Development of Microzonation Maps of Kuala Lumpur City Centre for Seismic Design of Buildings

By: *Assoc. Prof. Dr Azlan Adnan, Assoc. Prof. Hendriyawan, Aminaton Marto*

It has been known for many years that local site conditions play a major role in establishing the damage potential of incoming seismic waves, because it can strongly influence ground motion during earthquakes. The bitter experiences from past earthquakes (e.g. 1985 Mexico earthquake, 1989 Loma Prieta earthquake, 1994 Northridge earthquake, 1995 Kobe earthquake and 2004 Aceh earthquake) have reemphasised the importance of local site conditions on the amount of damage and loss of life [1,2]. It is, thus, important in seismic hazard analysis to consider the local site effects before implementing the results into earthquake-resistant structural design. The parameter analysed in local site analysis is typically acceleration, velocity, displacement or spectral acceleration with a specified probability of exceedance [3].

Mapping these parameters at local scales to incorporate the effects of local soil conditions is called microzonation for seismic hazard. Microzonation for seismic hazard has many uses as mentioned by Finn *et al.* [3]. It can provide input for seismic design, land use management, and estimation of the potential for liquefaction and landslides. It also provides the basis for estimating and mapping the potential damage to buildings. This paper presents the results of the microzonation study for Kuala Lumpur City Centre using one-dimensional shear wave propagation method to obtain peak acceleration and spectral acceleration on the surface. The results are then plotted into the maps of KL city centre to produce iso-acceleration and iso-amplification factors on the surface.

GROUND RESPONSE ANALYSIS

In this study, ground response analysis was performed using one-dimensional shear wave propagation method (1-D analysis). The method is based on the assumption that all boundaries are horizontal and that the response of a soil deposit is predominantly caused by shear wave propagating vertically from the underlying bedrock. Although the soil layers are sometimes inclined or bent, they are regarded as horizontal in most cases. Furthermore, the length of a layer is infinite compared with its thickness. It is, thus, practical to model them as 1-D horizontal layers. Analytical and numerical procedures based on this concept, incorporating linear approximation to nonlinear soil behaviour, have shown reasonable agreements with field observations in a number of cases [4].

The soil behaviour under seismic loading was analysed using a nonlinear approach. The advantages of the nonlinear method are [4]: (1) the stiffness of actual nonlinear soil changes over the duration of a large earthquake, such high amplification levels that occur in equivalent linear approach, will not develop in the field; and (2) a nonlinear method can be formulated in terms of effective stresses to allow the modelling of the generation, redistribution and eventual dissipation of excess pore pressure during and after earthquake shaking. The analyses were carried out using program NERA [5], which stands for Nonlinear Earthquake Response Analysis. This program use soil model proposed by Iwan [6] and Mroz [7] to model the nonlinear stress-strain curves of soil.

Ground response analysis requires the profile of dynamic soil parameters such as maximum shear modulus, G_{max} or shear wave velocity, V_s and damping, β. This parameter can be obtained from field dynamic tests or by converting from static field tests using empirical formula. Numerous researchers have investigated the relationship between maximum shear modulus or shear wave velocity and N-value of Standard Penetration Test (SPT). In this research, the static parameters from the SPT test were converted into V_s by using a formula proposed by Ohta & Goto [8] and Imai & Tonouchi [9].

GEOLOGIC SETTING OF KUALA LUMPUR

The general geology of the Kuala Lumpur area has been well documented by Gobbett [10] and Yin [11]. Basically, the Kuala Lumpur area consists of a flat alluvial plain bounded on the east and west by predominantly granitic ranges.

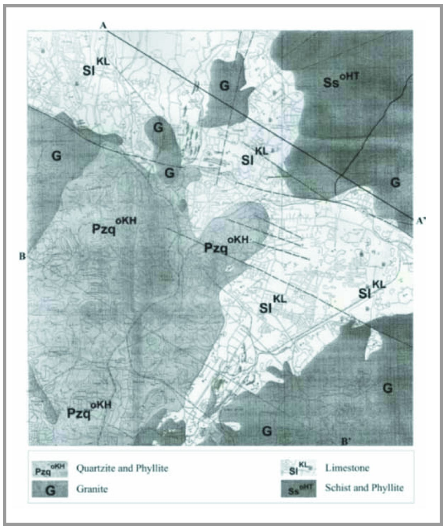

Figure 1: Bedrock geology of Kuala Lumpur [12]

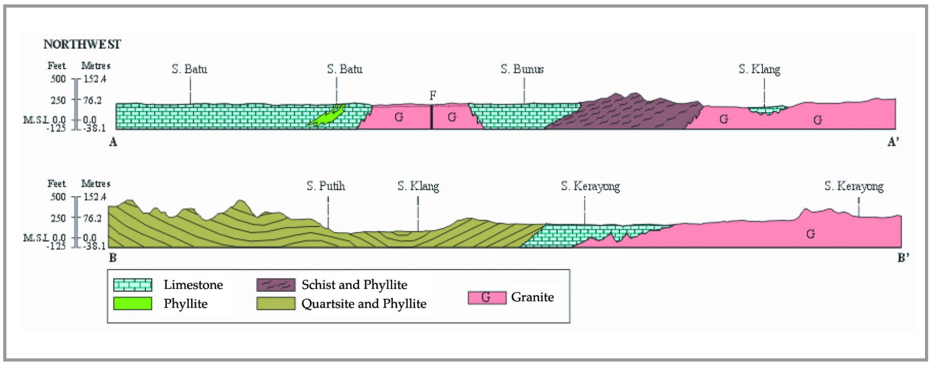

Figure 2: Diagrammatic sections along cross section AA' and BB' [12]

The floor of the valley consists of an extensive limestone bedrock which is overlain by alluvial deposits. An isolated limestone hill, namely the Batu Caves, and several other hillocks formed by the Hawthornden and Dinding schists occur in the northern areas of Kuala Lumpur. The general geology of the Kuala Lumpur area is shown in Figure 1 and the diagrammatic bedrock profiles are shown in Figure 2.

SITE CLASSIFICATION

Site classification analyses for the Kuala Lumpur city centre were performed using 12 existing soil data. For each data, the soil dynamic properties are calculated by using formulas proposed by Ohta & Goto [8] and Imai & Tonouchi [9]. The results were summarised in Figure 3. The classification of a particular site was determined by referring to three specifications: 1997 UBC / 2000 IBC [13, 14], Eurocode 8 [15], and Bray and Rodriguez-Marek [16]. Based on the existing data, the soil in KL city centre can be classified as SC, SD and SE in accordance with 2000 IBC [14] as shown in Table 1.

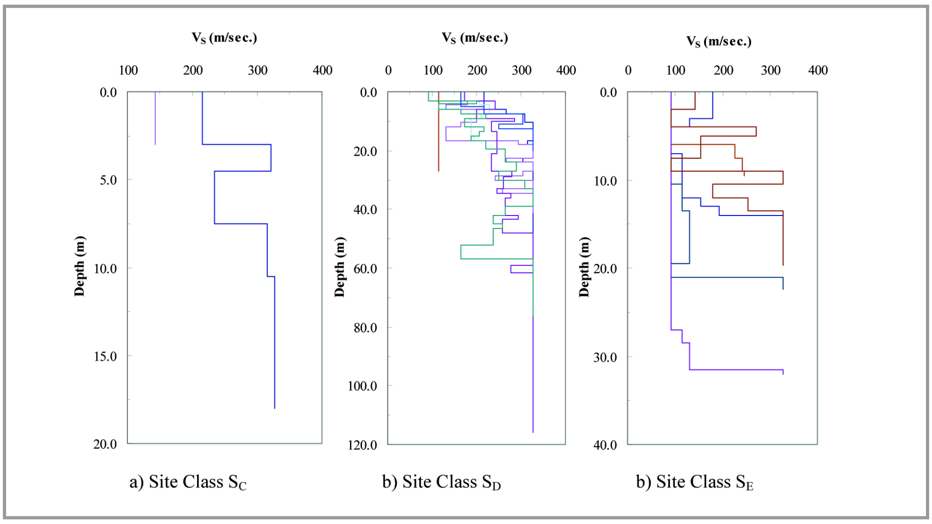

Figure 3: Soil dynamic properties for KLCC

Table 1: Soil Classification of KLCC

No.	Location	V_s (m/s)	T_n (sec.)	Soil Classification		
				2000IBC [14]	EC8 [15]	BR 1997 [16]
1.	Location-1	319.00	0.67	D	C	C-3 / E-1
2.	Location-2	191.02	0.66	D	C	C-3 / E-1
3.	Location-3	228.13	0.45	D	C	C-2
4.	Location-4	305.25	0.34	D	C	C-1
5.	Location-5	217.48	1.59	D	C	D-3
6.	Location-6	395.95	0.25	C	B	C-1
7.	Location-7	182.78	1.20	D	C	D-1 / D-2 / D-3
8.	Location-8	316.43	0.31	D	C	C-1
9.	Location-9	150.57	0.42	E	D	C-2
10.	Location-10	652.85	0.08	C	B	A
11.	Location-11	107.56	0.75	E	D	C-3 / E-1
12.	Location-12	178.98	0.35	E	D	C-1

Table 2: Results of 1–D analyses for KLCC

No.	Location	Soil Type	PSA (g's)				Amplification Factor			
			Synth-1	Synth-2	Synth-3	Synth-4	Synth-5	Synth-6	Synth-7	Synth-8
1.	Location-1	S_D	0.111	0.122	0.297	0.232	1.52	1.67	1.99	1.56
2.	Location-2	S_D	0.158	0.146	0.238	0.245	2.16	2.00	1.60	1.65
3.	Location-3	S_D	0.180	0.165	0307	0.304	2.47	2.26	2.06	2.04
4.	Location-4	S_D	0.143	0.135	0.232	0.289	1.96	1.85	1.56	1.94
5.	Location-5	S_D	0.112	0.087	0.154	0.169	1.53	1.19	1.03	1.13
6.	Location-6	S_C	0.162	0.105	0.280	0.267	2.22	1.44	1.88	1.79
7.	Location-7	S_D	0.160	0.113	0.221	0.223	2.20	1.55	1.48	1.50
8.	Location-8	S_D	0.189	0.165	0.329	0.314	2.59	2.27	2.21	2.11
9.	Location-9	S_E	0.132	0.119	0.203	0.211	1.81	1.63	1.36	1.42
10.	Location-10	S_C	0.077	0.090	0.225	0.175	1.05	1.23	1.51	1.17
11.	Location-11	S_E	0.119	0.100	0.162	0.170	1.64	1.36	1.09	1.14
12.	Location-12	S_E	0.157	0.147	0.230	0.232	2.16	2.02	1.54	1.56

RESULTS OF SHEAR WAVE PROPAGATION ANALYSIS

Shear wave propagation analyses were performed for all existing soil data to obtain peak acceleration and amplification factor at the surface. Two hazard levels were used in the analysis to represent 10% and 2% Probability Exceedance (PE) in a design time period of 50 years or correspond to a return period of approximately 500 and 2,500 years respectively. These hazard levels were calculated using the total probability theorem as proposed by Cornel [17]. Based on our previous study, the peak ground accelerations for Kuala Lumpur are 0.073g (73.4 gal) and 0.149g (149 gal) for 500 and 2,500 years return periods of ground motions respectively [18, 19]. Four time histories were used in the analysis: Synth-1, Synth-2, Synth-3, and Synth-4. Synth-1 and Synth-2 represent ground motion for 500 years return period, while Synth-3 and Synth-4 represent 2,500 years return period [19].

The results of acceleration and amplification factors at the surface of KL city centre were summarised in Table 2. The amplification factors show the ratio between acceleration at bedrock and at surface. Based on the results, most of the ground motions have been amplified at the surface. Generally, the amplification factors for 500 years return period are higher than the 2,500 years return period.

The effects of using different time histories can be seen in Figures 4 and 5 for the 500 and 2,500 years return periods of ground motions respectively. The results indicate that the selection of appropriate time histories is one of the most critical in ground response analysis. The selection of time histories could change the results of accelerations at the surface significantly. The accelerations at the surface can vary up

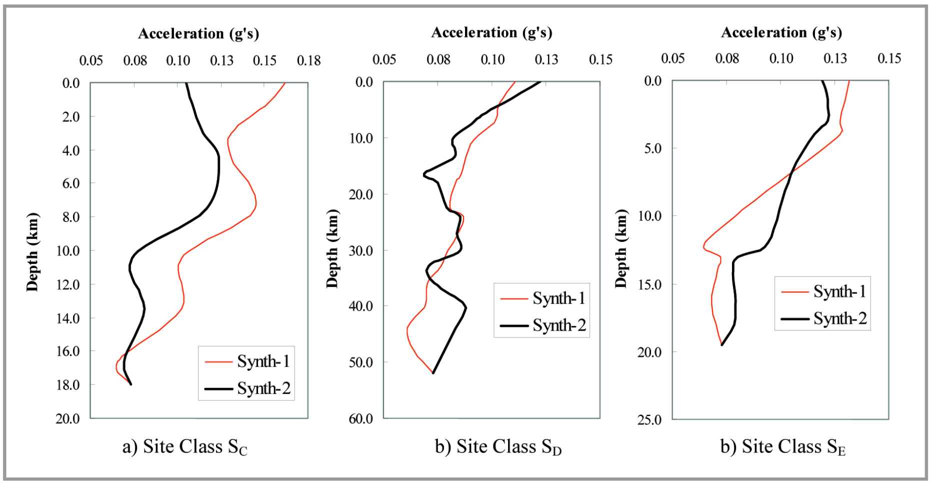

Figure 4: 1–D analysis using two time histories for 500 years return period

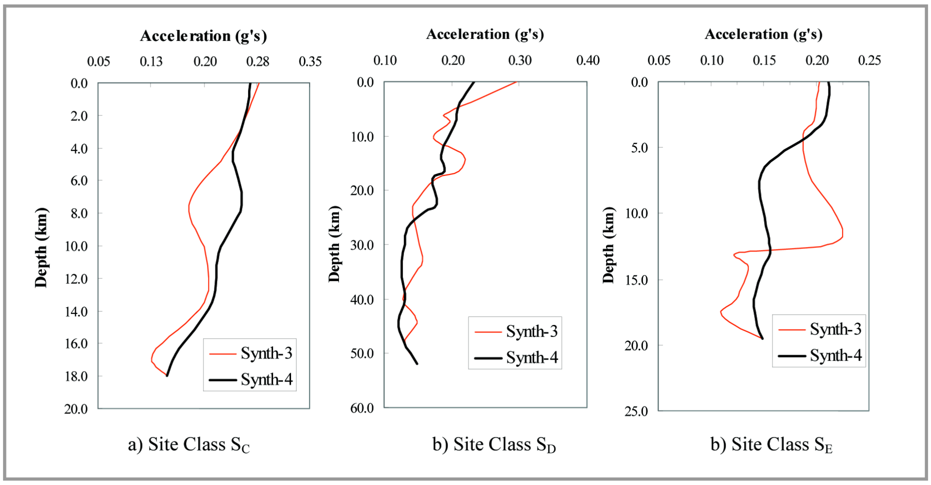

Figure 5: 1–D analysis using two time histories for 2,500 years return period

to about 35%. The results of site response analysis at several points were used to develop a contour map of surface acceleration and amplification factor for the 500 years and 2,500 years return periods. The iso-acceleration contour maps for KL city centre are shown in Figures 6 and 7. According to the figures, the accelerations at the surface of KL city centre range between 9% g (90 gal) and 19% g (190 gal) for 10% PE in the 50-year hazard levels and between 18% g (180 gal) and 34% g (340 gal) for 2% PE in the 50-year hazard levels. The amplification factors for the two hazard levels (10% and 2% PE in 50 years) range between 1.2 and 2.6. Generally, the acceleration and amplification factors decrease from the west to the east side of KL city centre.

SUMMARY AND CONCLUSION

The microsonation study for the Kuala Lumpur city centre in Peninsular Malaysia was performed using 1-D shear wave propagation analysis. Four time histories were used in the analysis to represent ground motion for 500 years (Synth-1 and Synth-2) and 2,500 years (Synth-3 and Synth-4) return periods. The analyses were performed using a nonlinear approach in order to consider the actual nonlinear response of a soil deposit. The results of ground response analysis show that both the time histories and local soil conditions (soil properties and stratigraphy) are critical to the results of ground response analysis. The accelerations at the surface of KL city centre range between 9% g (90 gal) to 19% g (190 gal) for the 500 years return period and between 18% g (180 gal) to 34% g (340 gal) for the 2500 years return period. The amplification factors for those two hazard levels (10% and 2% PE in 50 years) range between 1.2 and 2.6. Generally, the acceleration and amplification factors decrease from the west to the east side of KL city centre.

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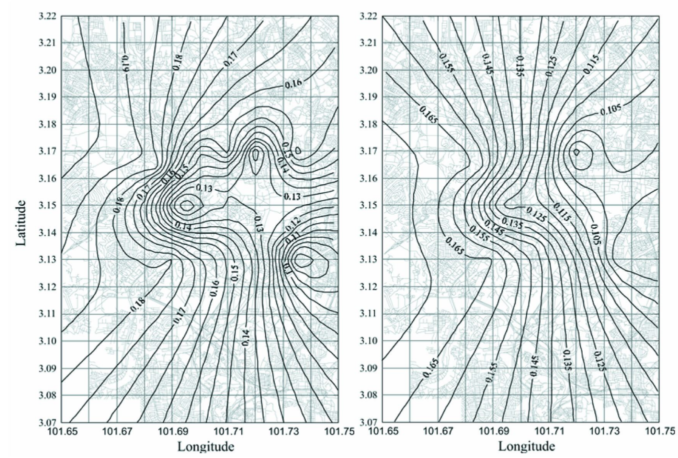
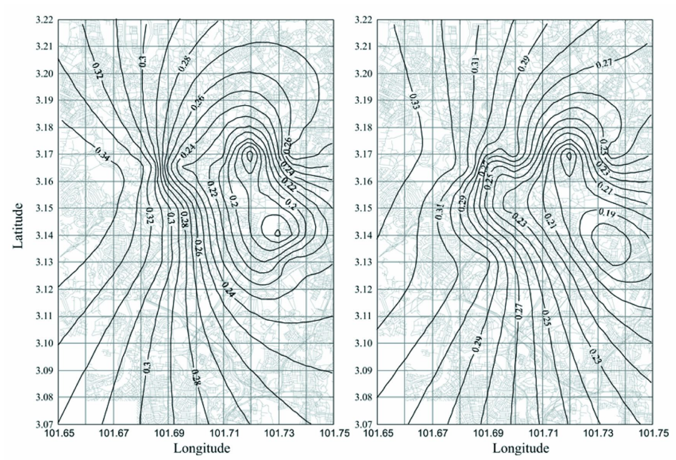


(a) Synth-1 (b) Synth-2

Figure 6: Contour of acceleration at surface of KLCC for 500 years return period (PGA=0.073g)



(a) Synth-3 (b) Synth-4

Figure 7: Contour of acceleration at surface of KLCC for 2,500 years return period (PGA=0.149g)

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