

# SEISMIC DESIGN OF BUILDINGS IN HONG KONG

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*This paper describes the seismic hazard in Hong Kong and compares the findings with other published data. The paper describes the magnification of bedrock accelerations found at three deep soil sites which are typical for Hong Kong reclamation sites.*

*An appropriate seismic design procedure is presented for typical building structures in Hong Kong founded on bedrock and reclamation sites. The recommendations are briefly compared with the United States Uniform Building Code and the Chinese Code requirements.*

*The paper concludes that seismic design for buildings in Hong Kong will generally not effect high rise buildings. However, low rise buildings and transfer structures are more susceptible and should be checked for seismic loading in design.*

*The seismic design method proposed in this paper is broadly based on the recommendations currently being considered in New York.*

## Introduction

Hong Kong is in an area of low to moderate seismicity. The Hong Kong building code has no requirement for seismic design or detailing. The typhoon wind loads are very high and because ground floor space is so valuable, structural gymnastics are frequently used to achieve irregular, open structures with maximum lettable space at ground level (soft storey structures as discussed later).

While there is much published information on appropriate seismic design procedures and practice for areas of high seismicity, the guidance for areas of low to moderate seismicity is limited. This is probably due to lack of historical data on the performance of ordinary structures under large earthquakes. The relatively small earthquake ( $M = 5.6$ ) which occurred very close to the town centre of Newcastle in Australia, an area of low seismicity similar to Hong Kong, caused about 20 billion Hong Kong dollars of damage and 13 deaths (EEFIT, 1991). This event increased the momentum within many countries to review the seismic hazard in areas of low seismicity which can be subject to rare but significant events.

The proposed seismic design procedures outlined in this paper are based on the Draft code recently prepared for the City of New York. New York, like Hong Kong, is in an area of low to moderate seismicity and has been developed without any seismic design provisions. The Draft code, however, is expected to be adopted in the near future. The design procedures proposed here are somewhat tentative and are, by

their nature, continually developing. Ultimately the community must decide, relying on guidance from the engineering profession, on how much they are prepared to pay and to what level of security they require in the event of a rare but distressing earthquake-induced ground motion occurring in Hong Kong.

## Seismic hazard assessment

Hong Kong is located on the South China Sea plate. The nearest active tectonic feature is the boundary between the Philippine Sea Plate and the South China Sea Plate between Taiwan and the Philippines (Bennett, 1984).

In 1991, the Hong Kong Geotechnical Control Office published a "Review of Earthquake Data for the Hong Kong Region" (GCO, 1991), which provides data on historical earthquakes within a 350 km of Hong Kong. The data include an assessment of "observed" and "felt" effects of earthquakes going as far back as 1067. Also, "macroseismic" magnitudes to the earthquakes are assigned. Twenty-eight earthquakes greater than magnitude 4.8 are identified within 350 km of Hong Kong. The magnitude 5.7 earthquake in 1874, 30 km from Hong Kong, is the largest earthquake within 100 km to occur during the past 500 years; Hong Kong, at that time, was a small fishing village and unfortunately there is no record of the damage experienced by it. The magnitude 7.4 earthquake in 1918, which occurred about 300

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km from Hong Kong, is the largest in the data. Records show that several brick buildings collapsed in nearby Guangzhou (Lau, 1972). The locations of large earthquakes which should have been felt in Hong Kong are shown in Figure 1.

There are two standard approaches for defining seismic hazard at any specific location; the deterministic approach and the probabilistic approach. The deterministic approach relies on identifying individual nearby and more distant active, fault features, and assigning maximum magnitude earthquakes to each. The probabilistic approach calculates a level of ground motion, such as peak horizontal acceleration for example, having a specified probability of being exceeded within any desired time period. This probability can also be expressed in terms of a desired return period. At locations remote from plate boundaries, such as Hong Kong, active fault features are very difficult to confidently identify and consequently the probabilistic approach to seismic hazard assessment is generally preferred over the deterministic approach.

### The probabilistic seismic hazard assessment method

The probabilistic seismic hazard assessment approach is illustrated in Figure 2. The method includes identifying seismic source zones, each of which is assumed to have random earthquake activity with a known rate. For each zone, the annual rate of earthquake activity greater than a certain magnitude, and how the magnitude of the earthquakes varies must be specified. The maximum and minimum magnitude contributing to the overall hazard must also be considered. An attenuation relationship, which defines the level of the expected ground motion (acceleration for example) at a certain distance from an earthquake of known magnitude, is also required together with a measure of the variability of this ground motion. It is well established that acceleration, for example, is log normally distributed and therefore the variability can be defined in terms of the standard deviation of the logarithm of the acceleration. This variability is directly incorporated into the probabilistic calculations.

### Input data to the seismic hazard calculation

The Arup program SISMIC has been used to calculate peak ground accelerations and bedrock response spectra for

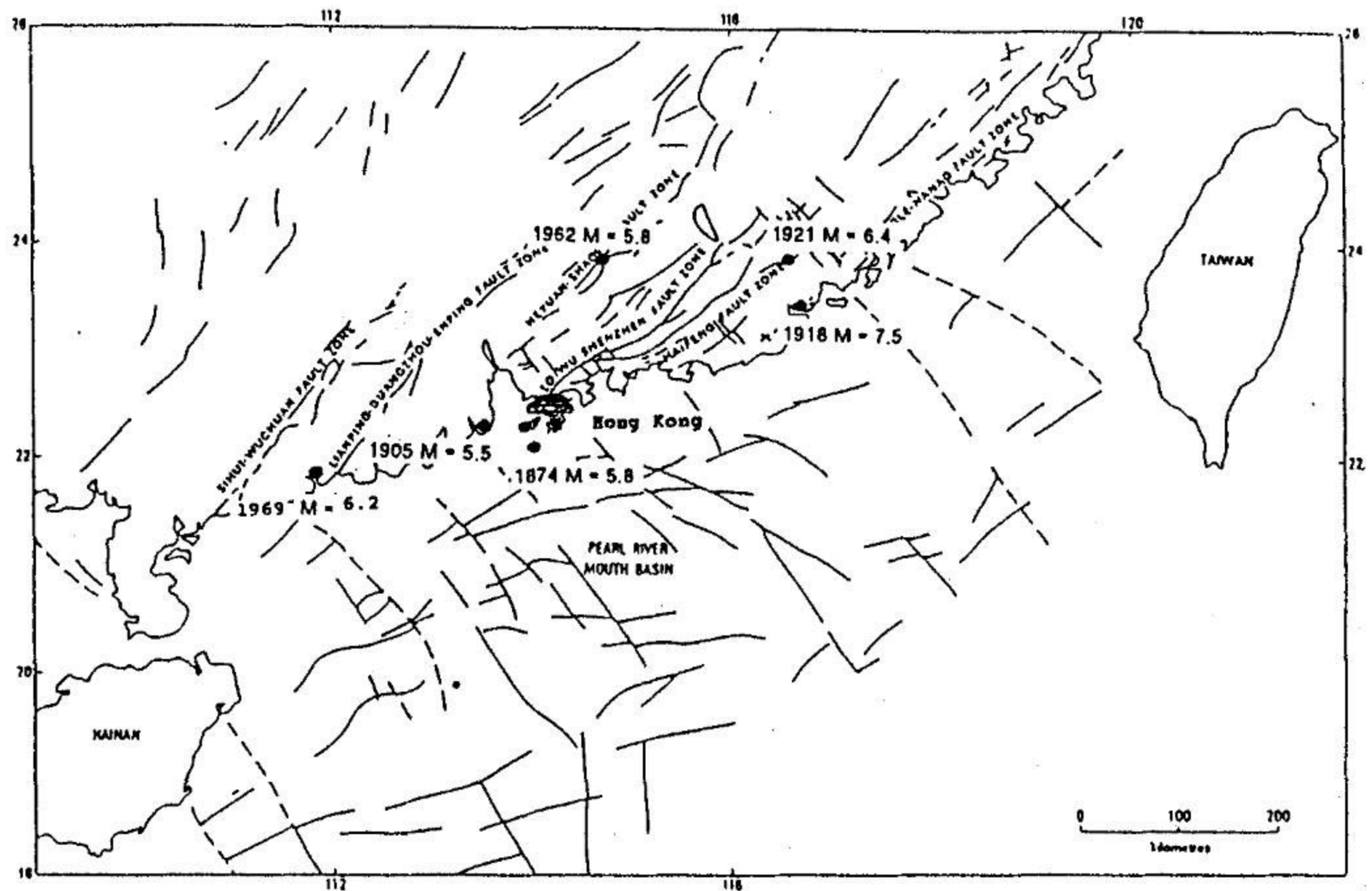


Figure 1: Recent major earthquakes near Hong Kong (derived from He & Chen, 1988).

return periods of 500 and 1000 years. The data used in the calculations were as follows.

### Seismic source zones and earthquake recurrence

Two earthquake catalogues have been used to derive the source zones and their associated earthquake recurrence, the instrumental catalogue collected this century, as summarized by the International Seismological Centre in the UK, and the Pun (1991) historical catalogue of earthquakes up to 300 km from Hong Kong. The latter catalogue was assembled under the direction of Prof. Ambraseys at Imperial College, University of London.

The instrumental catalogue is plotted according to magnitude and location in Figure 3. Zone 1 on the figure represents the area around Hong Kong that appears, from the catalogue, to exhibit relatively uniform seismicity. The earthquakes within this zone, since 1920 and 1963 (the dates which represent relatively uniform worldwide instrumental data), are shown on a conventional Gutenberg-Richter recurrence plot in Figure 4a. The figure indicates that the instrumental catalogue is complete for earthquakes having a magnitude greater than about 6 since 1920 and for earthquakes having a magnitude greater than about 4.5 since 1963.

Zone 2 on Figure 3 shows the area applicable to the historical catalogue. It is a sub-area of Zone 1 and extends to about 300 km from Hong Kong and out to about 100 km offshore. This distance offshore is considered to be at the limit of reliable perceptibility for a magnitude 5 earthquake occurring offshore and consequently included in the historical catalogue. The earthquake recurrence within Zone 2 indicated by the historical catalogue is shown in Figure 4b. The figure

indicates that the historical catalogue is complete for earthquakes having a magnitude greater than about 6 since 1500 and for earthquakes having a magnitude greater than about 5 since 1870. The earthquake recurrence within Zone 2 indicated by the instrumental catalogue is also shown in Figure 4b. It can be seen that there is reasonable agreement between the two catalogues. Figures 4a and 4b also show the earthquake recurrence curve used in the calculations. The curve has been normalized to the relative areas of Zones 1 and 2 and show that the activity is consistent between the two zones and time periods. This is significant and increases the confidence in which both the catalogues can be applied.

In the vicinity of Hong Kong a uniform source zone would appear to be appropriate and this source model has therefore been used in the seismic hazard calculations. The observed earthquake recurrence, normalized to an area of  $10^6 \text{ km}^2$  is shown on Figure 5 and compared to other countries. As can be seen the rate of earthquake activity in the vicinity of Hong Kong is similar to Eastern USA.

The depth distribution of earthquakes used in the calculations were assessed to be similar to that observed in other areas of low to moderate seismicity (Arup - UK study 1993); and comprises 20% at 5 km, 30% at 10 km, 30% at 15 km and 20% at 20 km. A magnitude of 4 was assumed to be the minimum size earthquake that would sensibly contribute to the seismic hazard and a maximum magnitude of 7.2 was also assumed.

#### Attenuation relationships

Two attenuation relationships have been used in the analyses. They are the relationship published by Dahle et al (1990) which was specifically developed for bedrock sites in regions remote from plate boundaries, such as Hong Kong, and that by Boore & Joyner (1991) which was developed for deep soil units in the eastern part of the USA, again an area of low to moderate seismicity similar to Hong Kong. Variability of the ground acceleration was assumed to be the average of those observed elsewhere (BGS and Arup, 1994) and has been assigned values of the standard deviation of the natural log increasing from 0.6 for peak ground acceleration to 0.74 for

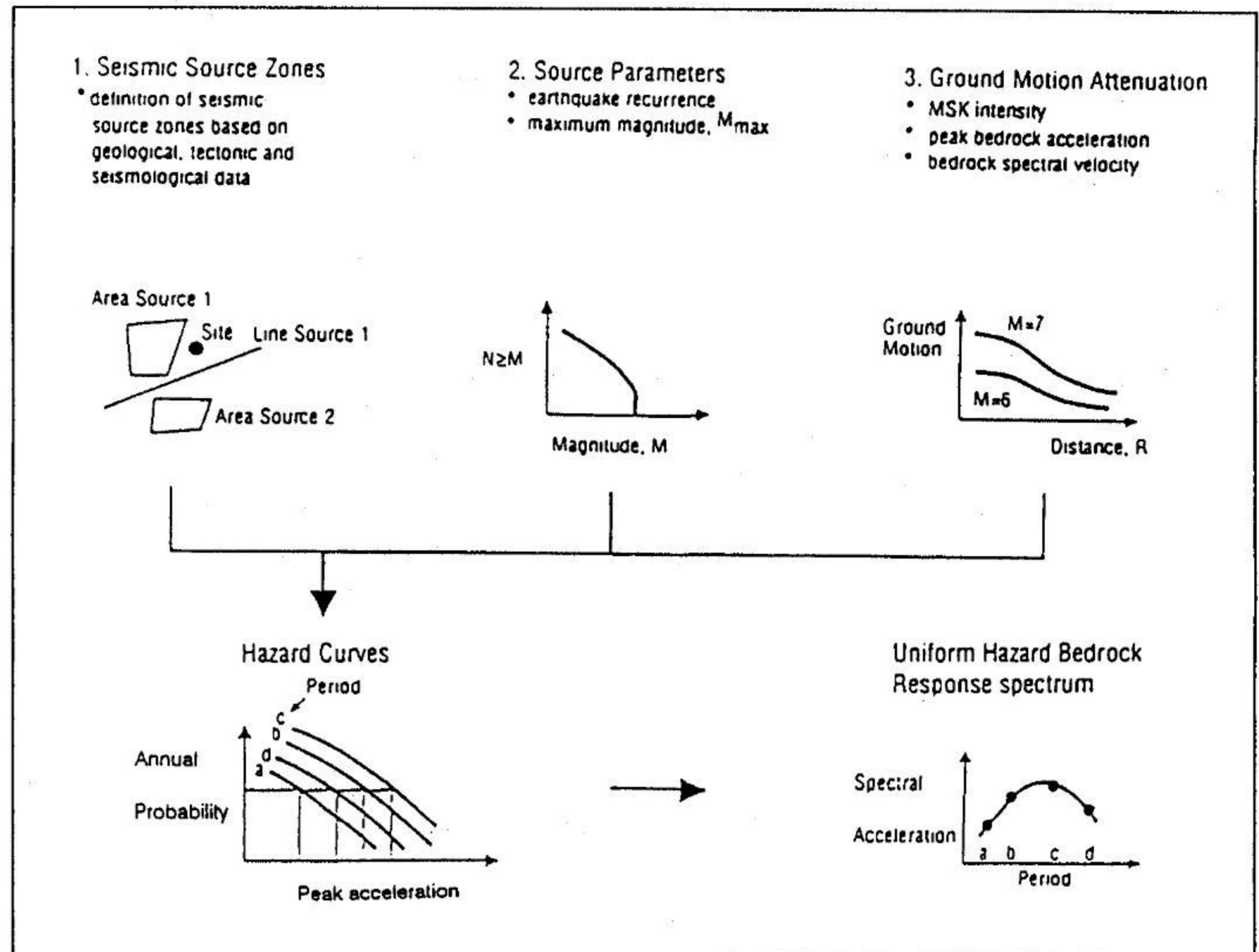


Figure 2: Probabilistic seismic hazard assessment methodology.

the 2 second fundamental period acceleration.

#### Calculated peak ground accelerations and response spectra

The calculated peak ground accelerations are:

Annual Probability of being Exceedance (Return Period: Years)	Peak Horizontal Acceleration (m/s)	
	Dahle et al (1990)	Boore & Joyner (1991)
$2 \times 10^{-3}$ (500)	1.2	1.3
$1 \times 10^{-3}$ (1000)	1.6	1.7
$5 \times 10^{-4}$ (2000)	2.2	2.5

Figure 6 shows the 1000 year return period uniform hazard bedrock spectrum derived by calculating response spectral values at a range of fundamental periods. At each fundamental period the spectral value has the same probability of being exceeded. Response spectra are very useful because they give a direct indication of the maximum force experienced by an elastic system with a certain level of damping (in this case 5%).

The relative contribution of earthquake distance and magnitude is shown in Figure 7. As can be seen the peak ground acceleration (the same as low period response spectral values) has a significant contribution from earthquakes of about mag-

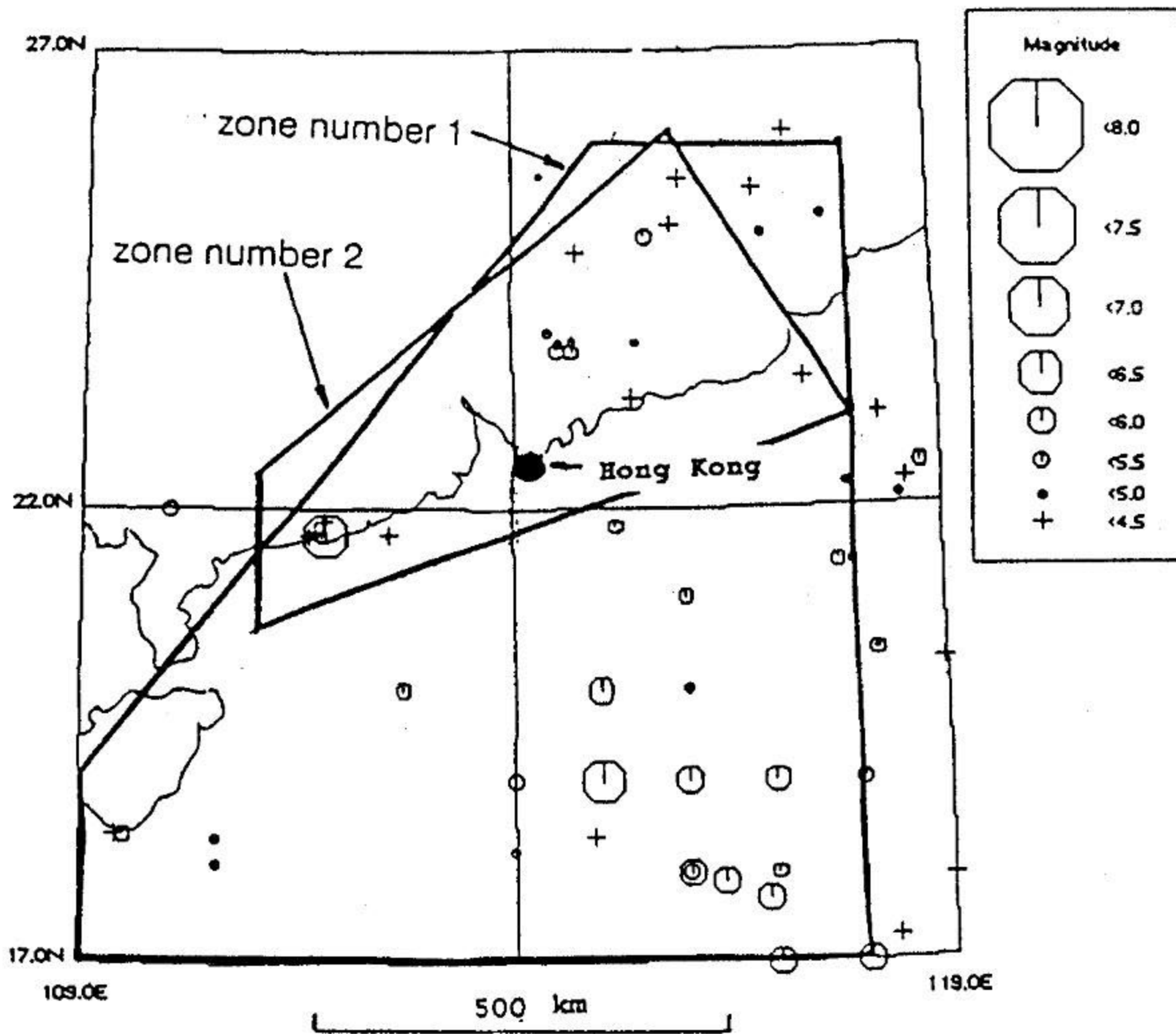


Figure 3: Recent instrumental seismic data  $M > 4$  since 1963.

nitide 6 and occurring about 20 km away. For a 2 second period motion greater magnitudes between 50 to 100 km away are the major contributors to the hazard.

### Building design

In the absence of any code requirements for seismic design in Hong Kong, the authors have developed a procedure to be applied to the design of buildings.

There is little published data and few codes which cover appropriate design techniques for areas of low to moderate seismicity. The Draft New York Seismic Code (NCEER, 1991) has been used as a basis for developing a design procedure because it is one of the most modern codes developed specifically for an area of low to moderate seismicity. There has been no attempt to directly relate the seismic hazard of New York, however Figure 5 shows that the East Coast of the USA has a similar seismicity to Hong Kong. The Draft New York Code is largely based on the American UBC/SEAOC codes which are commonly used in South East Asia and many other parts of the world.

### Equivalent zoning to UBC

The UBC, and the Californian Code (SEAOC, 1988) are based on ground accelerations which have a 10% probability of being exceeded in 50 years. Statistically this is equivalent to a return period of 475 years. The Z factor, as defined by the code, corresponds to the effective peak ground acceleration with this probability of occurrence.

On the basis of ground accelerations, Hong Kong (calculated to have a peak ground acceleration of about 12%) should be classified as Zone 2A. However, it is becoming well known that the UBC response spectral shape at longer fundamental periods is very conservative in areas of low seismicity. Figure 8, for example, shows the UBC Zone 1 spectra for soil type S2 (deep stiff soil) and compares this with the Hong Kong spectrum for the same soil. At periods longer than 0.5 seconds, it can be seen that even the UBC Zone 1 curve overestimates the spectral acceleration for Hong Kong.

Recent work by Algermissen & Leyendecker (1992) and others in the USA have confirmed this trend. Figure 9 shows his calculated spectra for a range of US cities located in a variety of zones. Also shown is our curve for Hong Kong. On this basis it appears that Hong Kong corresponds to cities in the US considered to be in Zone 1 to Zone 2A. It appears likely that the Algermissen curves will be adopted in forthcoming revisions of the US codes of practice.

### Design return periods

As stated previously the UBC and SEAOC are based on the 475 year return period value (very similar to the 500 year return period value) which is the event with a 10% probability of occurring in 50 years. In areas of high seismicity the ground motion from a maximum credible earthquake is about double that of a 500 year return period value. In areas of low to moderate seismicity the ground motion from the maximum credible event can be several times larger than the 500 year return period value.

Therefore to maintain the same level of reliability or safety under the maximum credible event, the 500 year return period value is questionable for use as a design value in areas of low seismicity. This has been noted by Booth & Skipp (1991) and Nordenson (1989) who have demonstrated that by adopting the 1000 year return period value, the same level of reliability is obtained in areas of low seismicity as that achieved in areas of high seismicity which use the 500 year return period value for design.

However the question remains, is this increase necessary. Should areas of low to moderate seismicity make provisions for such unlikely events? This is clearly a question for clients and the community. Zoning in the United States is proceeding on the basis of a 475 year event. New Zealand designs are also based on this irrespective of the level of seismicity although engineers are warned against using this return period for structures with limited ductility. The authors consider that

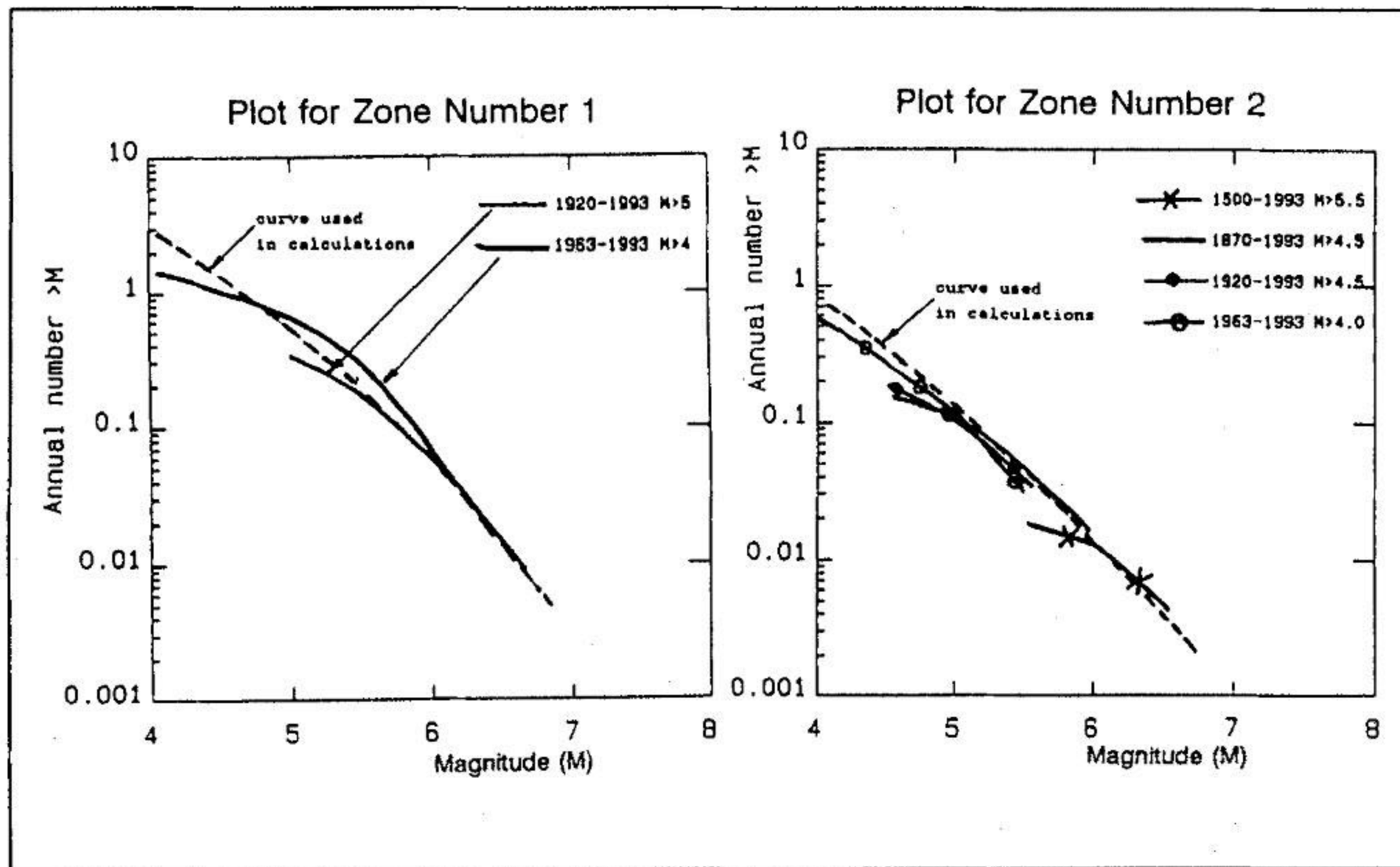


Figure 4: Earthquake recurrence plot for zones of uniform seismicity.

the 1000 year value should be used in Hong Kong.

#### Effects of local ground conditions

The amplification of earthquake ground motion due to

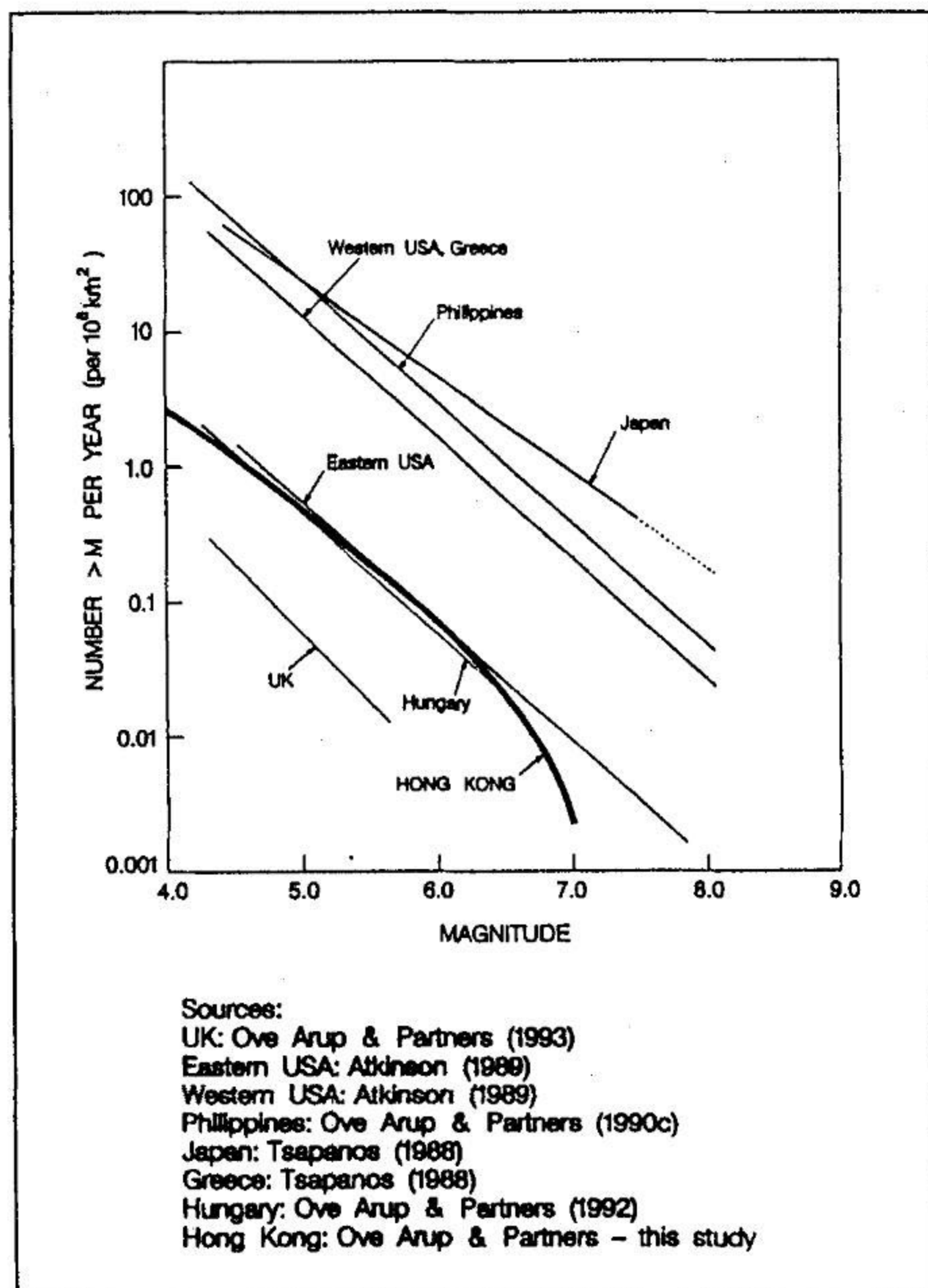


Figure 5: Relative seismic activities.

deep soft soil have been investigated. Three sites in areas of reclamation have been investigated and their soil profiles are shown in Figure 10. For each of the three sites the earthquake site response has been calculated by analysing the response of a one-dimensional soil column subjected to scaled earthquake time histories using the Ove Arup & Partners' non-linear one-dimensional site response program SIREN (Heidebrecht et al, 1990). Three earthquakes between magnitudes 6 and 7 from Canada, Japan and Mexico were used with epicentral distances of 7.5 to 160km. The resulting uniform hazard surface spectra for a return period of 1000

years are shown in Figure 6. As can be seen the spectra are amplified over the bedrock spectrum at structural periods about 1 to 2 seconds as expected for these types of sites.

Given the typical soil conditions in the region it is likely that Figure 6 shows the likely variation of response spectra in Hong Kong.

#### Lateral force coefficient and spectral shape

The Lateral Force Coefficient, which defines the total base shear on the building, has been assessed from the site specific spectra. The lateral force coefficient does not follow the shape of the response spectrum exactly, but is intended to be increasingly conservative for long period structures. Various reasons for this are stated in the commentary to the NEHRP(1988) Section 1.4.1 which concludes that 'It was judged that a weighting factor should make the lateral force coefficient approximately 50% greater at a fundamental period of 2 seconds for the stiff soil condition than would be obtained by direct use of the response spectrum. This increase should gradually reduce as the building period shortens.' Figure 11 shows the lateral force coefficient curves derived from the Hong Kong bedrock response spectrum and from the site specific spectra for the three sites on reclamation. It can be seen that the requirements of NEHRP to provide a 50% weighting at a fundamental period of 2 seconds has been met.

#### Design base shear

The working load design horizontal base shear (V) shown in Figure 11 is defined by the following equation:

$$V = \frac{ZICW}{R_w}$$

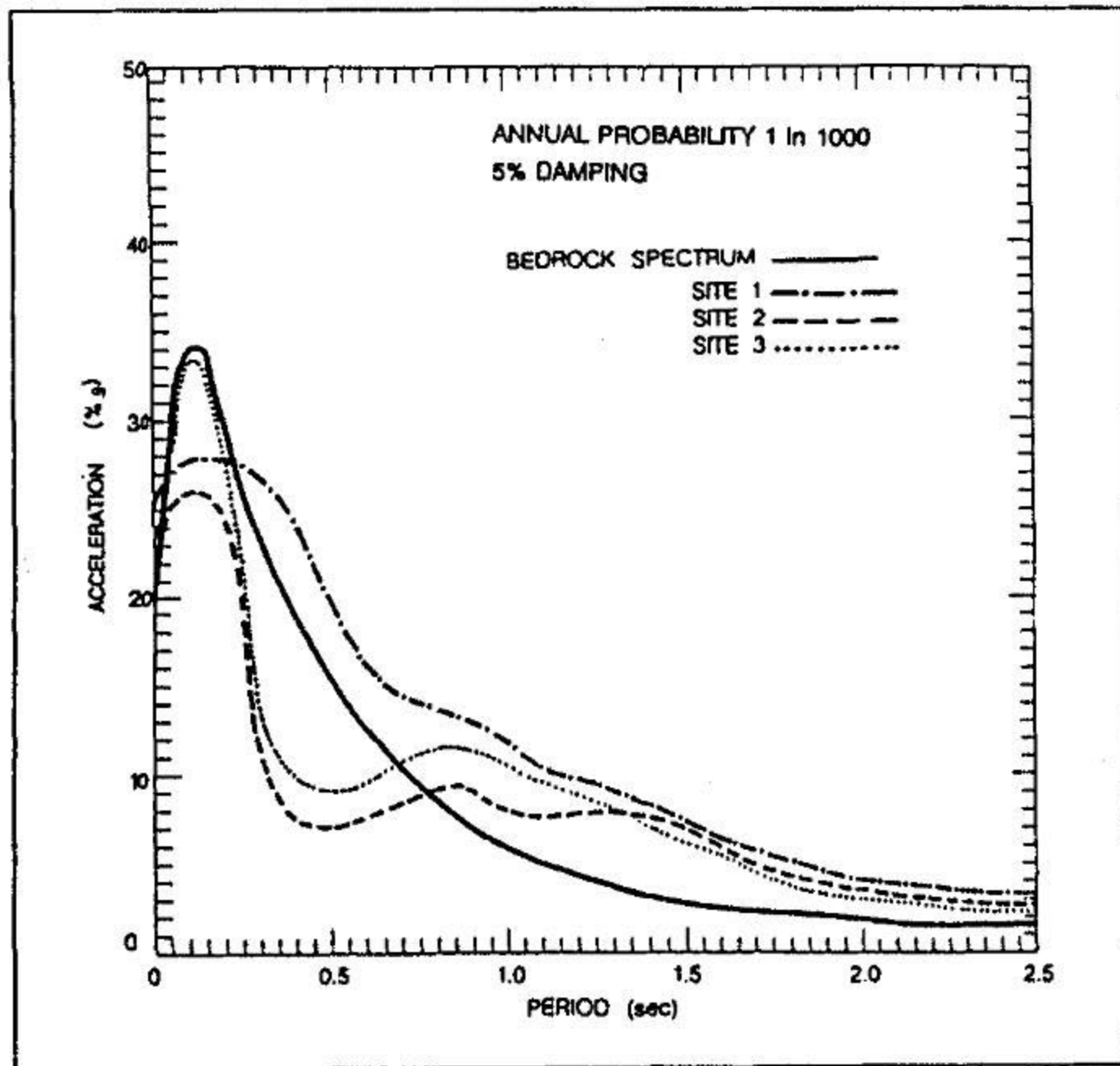


Figure 6: Site specific response spectrum.

Where  $R_w$  = System Factor

$Z$  = Zone Factor = 0.15

$I$  = Importance Factor = 1.0

(a higher value would be appropriate for special structures: hospitals, etc schools, etc)

$C = \frac{S}{T^{1.1}} \dagger 2.7 = 0.47$  for rock and hard soil sites

$S$  = Soil factor = 0.67 for reclaimed sites

$T$  = Fundamental Period =  $0.073(h)^{3/4}$  frame (see) =  $0.049(h)^{3/4}$  wall

$h$  = Building Height (m)

The base shear and design forces can be calculated from these equations and used for the design of all regular structures.

For regular structures the  $R_w$  factors the authors recommend the values in the New York Code are used. This is because the code has values for structural systems designed without any seismic provisions. Their recommended values are:

Ordinary Moment Frame (OMF)	$R_w = 4$
Shear Wall	$R_w = 6$
OMF and Shear Wall	$R_w = 5$

A simple static equivalent approach using a triangular load distribution as recommended in the UBC would be appropriate for most structures although a dynamic response spectrum

approach could be more appropriate for complex structures.

The table below summarises the differences between the Draft New York code and the procedure proposed for Hong Kong:

	Draft New York code	Proposed HK procedure
Return Period	500 yrs	1000 yrs
Base Shear $V$	$V = \frac{CIZW}{R_w}$	$V = \frac{CIZW}{R_w}$
Zone Factor $Z$	$Z = 0.15$	$Z = 0.15$
Spectral Factor $C$	$\frac{1.25S}{T^{2/3}}$	$\frac{S}{T^{1.1}}$
Soil Factor $S$	Rock $S = 0.067$ Reclamation $S = 1.2$	$S = 0.47$ $vS = 0.67$
Period in seconds $T$	Wall $T = 0.049 h^{3/4}$ Frame $T = 0.073 h^{3/4}$	$T = 0.049 h^{3/4}$ $T = 0.073 h^{3/4}$
$R_w$ - Shear Wall	6	6
- Ordinary Frame	4	4
- Ductile Frame	(12)	(12)
- Transfer Structure	-	3

### Comparison with wind loads

Figure 12 shows a comparison of wind forces and seismic forces, in terms of horizontal base shear, for various heights and types of buildings. It shows that tall buildings are dominated by wind loading. It can be seen that seismic shear loads start to become as large as wind load below 100m and are likely to be larger than wind loading below 30m.

To study the comparative loading in greater detail the bending moments induced in the structure have also been studied. The seismic shear force distribution is triangular peaking at the top of the structure whereas the wind force is more constant with height as shown in Figure 13. The seismic force will therefore lead to a larger moment than that arising from same wind shear force.

The comparisons in Figure 13 are for concrete shear wall structures founded on reclamation and are based on a building of 36 x 36m plan size with floor heights of 3m but with the first three floors at 5m centres. A dead load of 12kPa per floor has been assumed and the wind loads are based on general terrain. The curves in Figure 13 are a comparison of wind moments, governed by frontal area, and seismic moments which are governed by mass. Therefore if the frontal area, or building width changes the curves would have the same relationship to each other and only the scale would change. In contrast if the depth or mass of the building is reduced by half or doubles then the wind load would be unchanged whilst the seismic load would half or double. The results show that for a 36m deep building on soft ground, the wind and seismic moments, are the same at approximately 18 storeys (67m). Below this level seismic forces control and above this level wind controls. For the 8 storey building the seismic moments are 64% larger than the wind forces. So if, for example, the 8

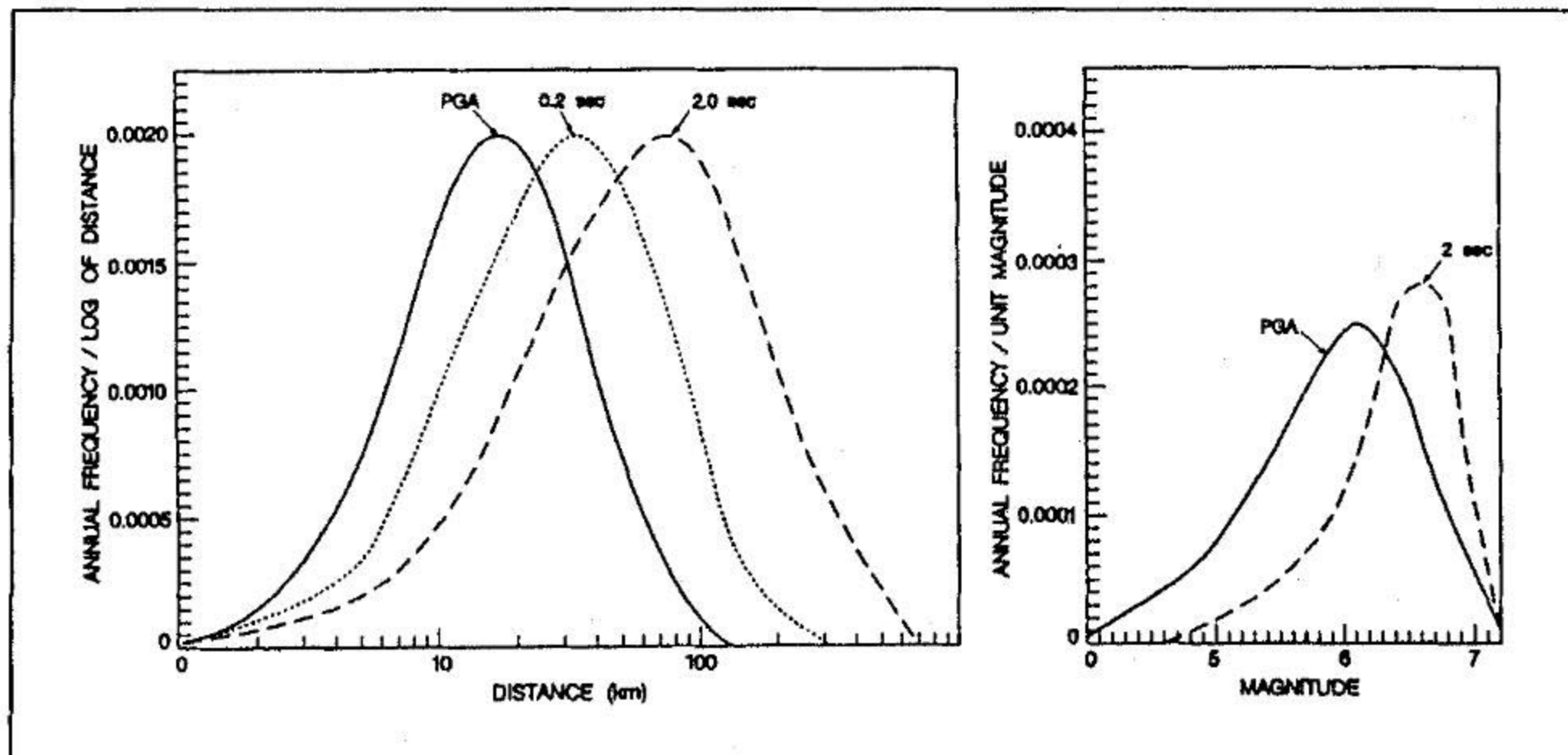


Figure 7: Contribution of distance and magnitude to the 1 in 100 annual probability seismic hazard in Hong Kong.

storey building was only 18m deep and on hard ground the seismic loads would reduce to 60% of the wind loadings.

The comparisons so far have been based on shear wall structures ( $R_w=6$ ). Ordinary concrete moment frame structures have less ductility and have a lower  $R_w$  factor ( $R_w=4$ ), however this is offset by the increased flexibility of the frame structure which attracts less load. These factors approximately cancel out and the nominal design load for a shear wall and ordinary frame structure are similar. It should be noted that, historically, frame structures without shear walls do not perform as well as structures which incorporate shear walls.

Special requirements for ductile detailing could greatly reduce the nominal design base shears for seismic loading.

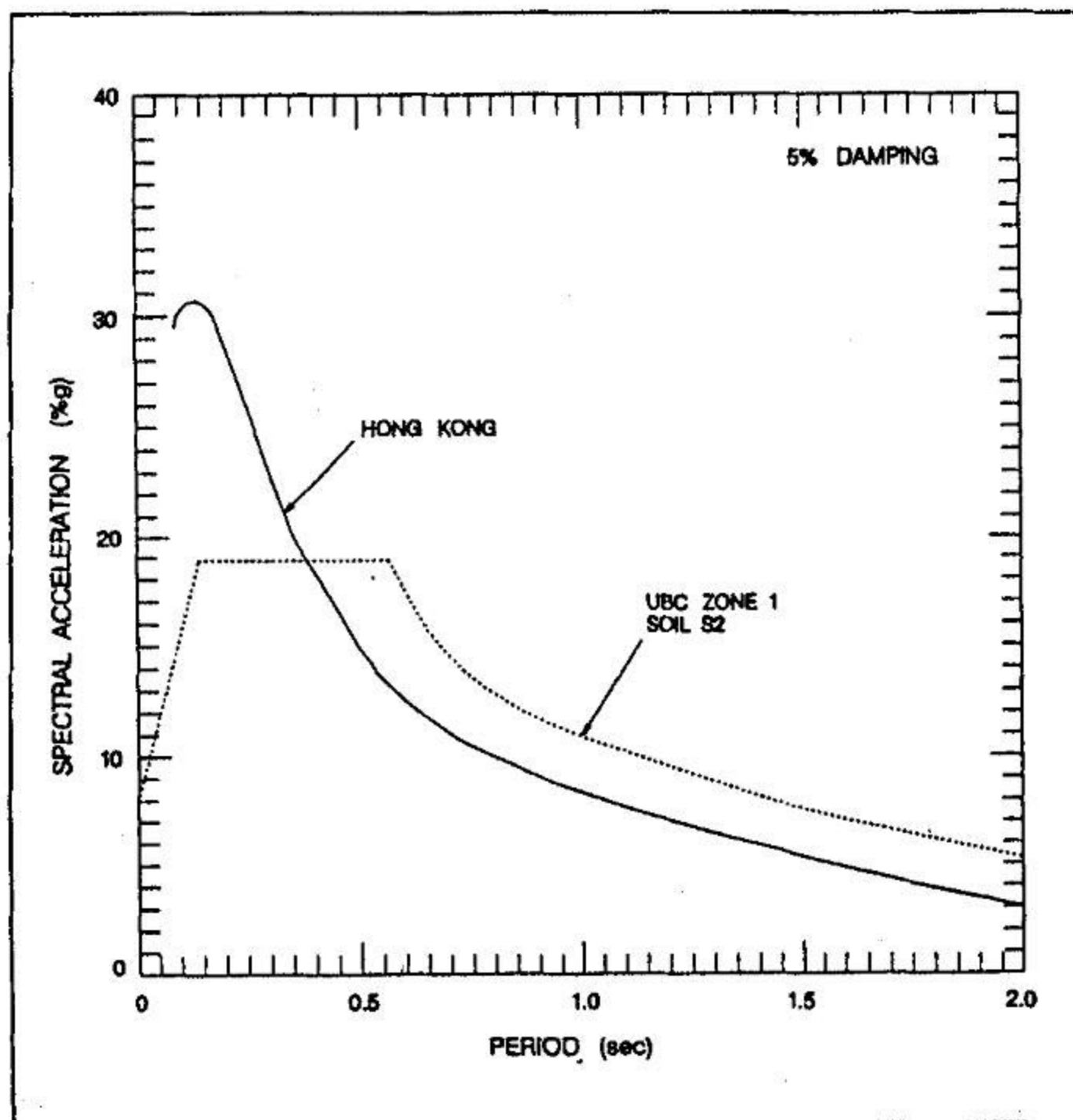


Figure 8: Comparison of Hong Kong and UBC Zone 1 spectra (Annual probability 1 in 00).

According to the UBC base shears for a ductile reinforced concrete frame structure would be one third of those of an ordinary concrete frame with no special detailing. Ductile detailing may be appropriate in Hong Kong for some special low to medium rise structures.

### Chinese code

The new Chinese seismic design code for building GBJ11-89 was introduced in March 1989 to replace the former code TJ11-78 which became obsolete in 1992.

A seismic intensity zoning map has been established in China which forms the basis of earthquake resistant design for building as required by the new code. Seismic design is required for area designated with Intensity 6 or above. The corresponding 475 year return period peak ground accelerations are:

Intensity	Peak ground acceleration
6	0.05g
7	0.10g
8	0.20g
9	0.40g

Buildings designed in accordance with the code are deemed to fulfil the 3-levels limit state design criteria.

The Chinese seismic code GBJ11-89 provides response spectra for different combinations of intensity, earthquake level and ground conditions. Normalized response spectra can therefore be drawn as shown in Figure 14. Where applicable the spectra can be adjusted to account for far field earthquake effects. The design spectra proposed here for Hong Kong are also shown on this figure and, as can be seen, the design spectral shapes are very similar to those suggested by the Chinese Code.

The Chinese Code requires a response spectrum analysis for buildings over 40m and time history analysis for buildings over 80m. The design procedures are therefore quite complex. In addition, the Chinese Code has onerous detailing requirements which are designed to give the level of ductility such that the intended response can be achieved. The imposition of these rules in Hong Kong would require a fundamental change to the way buildings here are designed and constructed.

### Application of the Chinese code to Hong Kong

The map for intensity distribution compatible with the Chinese code (Hu Shipping, 1993) shows that although Shenzhen, north of Hong Kong across the border, is designated as Intensity 6, Guangzhou, further to the north, and Hong Kong are designated as Intensity 7.

The requirements in the Chinese code for an area designated as Intensity 7 are as follows:

### Chinese code requirements

Level	Return Period	Peak Acceleration (g)		Intended Response	Analysis Method
		Chinese Code	This Paper		
Minor	50	3.5%	4%	Elastic response, undamaged	For $h < 40\text{m}$ , Static Equivalent For $h < 40\text{m}$ , Response Spectrum For $h < 80\text{m}$ , Soil I & II } time history For $h > 60\text{m}$ , Soil III & IV } time history
Moderate	475	10%	12%	Repairable damage	No analysis
Major	2000	22%	22%	No collapse	Drift based on modified elastic analysis for frame structure only.

A design Intensity 7, as recommended by the Chinese code, correspond well with the findings of this paper.

Structures are classified in the Chinese code into different Classes depending on their height and structural system. Class 1 corresponds to the most onerous requirements and Class 3 the least. The classification system and corresponding detailing requirements are summarized below:

Intensity 7	Structure Classification	Ultimate Axial Stress (HK Code)	Strong Column Weak Beam	Column Joint
Class 1	$h > 80\text{m}$ wall over frame	$0.43 f_{cu}$	$\Sigma M_c = 1.35 \Sigma M_b$	Calculation
Class 2	all others	$0.50 f_{cu}$	$\Sigma M_c = 1.35 \Sigma M_b$	Calculation
Class 3	$h < 80\text{m}$ , shear wall $h < 60\text{m}$ , frame wall $h < 35\text{m}$ , frame	$0.55 f_{cu}$	Special detailing only	Special detailing only

The Chinese code requires column to have a gross axial stress limit which makes them large and lightly reinforced when compared to those currently used in Hong Kong. There is no benefit in more than 1 - 1.5% reinforcement in columns. In addition the code enforces standard rules to achieve high ductility structures. This is achieved by having columns

which are stronger than the beams they connect to and therefore hinges are formed in the beams rather than the columns. Links are also required in the beam - column intersection. Staggered laps and fully tied links are also required in the columns. Examples of beam and column detailing are shown in Figures 15 and 16.

If the detailing rules described above were to be used, the New York draft code would recommend a larger  $R_w$  value which would lead to a much lower base shear. We consider that the Chinese detailing rules are over conservative for Hong Kong and would require a radical change to design, construction and planning of buildings.

### Soft storey structures

The special case, which requires discussion, are 'soft storey' structures. These structures are defined by the UBC code, as ones in which the lateral stiffness of that storey is less than 30% of the storey above or less than 40% of the combined stiffness of the 3 storeys above. Figure 17 shows the ductility demand for a typical soft storey structure.

Historically, soft storey structures do not perform well in earthquakes. Although they tend to have long periods and therefore attract small loads they have little or no ductility and therefore should be designed to behave elastically in earthquake conditions.

The following approach is suggested for transfer type structures which are a typical soft storey system found in Hong Kong:

- 1000 year design spectrum.
- $R_w = 3$ .
- Nominal ductile detailing below the transfer plate.
- Particular care needs to be taken to incorporate all P-delta effects at ultimate loads.

The  $R_w$  value of 3 is effectively an ultimate elastic response and comes from the ultimate load factor of 1.4 and the fact that structures are about twice as strong as they are designed to be (The Canadian code specifically documents the overcapacity as an adjustment factor which has a value of 1.8). However, modern structures are becoming more refined and are less likely to have the overcapacity that is historically assumed; this was observed for reinforced concrete structures in the 1989 Newcastle, Australia, earthquake (EEFIT, 1990). Hong Kong codes are rather conservative however, both in limitations on material strengths and high load factors and it is likely this overstrength exists.

The main problem with the above approach is that the maximum credible earthquake can exceed the 1000 year values and under these circumstances the soft storey structure has no designed capacity.

The Chinese code approach on soft storey structures is to prohibit them by limiting the stiffness of the lowest storey as follows:

- It defines the structure as a Class 1 Structure.

- ii) The total stiffness of the soft storey shall not be less than 50% of the upper levels.
- iii) The moments at base level are magnified by 50%.
- iv) The ultimate axial stress is limited to  $0.35f_c$  ( $f_c$  = ultimate core strength).
- v) Links and ductile detailing are more onerous for a Class 1 Structure.

## Conclusions

The following conclusions are made:

- Analysis shows that Hong Kong has a moderate seismic hazard. The engineering community needs to be aware of this risk and needs to develop measures to mitigate the risk.
- A consensus on appropriate seismic design procedures for Hong Kong is urgently required.
- The basis of such a procedure has been outlined in this paper.
- The Chinese code would result in comparable base shears but has much more onerous detailing requirements and would require a radical change to the design, planning and construction of buildings in Hong Kong.
- A code and design spectra developed specifically for Hong Kong would minimise the changes to building design and construction and would mitigate the effects of earthquakes to a level considered appropriate by the community.

## Acknowledgements

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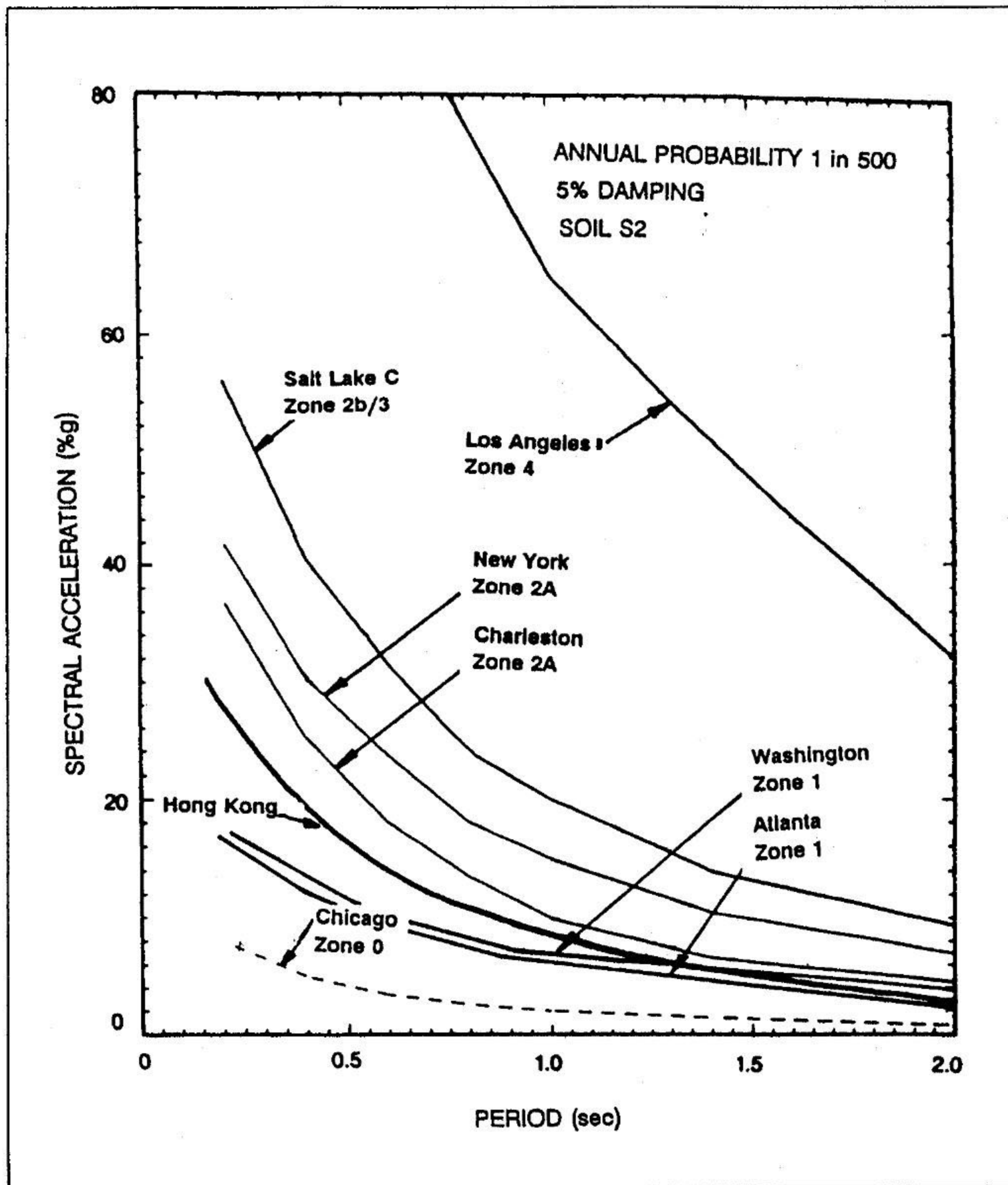


Figure 9: Comparison of US cities with Hong Kong.

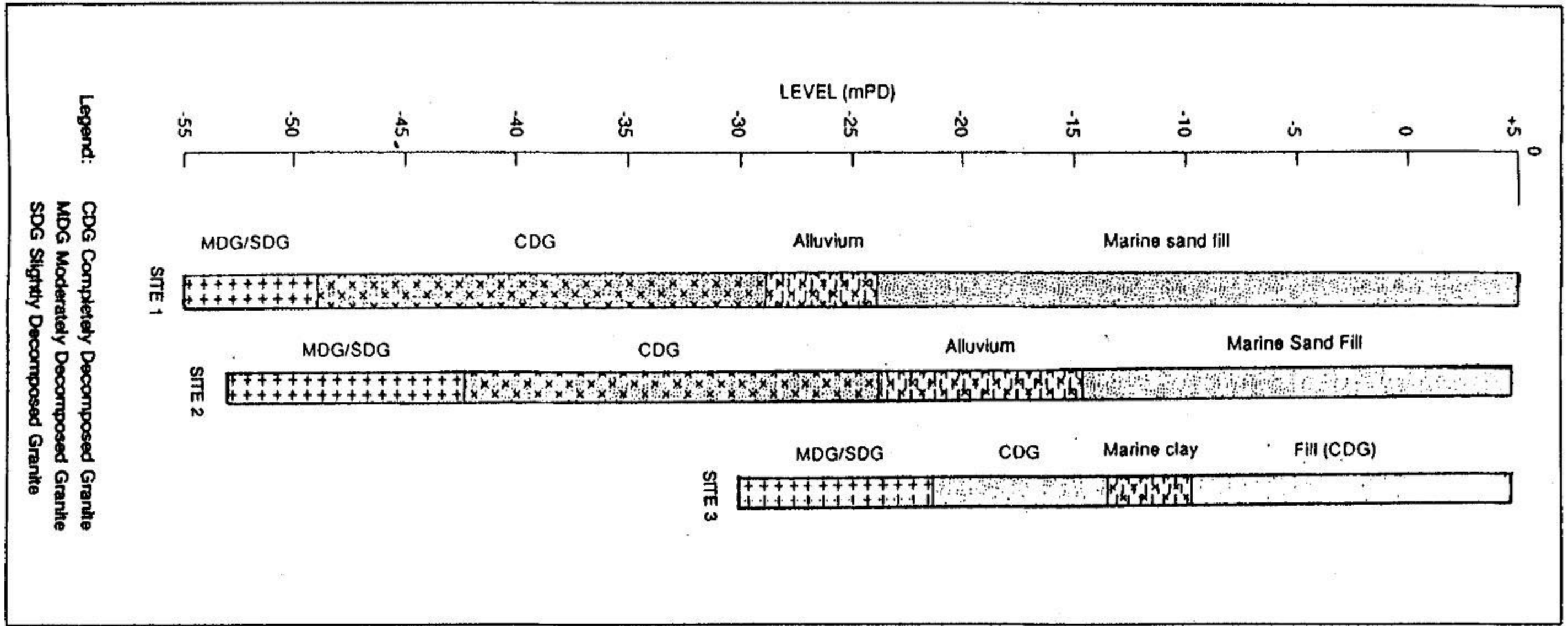


Figure: 10 Soil profiles from areas of reclaimed land use in site response analyses.

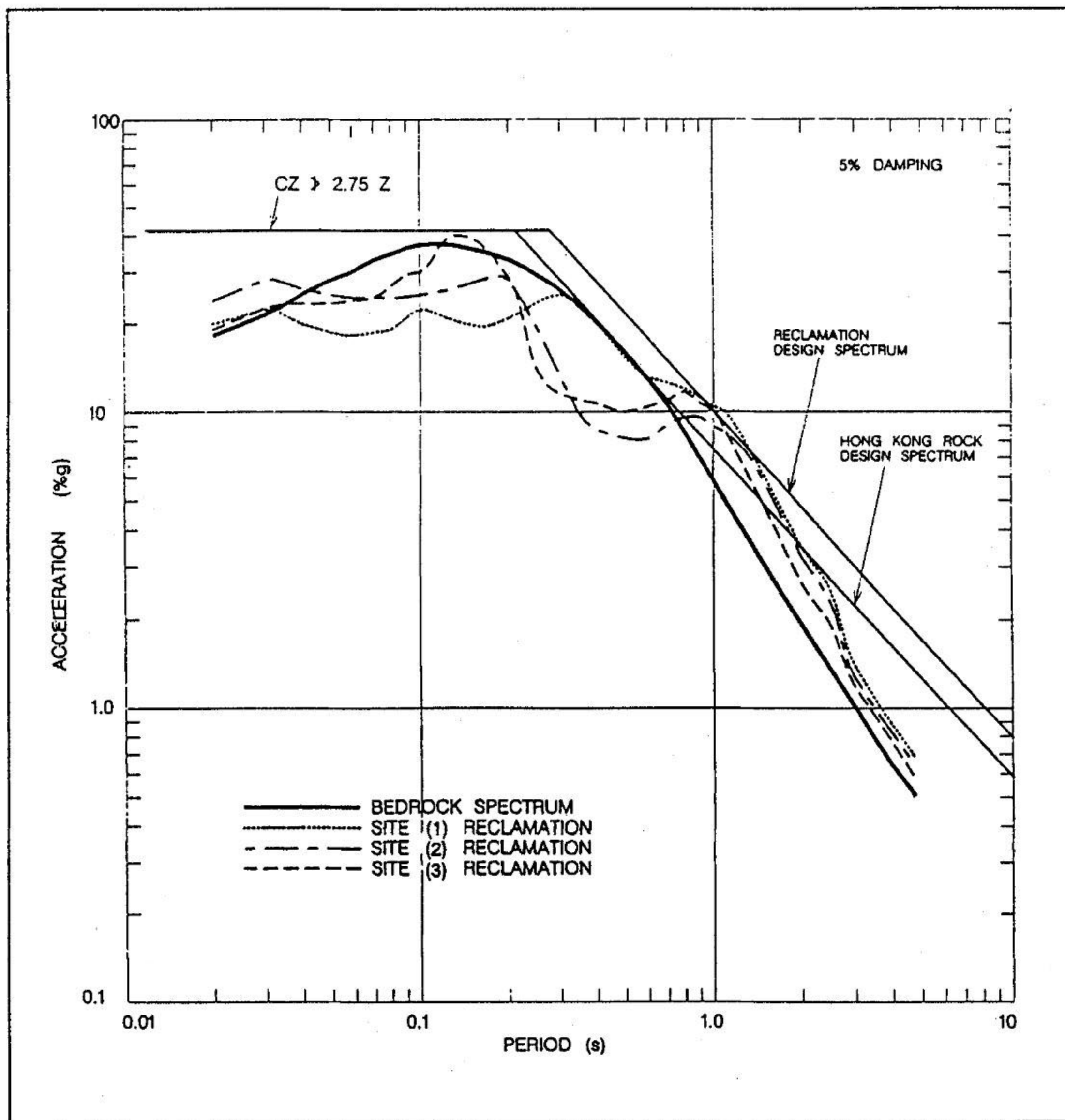


Figure: 11 Design spectra for annual probability of 1 in 1000.

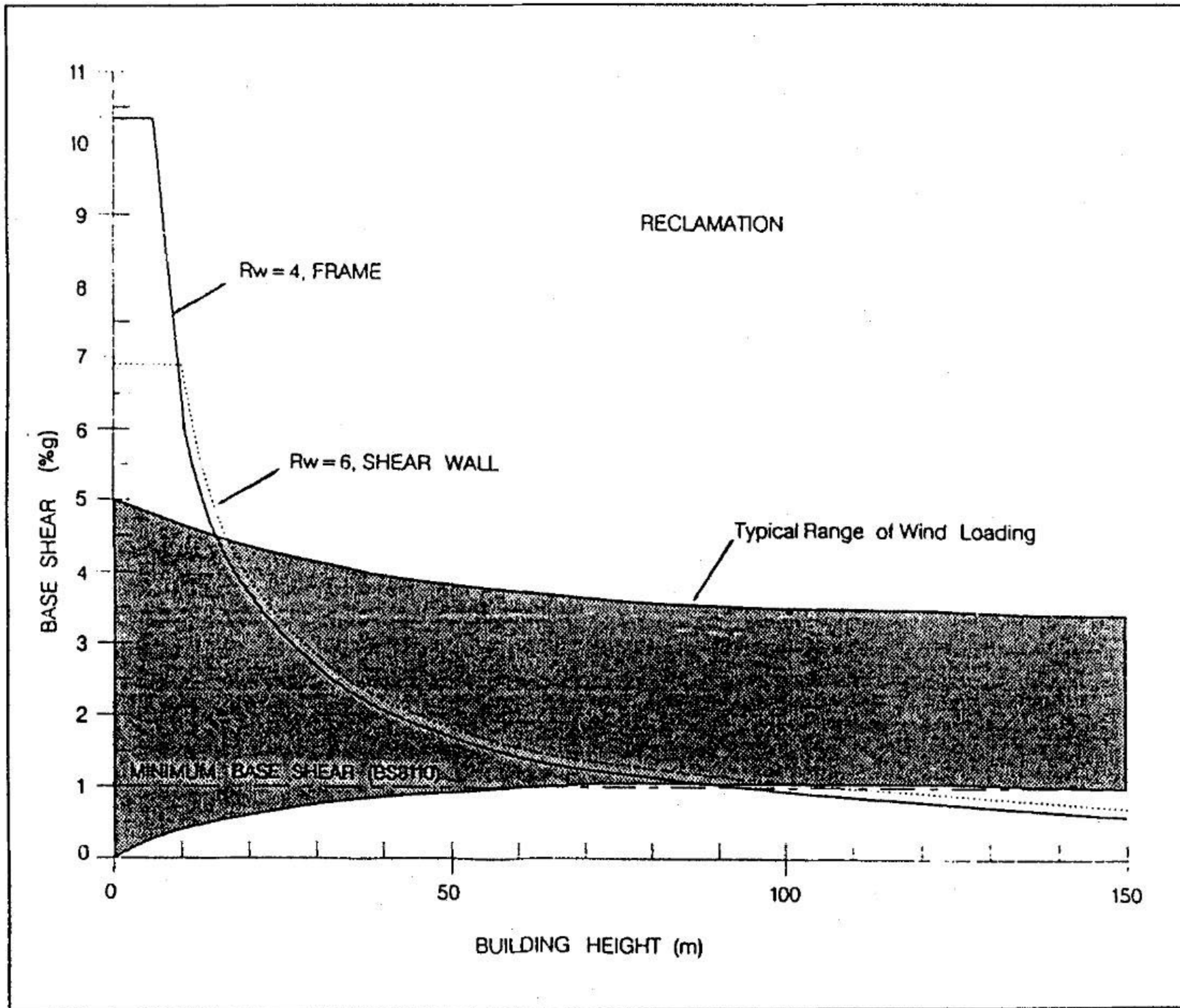


Figure 12: Comparison of wind and seismic loading.

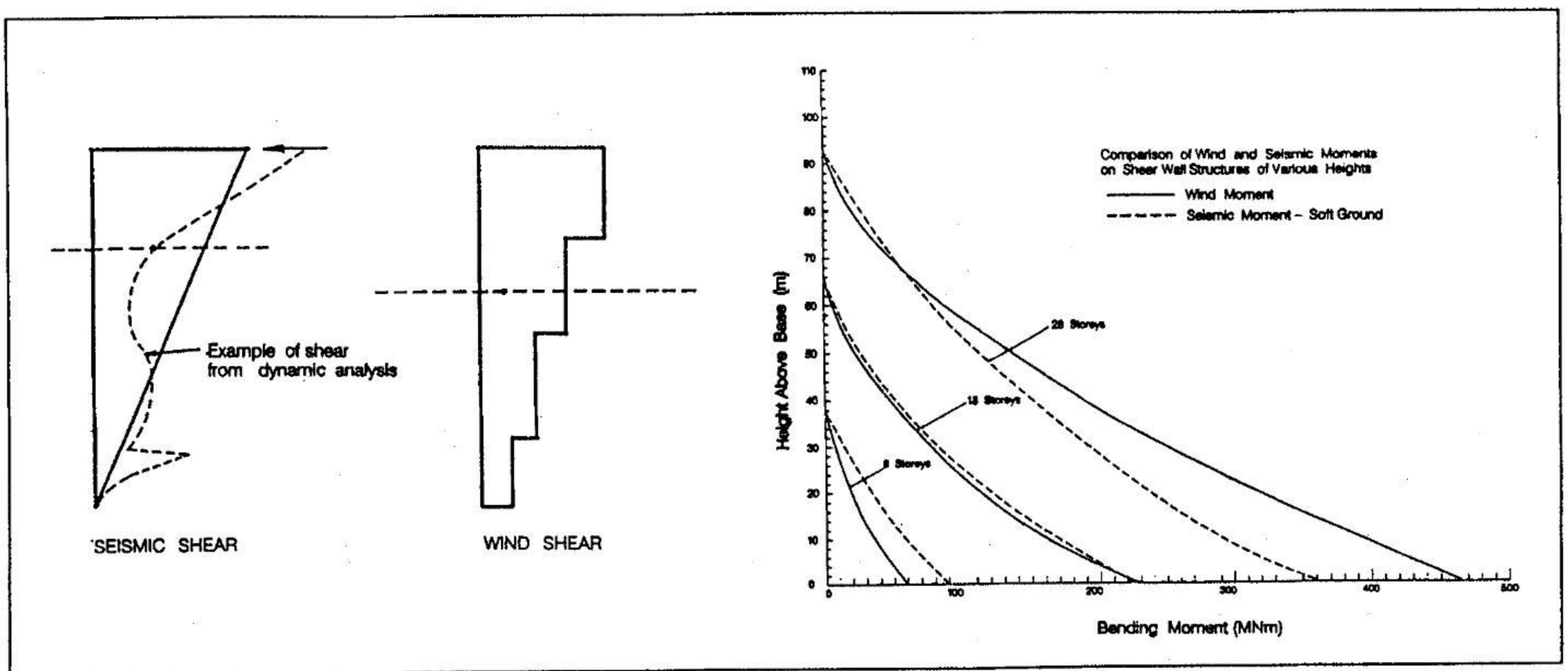


Figure 13: Comparison of wind and seismic loads on 3 buildings.

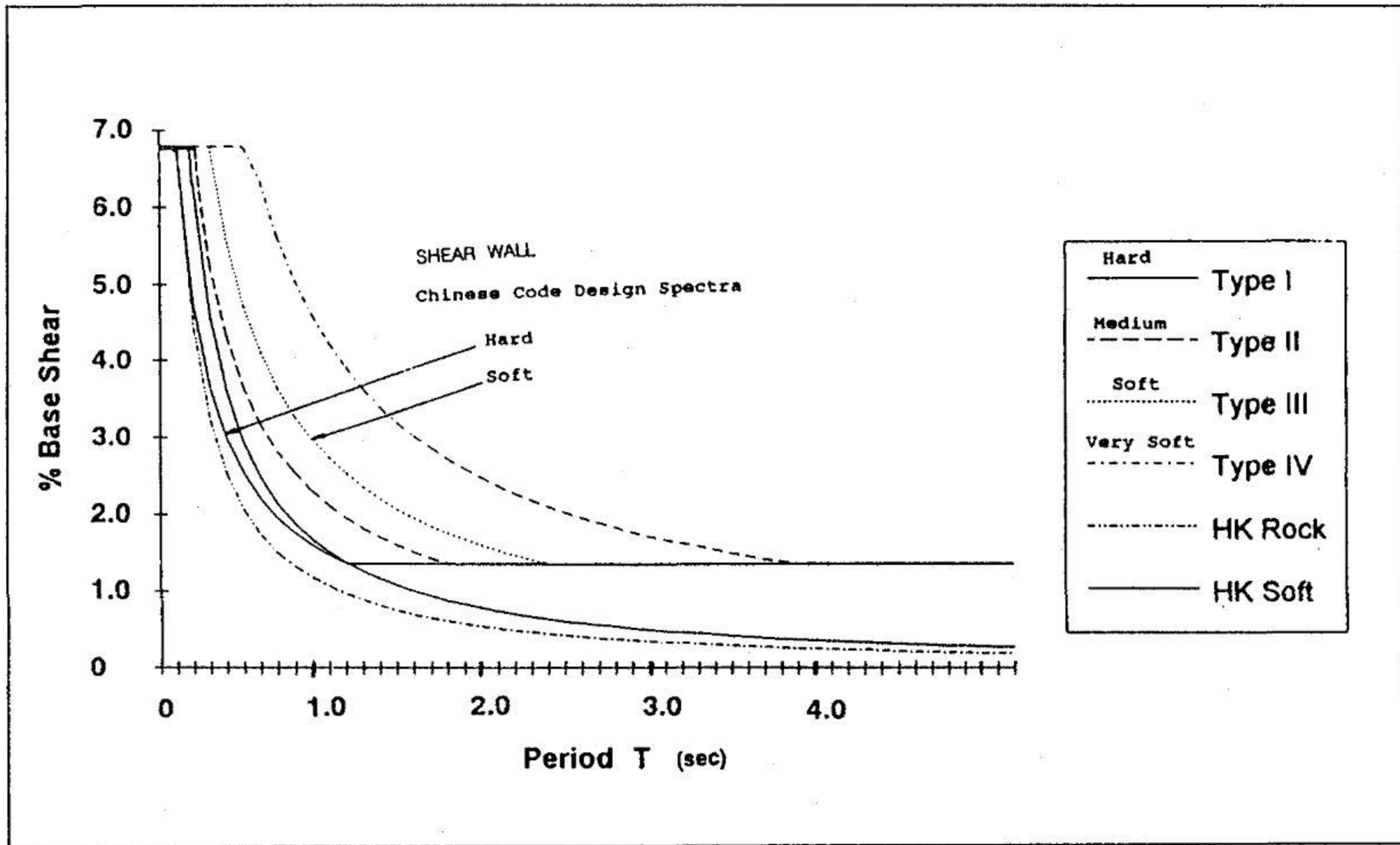


Figure 14: Comparison of proposed shares and Chinese code base shear requirements.

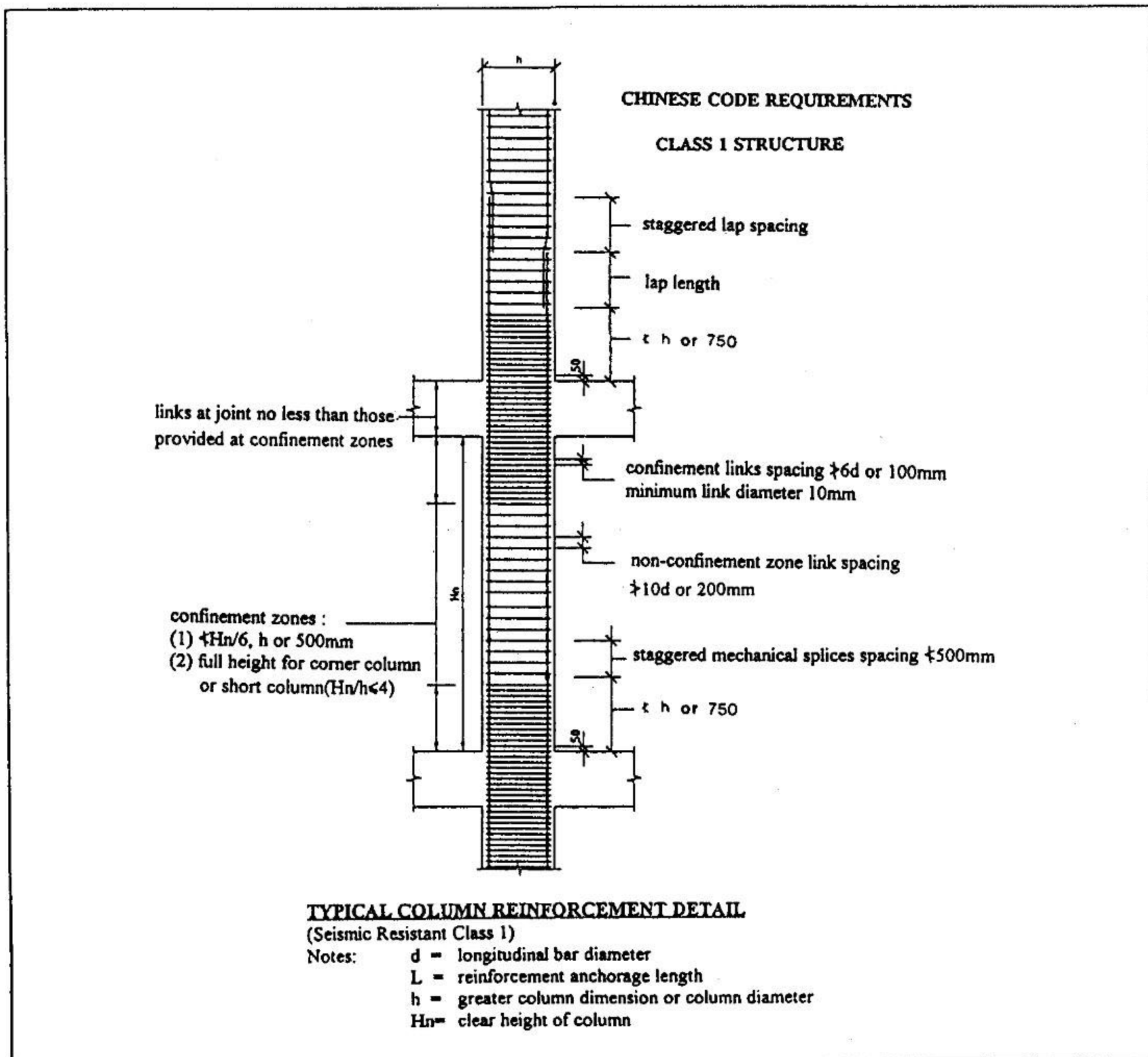


Figure 15: Typical column detail (Class 1 structure).

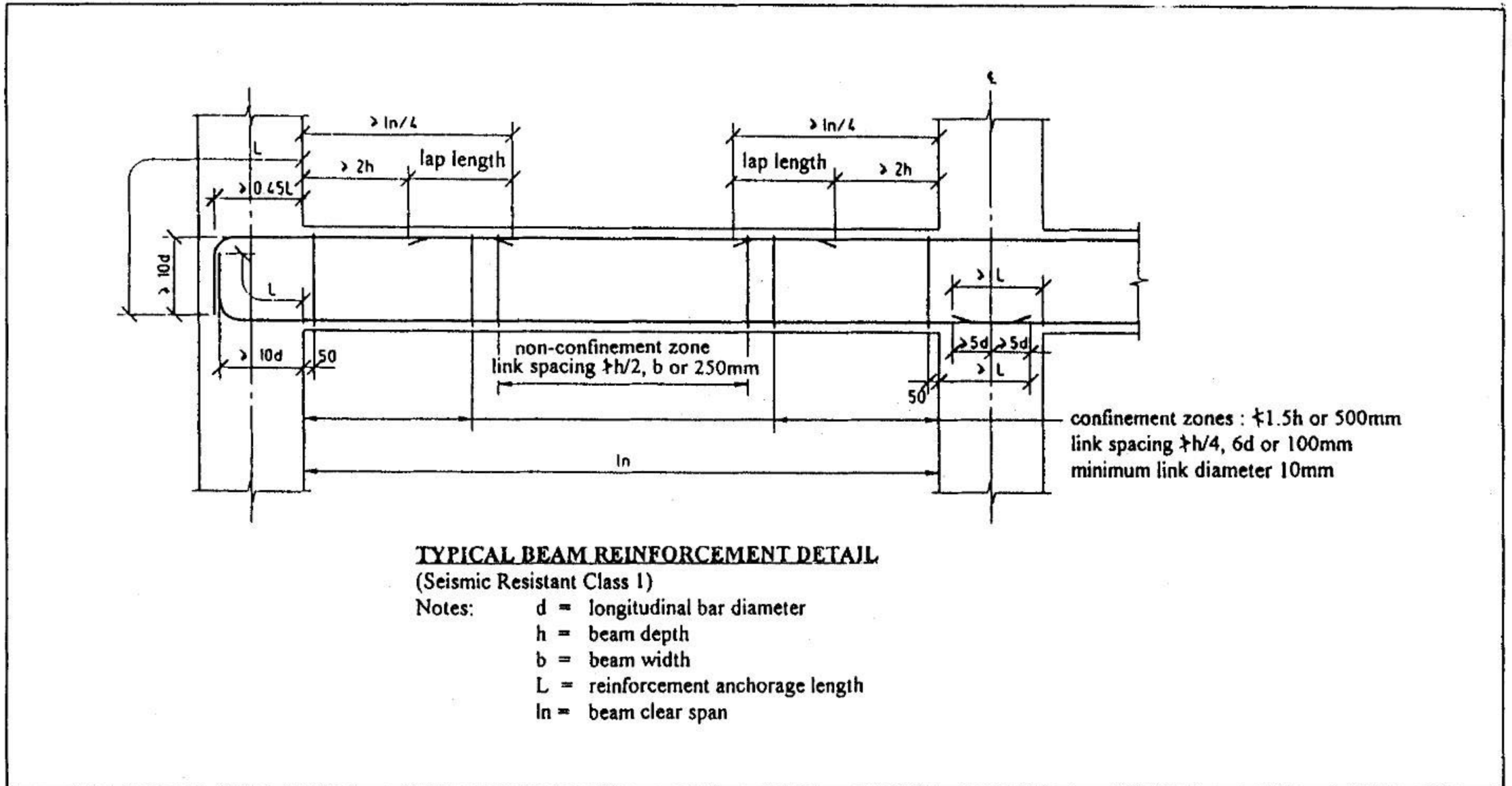


Figure 16: Typical beam detail (Class 1 structure).

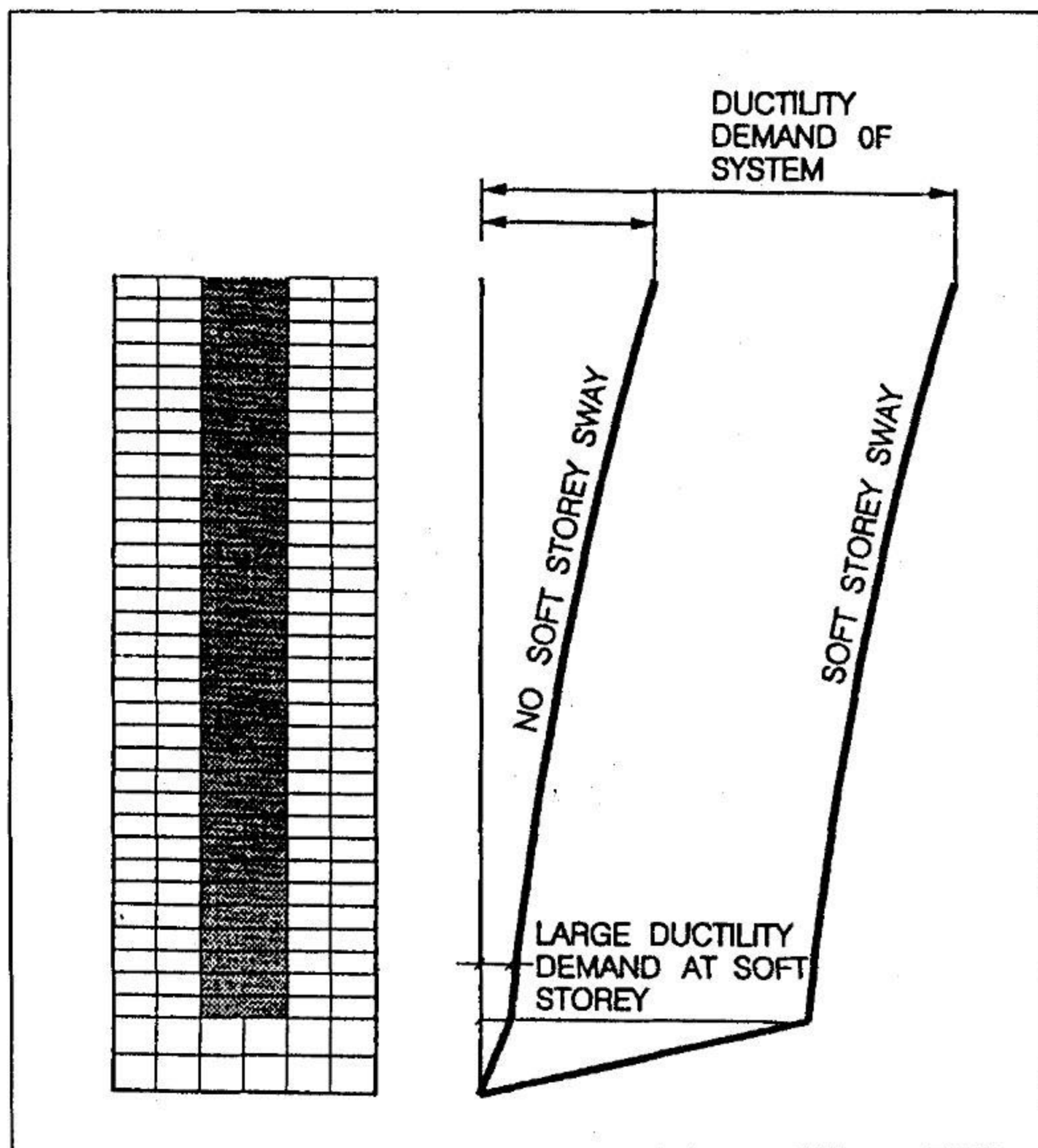


Figure 17: Soft storey ductility demand.