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# Macrozonation Map of Kota Kinabalu, Sabah

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**ABSTRACT**

Sabah had been experienced moderate intensity of earthquake in the fault areas located in Kundasang of Ranau district. The magnitude Mw 5.8 earthquake has damaged approximately 50 buildings such as schools, hospital and mosque. This earthquake was the strongest to affect Malaysia in history. This study has been carried out based on three objectives. The first objective is to determine the type of soil in Kota Kinabalu. Secondly is to produce the contour map Contour of soil amplification factor, f in Kota Kinabalu. Lastly is to conduct the pushover curves for building model. The analysis samples of input motion of 5.9 MW, ts = 0.01 s was used to get the maximum acceleration for PGA and PSA. The soil amplification factor, f is derived as the derivation of PSA and PGA values. So the soil amplification factor values of soil sample are used for the factor affecting the pushover analysis of the building model located at 'Karamunsing' region of KK. It is known that most of their soils are consisting of a alluvium soil layer with various thickness in between 5 m to 20 m depth. This study shows that the soil amplification factors for each location in KK city are various with the input motion of 5.9 MW, ts = 0.01 s.



## 1. Introduction

Macrozonation is the evaluation of a series of small regions in order to identify common factors that exist for all those regions [1]. In Sabah, its geological data have the tertiary rocks which are younger than the sedimentary rocks. The formation of rocks in Kota Kinabalu (KK) region has its tertiary rocks such as sandstone and shale dominant areas. It is riches with forest area in the interior region of Sabah. The coastal areas of Sabah generally consist of swaps, marshlands and wetland forests including with mangrove, and other wetland forest types. It is believed that these wetland soils in most urban area such as KK, Sandakan and Tawau have a high density of soil layers with sand, clay and silt materials [2].

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## 2. Geological Data of Kota Kinabalu City

In Kota Kinabalu, geological data have the tertiary rocks which are younger than the sedimentary rocks. There are mostly consists of sandstone and mudstone in the KK region. Other than that, the coastal area of KK region consists of alluvium and peat while the hilly areas in KK are basically consisting of basic igneous rocks [2].

## 3. Dynamic Soil Properties

The dynamic soil properties in especially the shear wave velocity, $v_s$ from the standard penetration test (SPT) is the reliable input values in order to determine the shear modulus, Gmax [3]. The shear wave velocity is depending on the unit weight of the soil layer samples. The shear modulus for each soil layer samples will be computed based on the unit weight of soil [4]. With the values of shear modulus and shear wave velocity, $v_s$, the soil profile is produced and hence the spectral accelerations or known as PGA for each samples [5]. The soil amplification factor, f is derived as the derivation of PSA and PGA values as shows from the Equation 1.

$$f = PSA / PGA \qquad (1)$$

## 4. Methodology

The value for maximum acceleration, PGA is found in the input motion data selected as shown in the following Table 1. The input motion of Kota Kinabalu to Ranau (KKMR) is shown in Figure 1 which was discovered [6].

**Table 1**
Input motion data

| Input Motion Name | Magnitude | Distance to Fault Rupture (km) | USGS Site Class | PGA (g) | Time step, ts (s) |
|---|---|---|---|---|---|
| KKMRanau | 5.9 | 62.6 | A | 0.135 | 0.01 |

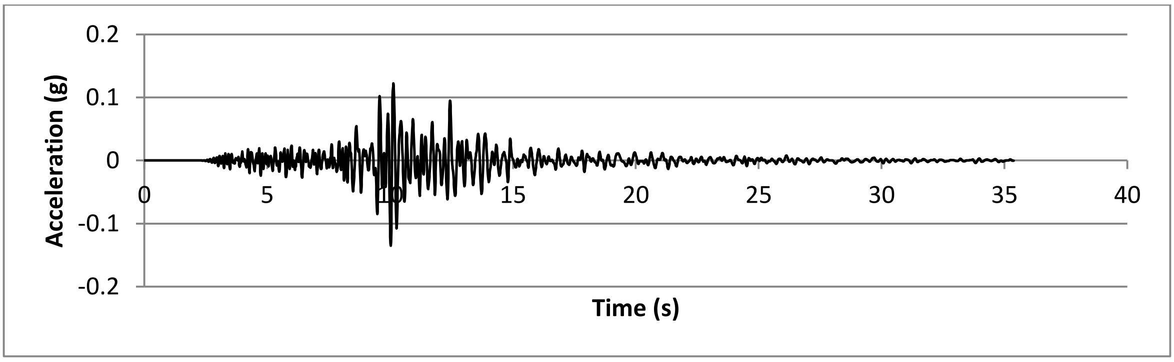


**Fig. 1.** Time History of KKMR (MW 5.9, ts=0.01s, PGA=0.135g)

Soil sample information such as the type of soil (such as clay, silt, sand and etc) and their unit weight are being referred by J. Atkinson [7]. So the soil profile for each soil sample is produced. The peak ground acceleration (PGA) and maximum pseudo-spectral acceleration (PSA) are obtained as shown in the following example of Table 2.

**Table 2**
The output values for the soil sample at the location profile

| | |
|---|---|
| Number of sublayer = | 3 |
| Ratio of critical Damping (%) = | 5 |
| Depth at top of sublayer (m) = | 3.67 |
| PGA value (g) = | 0.144 |
| PSA value of top of rock (g) = | 0.064 |

Hence, the amplification factor is determined based from the equation 1.

f = PSA / PGA = 0.064 / 0.144 = 0.444

## 5. Results
### *5.1 Contour Map of Kota Kinabalu City*

This section discussed the results achieving the second objective regarding to contour map of amplification factor in KK city. And also it discussed about the contour map of amplification factors. The Table 3 shows the pseudo-spectral at the surface of KK city in time motion of 5.9 Mw, t=0.01s. For the time motion of 5.9 Mw, t=0.01s, it can be seen that the accelerations at the surface of KK city are mostly at range between 20% g (200 gal) and 30% g (300 gal) for 18.7% PE and between 40% g (400 gal) and 50% g (500 gal) for 34.4% PE. The contour of amplification factor is shown in Figure 2. According to the Figure 6, the amplification factors for this time history motion of 5.9 Mw, t=0.01s is at range between 0.000 and 3.428.

**Table 3**
Range of pseudo-spectral values on time motion of 5.9 Mw, t=0.01s

| Range (gal) | Population estimation, PE (%) |
|---|---|
| 50-100 | 12.5 |
| 100-200 | 12.5 |
| 200-300 | 18.7 |
| 300-400 | 6.3 |
| 400-500 | 34.4 |

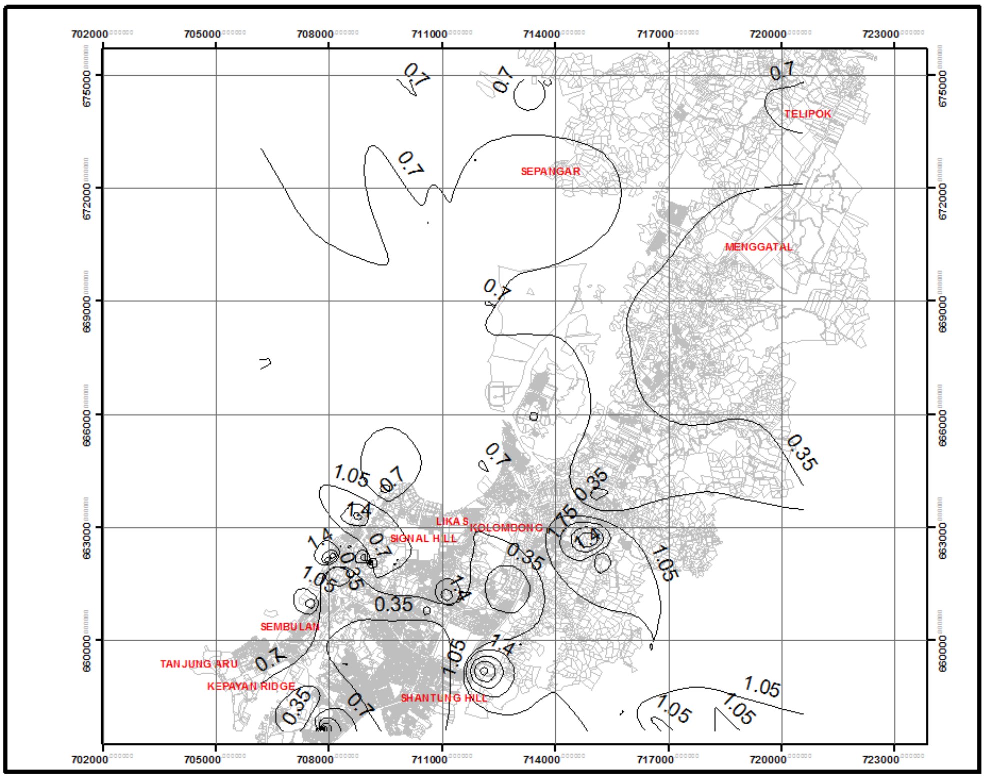


**Fig. 2.** Contour of soil amplification factor, f under 5.9 Mw, t=0.01s.

### *5.2 Response Spectrum*

British standard code (BS 8110) might contain specifications for the seismic hazard although this code is specifically designed for non-seismic behaviours. However, reinforced concrete buildings can be designed in according to BS 8110 and Eurocode 8 with and without seismic consideration for implementation study of seismic design in Malaysia [8].

Eurocode 8 is a useful document providing systematic guidance for seismic design of soil properties, buildings and other structures [9]. But it seems that it is difficult to apply for countries outside of Europe. However as it appears to have a very limited definition of the seismic hazard that is basically expressed in terms of the peak ground acceleration having a 10 % probability of being exceeded in the next 50 years [10]. It does incorporate spectral shapes that are anchored to this peak ground acceleration but this enables earthquake ground motion response spectra thresholds. It defines when seismic ground motion needs to be considered and whether ductile detailing of superstructures is necessary, to be estimated. Compare to British standard code, this Eurocode 8 has more reference in accordance of seismic design of soil properties, buildings and other structures.

Reference of Malaysian National Annex [11] is included for response spectrum of building model. From the Figure 3 shows the response spectrum function is set in refer with MS EN 1998-1:2015 [12]. It is known that this soil sample has ground type of C and PGA value of 0.144 g.

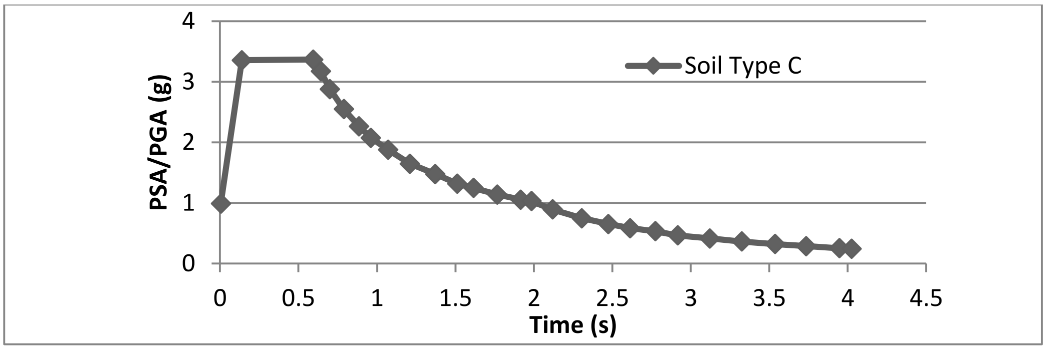


**Fig. 3.** Response spectrum of type I soil C [12]

The building model is to be set with load cases including with the input time motion of KKMR (5.9 Mw, t=0.01s) as mentioned from the Figure 1. This building model was built with reinforced concrete material and it carried out by nonlinear lateral force-displacement response to assess the seismic performance of its structure [13,14]. The dead loads and live loads are assigned on the frame components of building model [15]. The load cases for response spectrum and time history analysis are set up. The peak acceleration is set to 0.144 in response spectrum load case data. The scale factor is defined as from Equation 2.

$$\text{Acceleration (g)} \times 12/1\text{g} \quad (2)$$

Hence the scale factor in the load case data is assigned with value of 1.728 as shown in the equation below.

$$0.144\text{g} \times 12/1\text{g} = 1.728$$

*5.3 Pushover Curve*

Table 4 shows the base shear of the building model with roof displacement on time motion of 5.9 Mw, t=0.01s. It is also found the maximum allowable roof displacement of 47 mm will exceed at base force of 273.13 kN. A pushover curve of base force versus roof displacement is plotted as shown in Figure 4.

**Table 4**
Base Shear & Roof Displacement of Model by Nonlinear Pushover Analysis on time motion of 5.9 Mw, t=0.01s

| Step | Displacement | Base Force |
|---|---|---|
| | m | KN |
| 0 | 0.00214 | 12.224 |
| 1 | 0.0078545 | 44.8375 |
| 2 | 0.013569 | 77.451 |
| 3 | 0.0192835 | 110.0645 |
| 4 | 0.024998 | 142.678 |
| 5 | 0.0307125 | 175.2915 |
| 6 | 0.036427 | 207.905 |
| 7 | 0.047856 | 273.132 |

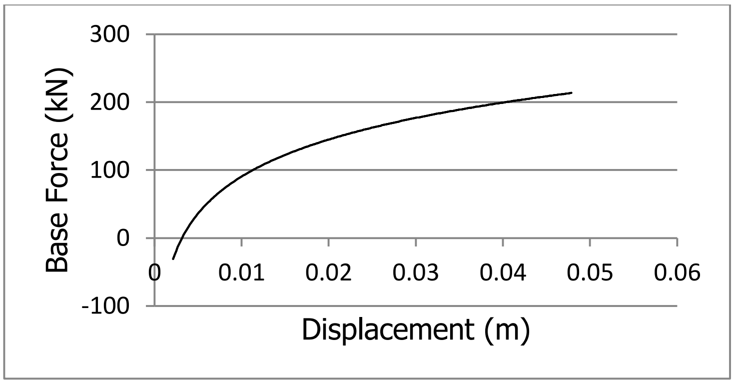


**Fig. 4.** Pushover graph of Base force (kN) Vs displacement (m) of building model on time motion of 5.9 Mw, t=0.01s

## 4. Conclusions

As a conclusion, this research is mainly described the dynamic soil properties for locations of KK city in Sabah, Malaysia. Ground response analyses were performed using one-dimensional shear wave propagation analysis. The analysis was performed with the input motion of 5.9 Mw and ts = 0.01 s. Hence the soil amplification factors for each location in KK city are at a range of 0.018 – 3.428 under this time motion. In this study, this analysis has been observed by using nonlinear approach for consideration of the actual nonlinear response of a soil deposit. From the results obtained, the soil amplification factors for each location in KK city are various. The results of ground response analysis show that the time history and local soil conditions (soil stiffness, stratigraphy and groundwater level) is important for ground response analysis. Generally, time history gives impact to the amplitude of peak ground acceleration, whilst the soil conditions influence the frequency content of the spectrum.

The performance point obtained from the demand capacity-curve that could give an insight into the real behaviour of structures in a real situation. The earthquake ground motion in KK region is in moderate intensity because of the long distance from the epicentre of KKMR region. With the design code of Malaysian National ANNEX, it shows the adaptation of application on the influence of soil condition on the building. This design code has consideration of earthquake load and its seismic resistance. Therefore, these subjects should be carried out with other approaches of ground response analysis in further study of this paper.

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