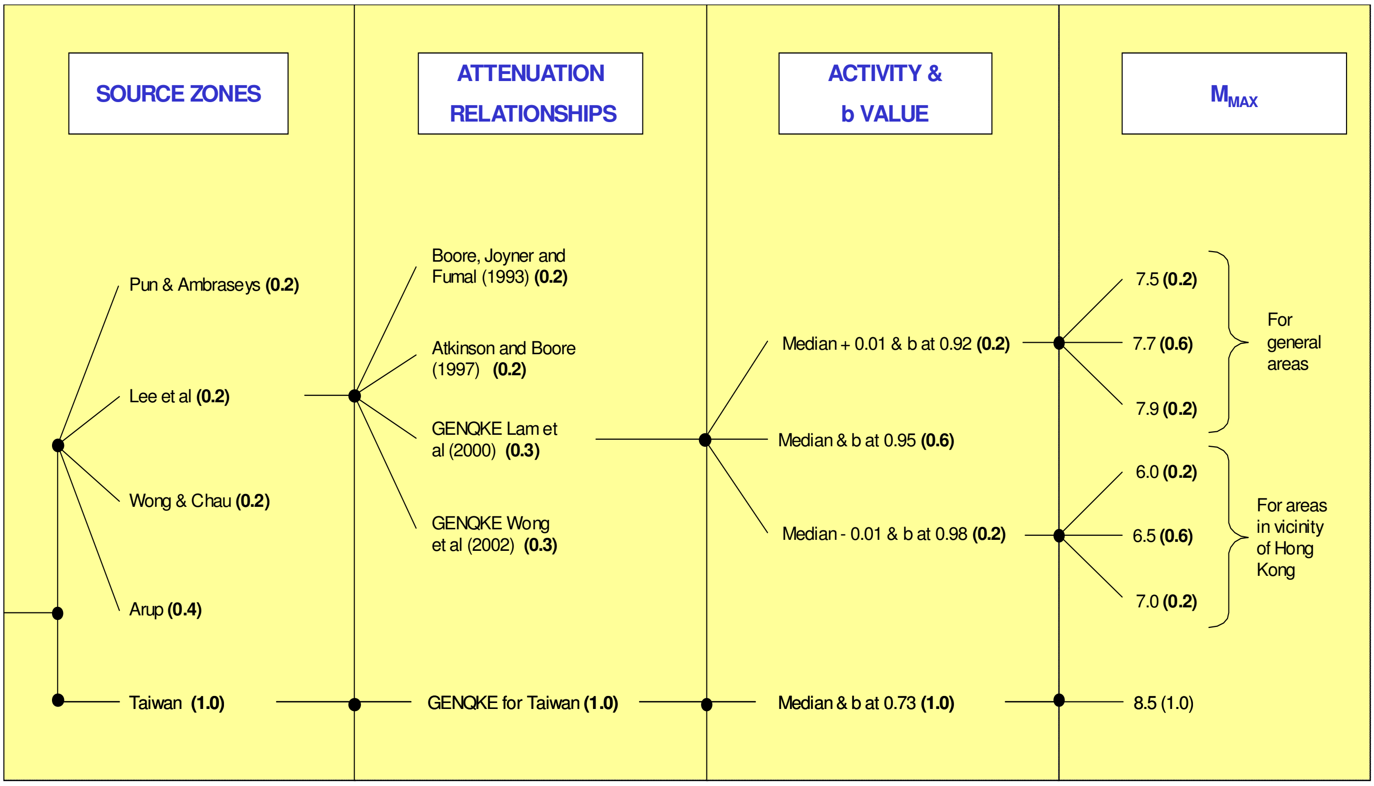


Figure 4. Attenuation relationships for peak ground acceleration and spectral acceleration used in Free et al. (2004) and Tsang (2006)



NOTE: (0.5) = Weight : For the 5 second period only the GENQKE attenuation relationships have been used.

Figure 5. Logic tree

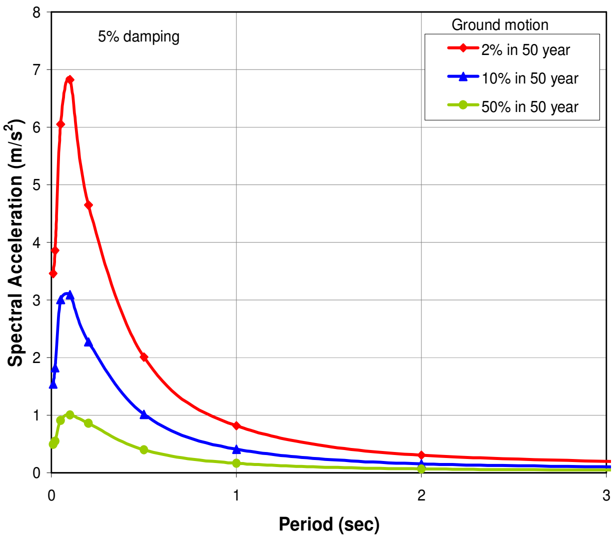


Figure 6. Horizontal acceleration UHRS on rock sites

The difference may be explained by the following two main reasons: (1) The seismological quality (*Q*) factors and upper crustal attenuation parameters (κ) adopted in the attenuation for the HKU study are based on the latest research as presented in Table 2. It is noted that the effect is significant to seismic waves of high-frequency contents with higher κ, hence, the hazard levels represented by peak ground acceleration (PGA) would be lower. (2) The HKU study has included major historical events in source-site distances up to 1500km. For such far-field and mostly large magnitude earthquakes, the contribution of long period seismic wave components is still significant, although most high frequency components of seismic waves have been attenuated. In the light of this, the hazard level in long period range especially for more frequent 50% in 50-years ground motion would be enhanced due to a larger number of "participating events" in the computation.

A sensitivity analysis has been carried out for using maximum magnitudes of 7.0 and 6.0 in the vicinity of HK for Arup model without different weightings. The results, as shown in Figure 9, indicate that the effect of maximum magnitude is not significant.

The 2% in 50-years ground motion acceleration response spectra are compared with the 0.2 and 1.0 second spectral values defined in IBC 2006 (2006) for New York City and the acceleration response spectral values determined for New York by Weidlinger Associates (2000). It can be seen that the 2% in 50-year hazard level for New York is very similar to the hazard level calculated for Hong Kong as shown in Figure 10. It is noted that the IBC model for New York is based on the hyperbolic relationship which stipulates that spectral acceleration is halved as the natural period is doubled. This will give more conservative results for design intent purpose than this hazard study for long period greater than 1.0 second.

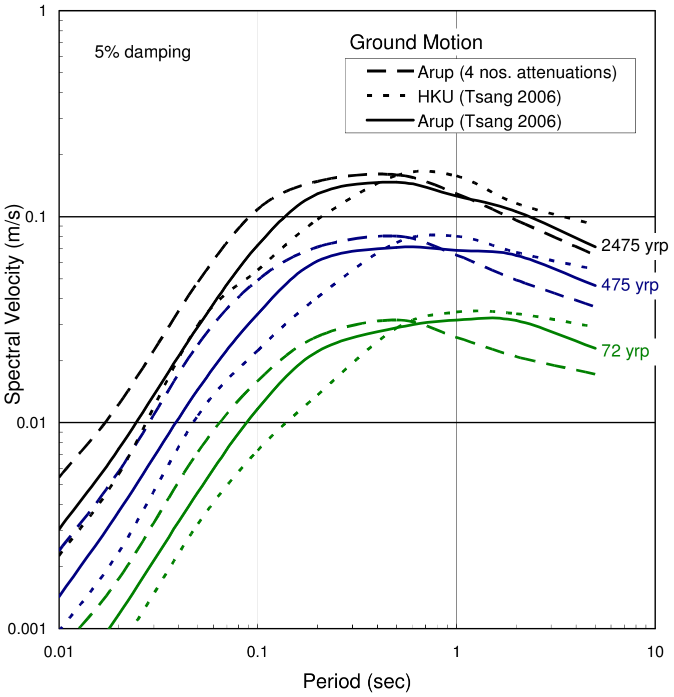


Figure 7. Comparison of horizontal velocity UHRS on rock sites using different attenuation relationships

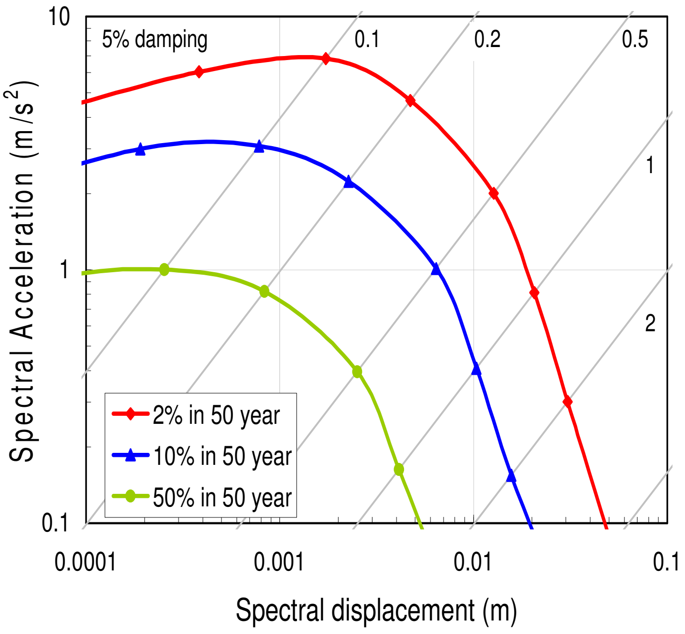


Figure 8. Horizontal acceleration-displacement response spectra (ADRS) on rock sites

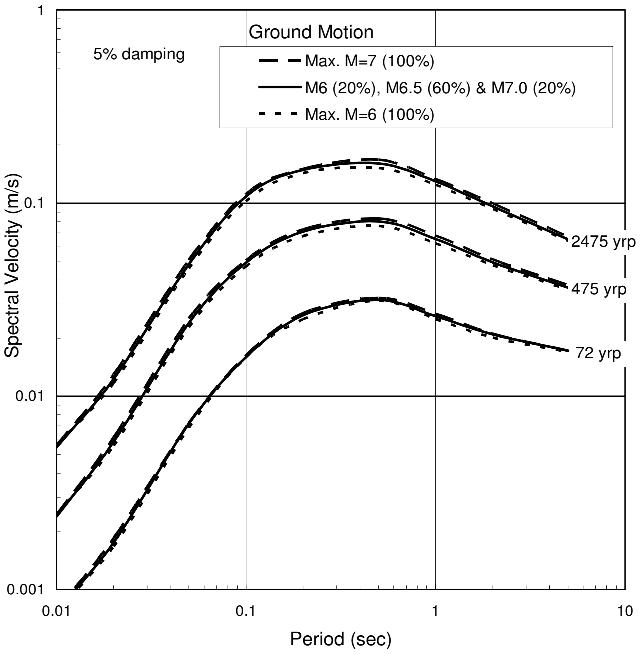


Figure 9. Comparison of UHRS using different maximum magnitudes in the vicinity of HK for Arup model

4.3 *Recent Earthquakes felt in Hong Kong*

There are two recent recorded earthquakes which were felt by many people across Hong Kong. One is a near-field earthquake of magnitude 3.5 occurring at Dangan Island on 14 September 2006 about 30km away from Hong Kong, with an estimated return period of 25 years. Another one is a far field earthquake of magnitude 7.2 occurred near Taiwan about 670km away from Hong Kong, with an estimated return period of 10 years. The ground motion data were recorded by the seismic monitoring network installed by the Hong Kong Observatory. Eight seismograph stations are situated on good bedrock sites within the territory of Hong Kong. Each seismograph station is equipped with a robust seismometer that provides velocity and acceleration outputs, with frequency range of 1 to 30 Hz. Detailed information of the network can be found in Tam et al. (1997).

The response spectra for these two earthquakes have been computed and plotted with the uniform hazard spectra with different return periods in Figure 11. Figure 11 shows that the far field earthquake event from Taiwan has higher spectral response in long period range than the near field event in Dangan Island, even though the return period of this far field event is shorter. However, the relatively high frequency content at short period of about 0.2 second period for this far-field Taiwan earthquake is unexpected. Figures 12 and 13 show the comparison of velocity spectra of recorded earthquakes with attenuation relationships used in the Arup and HKU studies. Figures 12a and 12b shows that the original attenuation relationship by Arup study fits the near-field Dangan Island earthquake quite well. It also indicates that HKU model gives the lower bound of spectral values for this near-field earthquake. Figures 13a and 13b indicate that the revised attenuation relationship by HKU fits better to the far-field Taiwan earthquake at short period, however, the spectral shape for this far-field earthquake is still quite unexpected with relative lower spectral values at period more than 0.2 second period. Also, it indicates that the recorded earthquakes have lower spectral values than both HKU and Arup models for 0.5 to 1 second periods. It must be emphasized that comparisons of this type with a single earthquake event, while being of interest, are not sufficiently statistically reliable to be able draw any meaningful conclusions. Many more events are required.

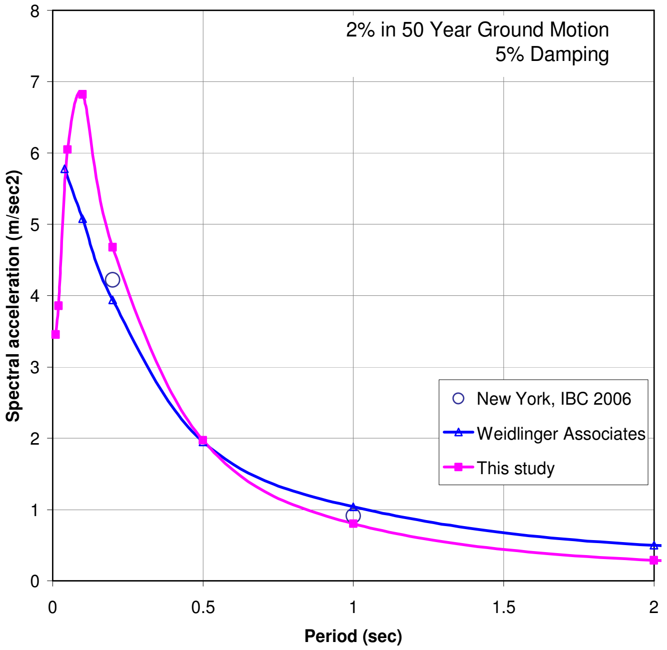


Figure 10. Comparison of bedrock 2% in 50-year UHRS with spectra for New York (IBC-2006 and Free et al. 2004)

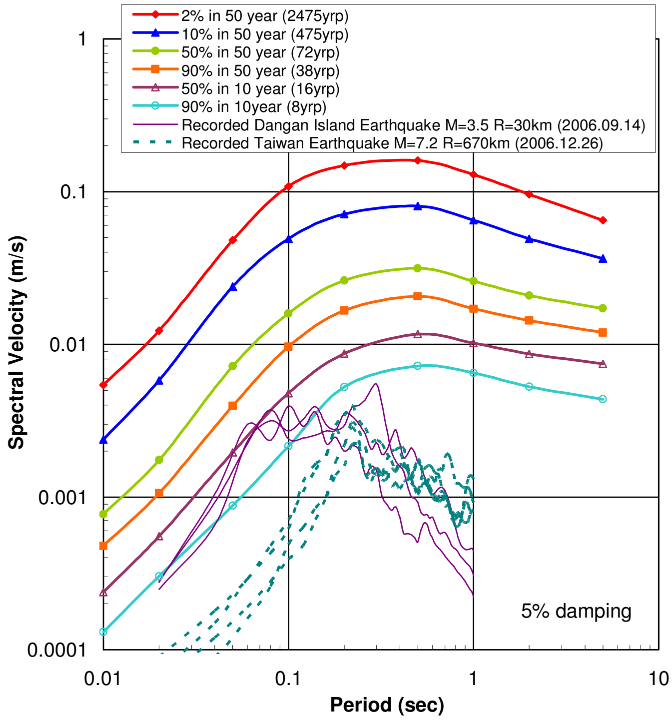


Figure 11. Recent recorded earthquakes spectra in Hong Kong

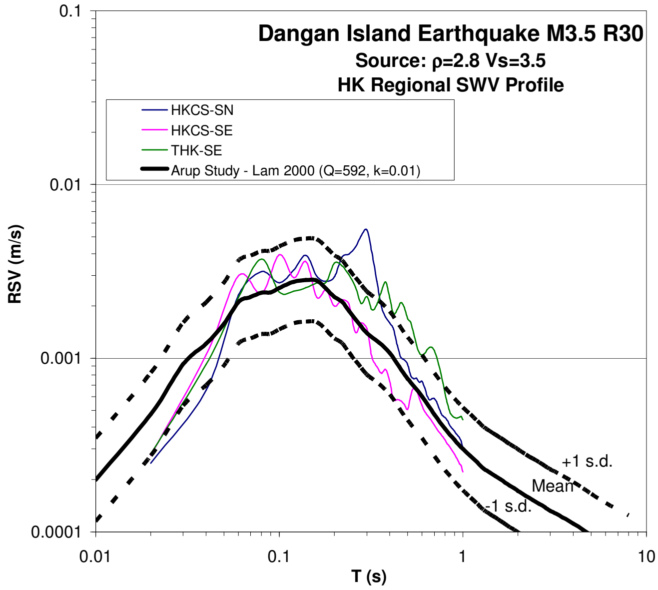


Figure 12a: Comparison of velocity spectra of Dangan Island earthquake with Arup study

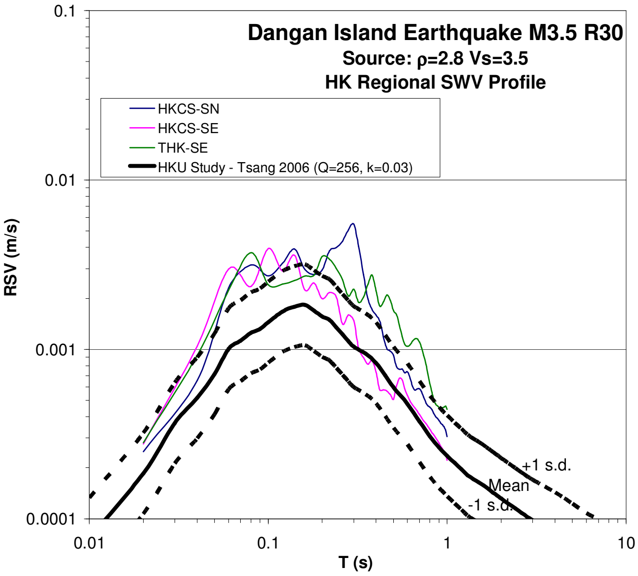


Figure 12b. Comparison of velocity spectra of Dangan Island earthquake with HKU study

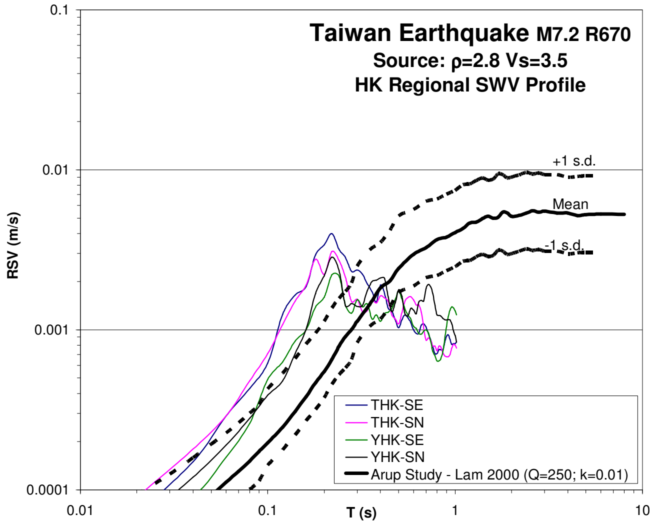


Figure 13a. Comparison of velocity spectra of Taiwan earthquake with Arup study

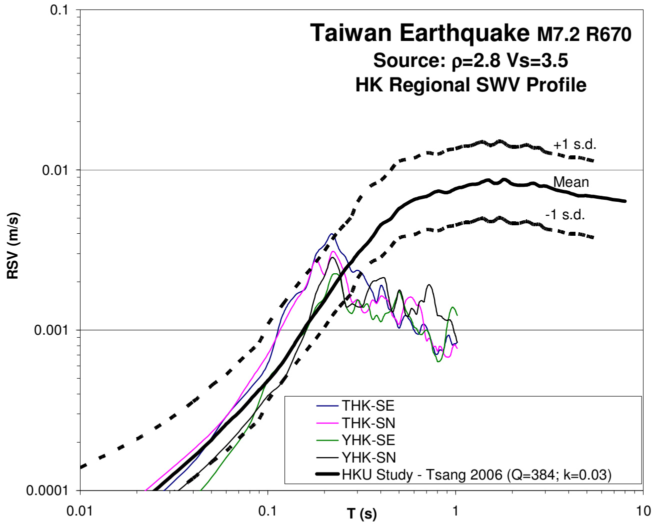


Figure 13b. Comparison of velocity spectra of Taiwan earthquake with HKU study

4.4 *De-aggregation of Hazard*

Based on the seismic hazard study conducted by Free et al. (2004), with the use of four attenuation relationships, the hazard results have been de-aggregated, in terms of magnitude and distance, to investigate earthquake occurrences that have contributed the most to the resulting ground-motion hazard. The de-aggregation was undertaken in accordance with the procedure recommended by McGuire (1995). Bazzurro & Cornell (1999) discuss various methods to carry out de-aggregation including the method proposed by McGuire. They discuss how, when determining the relative contribution at various distances, the log of the distance or the linear distance can be used. For a region with dispersed seismicity such as Hong Kong, it is considered that log of distance is more appropriate.

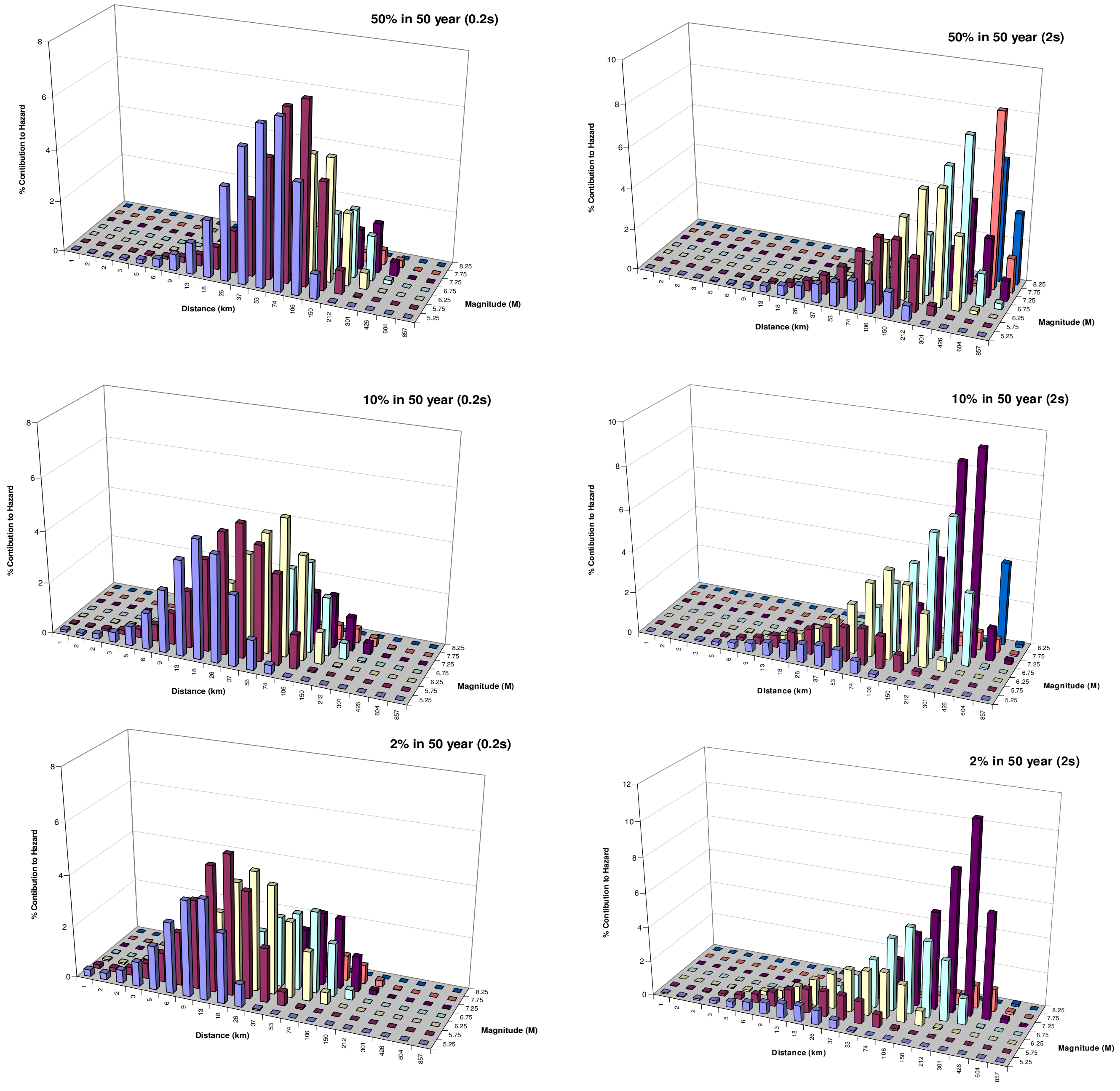


Figure 14. De-aggregation of UHRS at 0.2 and 2.0 seconds for three hazard levels, 50%, 10% and 2% in 50-year based on seismic hazard results using four attenuation relationships

De-aggregation has been carried out for peak horizontal acceleration, and the 0.2, 2.0 and 5.0-second response spectral ordinates at the three probabilities of being exceeded. The results of the de-aggregation at the 0.2 and 2 second acceleration response spectral values are shown in Figure 14.

Moreover, for the seismic hazard results solely based on HKU attenuation relationship, the de-aggregation plots, as shown in Figure 15, indicate that the percentage of contributions of different earthquake scenarios for 0.2 second are similar. However, the percentage of contributions of large earthquake magnitudes (M > 8.0) events from Taiwan is significantly higher in 2.0 seconds for 10% and 2% chance exceeding in 50 years.

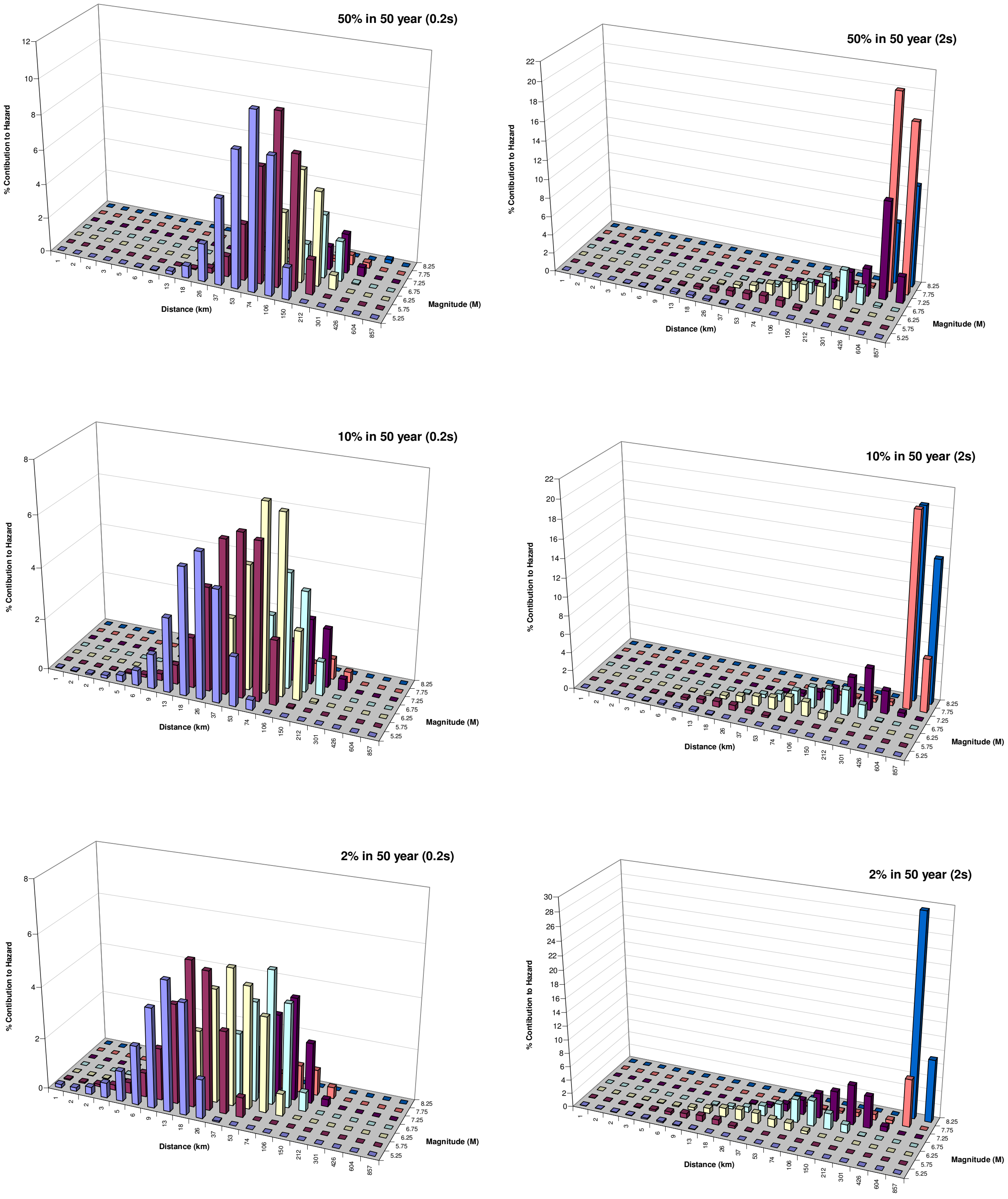


Figure 15. De-aggregation of UHRS at 0.2 and 2.0 seconds for three hazard levels, 50%, 10% and 2% in 50-year based on seismic hazard results using HKU attenuation relationship

5 DISCUSSION OF RESULTS

The observed seismicity in the region shows that the seismic activity is similar to that observed in the Eastern North America and about 50 times less than that in highly seismic areas such as California, Japan, Taiwan or the Philippines (see Figure 16). The statistics show that the probability for a large magnitude event with M > 7, within 100km of Hong Kong in 50 years, is around 1.5%. For a moderate size event, with magnitude M > 6, within 100km of Hong Kong in 50 years, the probability increases to between 6% to 12%. For a smaller size event, with a magnitude M > 5, within 100km of Hong Kong in 50 years, the probability is approximately 60% to 70%. For a very small magnitude event, with M > 4, within 100km of Hong Kong in 10 years, the probability is greater than 80%.

In summary, the seismic hazard for Hong Kong on rock sites (for 2% probability of being exceeded in 50 years) can be represented by the earthquake scenario of M = 6 at R = 30 km, which is the most critical to the seismic performance of the more vulnerable low rise buildings including soft-storey buildings. The alternative scenario of M = 6.5 at R = 40 km or M = 7.5 at R = 300 km can be used for the assessment of taller buildings.

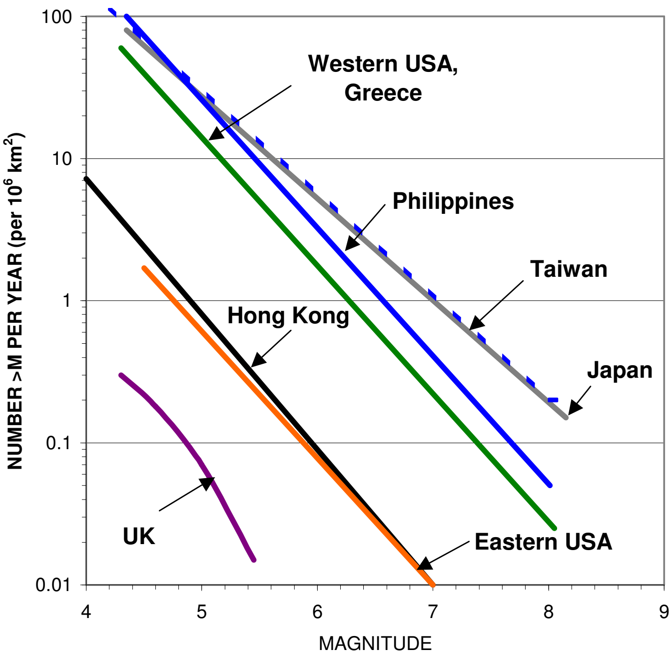


Figure 16. Comparison of seismicity of the Hong Kong region with other regions (Department of the Environment 1993)

6 CONCLUSIONS

Probabilistic seismic hazard assessment studies carried out in recent years for the Hong Kong region have been reviewed. The results of the seismic hazard assessment are presented in terms of uniform hazard horizontal response spectra for structural periods up to 5 seconds for bedrock ground conditions. The results are presented for ground motions with various probabilities of being exceeded in 50 years. To capture the uncertainty in the calculation, input for the probabilistic assessment a range of seismic source models, variations of seismic activities and several different attenuation relationships have been incorporated using the logic tree method. The results have also been compared with those obtained from a recently-proposed alternative approach developed in UHK. The results of comparison are found to be in good agreement in general.

The resulting ground motion seismic hazard shows peak horizontal ground accelerations of 5%, 15% and 35% of gravity for the ground motion levels with 50%, 10% and 2% probability of being exceeded in 50 years. The response spectral values in the medium to long structural period range are found to be very similar to those published for New York City at short period range up to around 1.0 second. Recent recorded earthquakes in Hong Kong are presented with the uniform hazard bedrock ground-motion spectra for different return periods.

The seismic hazard has been de-aggregated to determine scenario earthquakes for the three design levels. A selection of scenario earthquakes has been determined ranging from a magnitude M = 6.0 at 150 km to a magnitude M = 8.0 at 600km (originating in the Taiwan region) to represent the relatively likely ground motion having a 50% chance of being exceeded in 50 years. For less probable, extreme ground motions with a 2% chance of being exceeded in 50 years, the selection ranges from a magnitude M = 6.0 event at 30 km to a magnitude M = 7.5 event at 300km.

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