

THE EFFECT OF THE LATEST SUMATRA EARTHQUAKE TO MALAYSIAN PENINSULAR

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ABSTRACT

Although the Malaysian Peninsular is located relatively faraway from the seismic source zone of Sumatra but the nearest distance of earthquake epicenter from Malaysia is approximately 350 km. Tremors due to Sumatran earthquakes have been reported several times. The newest data from the Malaysian Meteorological Service informed that the newest earthquake near Sumatra on 2 November 2002 had caused tremor in several cities in the Malaysian Peninsular such as Penang, Port Klang, Selangor and Old Klang, Selangor. The tremor had caused panic among residents of the high-rise buildings in Penang and thousands were running out of their buildings.

The objective of this study is to evaluate the effect of the Sumatran Earthquake to the Malaysian Peninsular. This report includes the following items: 1) tectonic setting of Sumatra, 2) location, mechanism, and size of recent earthquake, and 3) analysis of ground acceleration at bedrock for Penang and Kuala Lumpur using several appropriate attenuation relationships.

Seismic analysis is performed in order to obtain Peak Ground Acceleration (PGA) at bedrock of Penang and Kuala Lumpur. Analysis is carried out using deterministic method and using attenuation relationships proposed by Youngs (1997) Atkinson and Boore (1997) and Petersen (2002). Comparison study using those three attenuation functions is also conducted in order to evaluate the effect of selection attenuation function at site location.

INTRODUCTION

Sumatra is one of the islands in Indonesia that experiences earthquakes very frequently. According to data compiled from International Foundations (USGS-NEIC), about 1000 earthquake events occurred during the year 1900 to 2002 with magnitudes, $M_s > 5.0$. The locations of the earthquake epicenters, during these years can be seen in Figure 1.

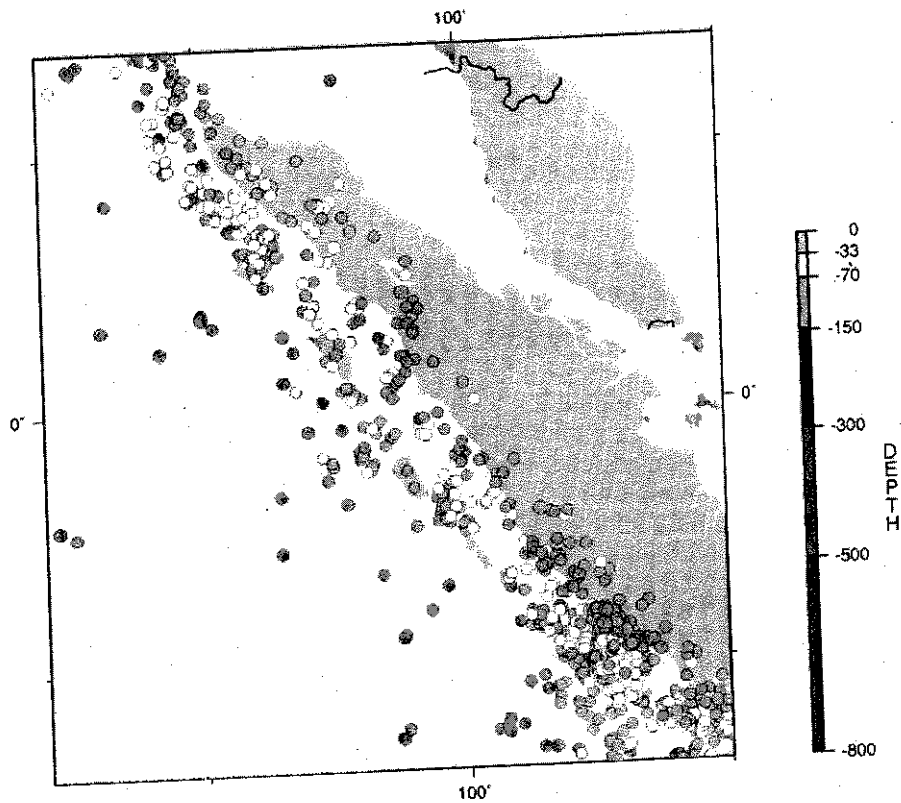


Figure 1. Location of epicenter of earthquake from 1900-2002 (source: USGS-NEIC)

The Malaysian Peninsular is located about 350 km away from the nearest fault line in Sumatra, relatively faraway from seismic source zone. However tremors due to the Sumatra earthquakes had been reported several times. The latest earthquake event occurred on the 2nd November 2002 at Northern Sumatra. The tremors had been felt in Penang and Port Klang and reportedly caused cracks on the buildings.

The objective of this study is to evaluate the effect of the Sumatra Earthquake to the Malaysian Peninsular. This report includes the following items: 1) tectonic setting of Sumatra, 2) location, mechanism, and size of recent earthquake, and 3) analysis of ground acceleration at bedrock for Penang and Kuala Lumpur using several appropriate attenuation relationships.

TECTONIC SETTING

Major tectonic feature of Sumatra area is the Sunda Arc which extends between the Andaman Island in the northwest and the Banda Arc in the east, resulted from subduction of the Indo Australian plate beneath the Sunda Shelf, a stable southern prolongation of the Eurasian plate. The Indo-Australian plate is sliding about 67 mm/year in a northerly direction against the Eurasian plate. The direction of relative plate motion is oblique to the northwest trend of the plate boundary (Huchon and Pichon, 1984). The frequency and magnitude of this subduction zone seismicity is influenced by the age, composition, and rate of convergence of the subducted plate. The largest thrust-fault earthquakes in the Sumatra subduction zone in the last two centuries were that of 1833, which had a magnitude of 8.8-9.2, and that of 1861, which had a magnitude of 8.3-8.5. Tectonic setting of Sumatra is also influenced by strike-slip faulting as a result of the component of plate-motion that is parallel to the trend of the plate boundary in the interior of the island of Sumatra. Tectonic setting of Sumatra can be seen in Figure 2.

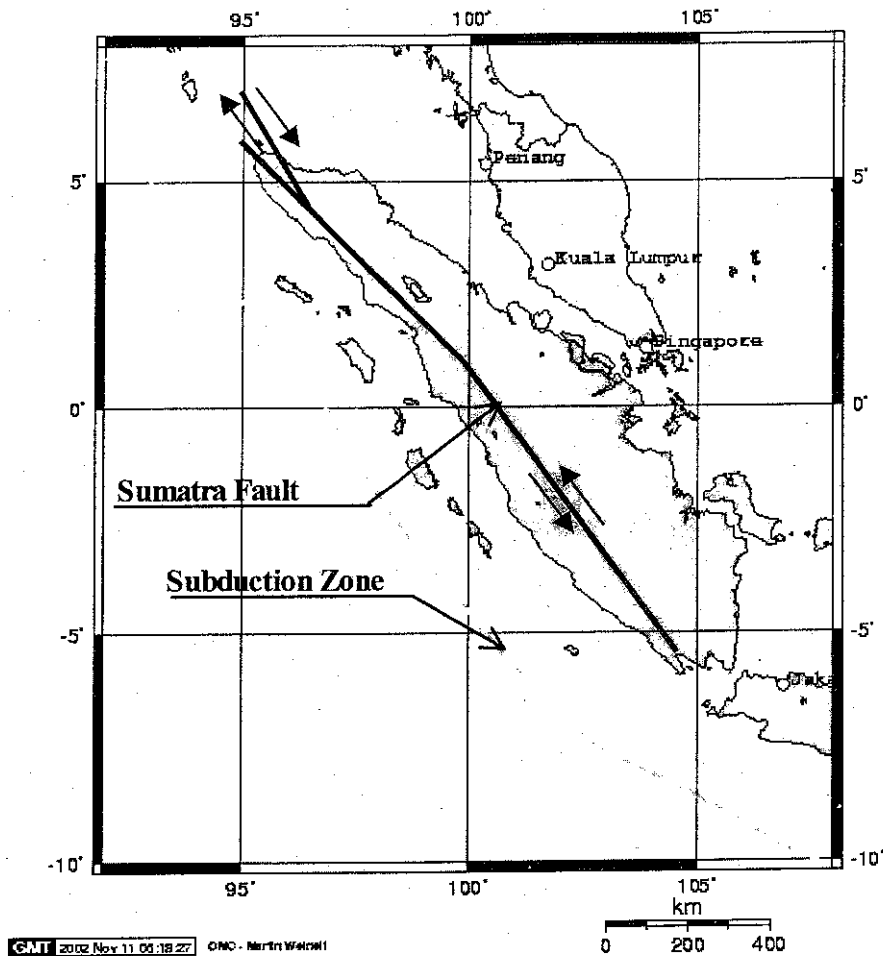


Figure 2. Tectonic setting of Sumatra

SUMATRA EARTHQUAKE - 2 NOVEMBER 2002 (NS2002)

Based on the Preliminary Earthquake Report from National Earthquake Information Center U.S. Geological Survey (USGS-NEIC), NS2002 was located at the longitude of 96.18E and latitude of 3.024 N. The depth of the earthquake was 33.0 km and moment magnitude, M_w , of the earthquake was 7.4. The distance of epicenter from Penang and Kuala Lumpur were approximately 523 km and 600 km, respectively. The location of the earthquake can be seen in Figure 3.

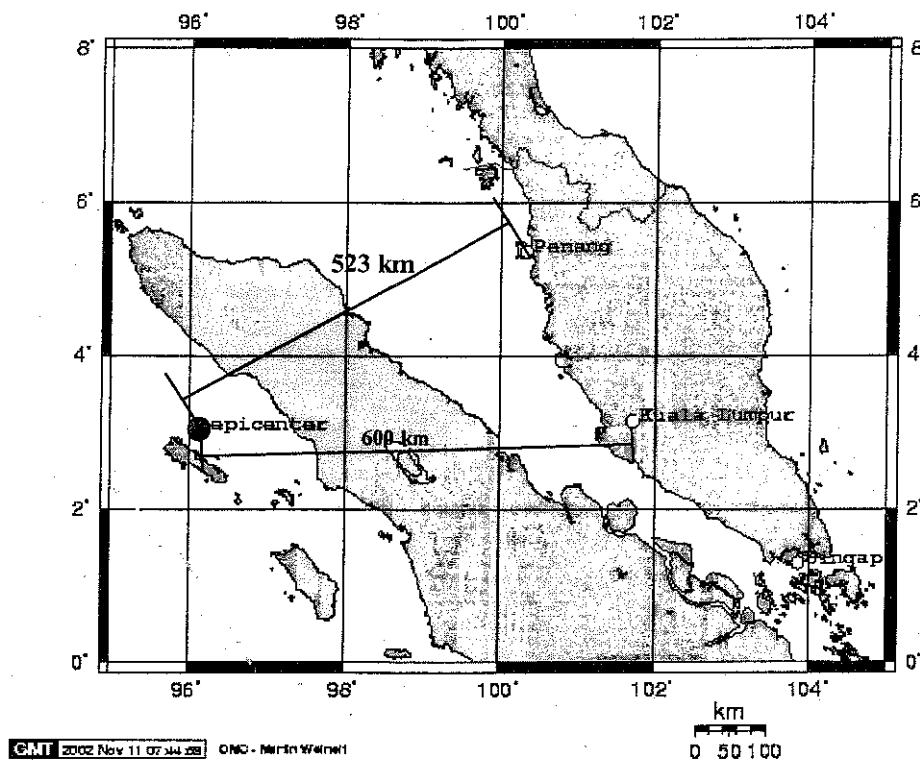


Figure 3. Location of the earthquake

Based on the report, the earthquake occurred as a result of thrust faulting on the boundary between the subducting Australian plate and the overriding Sunda block of the Eurasian plate. In order to verify the mechanism of that earthquake, spatial distribution of earthquakes nearby NS2002 were constructed from earthquake data occurred from the year 1900 to 2002. The earthquake data are selected from the rectangular area shown in Figure 4 with dimensions, 500 km x 1000 km.

The hypocentral profiles can be seen in Figure 5. The 0-km position shown on the profile is the trench axis. The hypocentral profile reveals downward dipping zone of seismicity. Based on that figure it can be seen the NS2002 located on subduction zone.

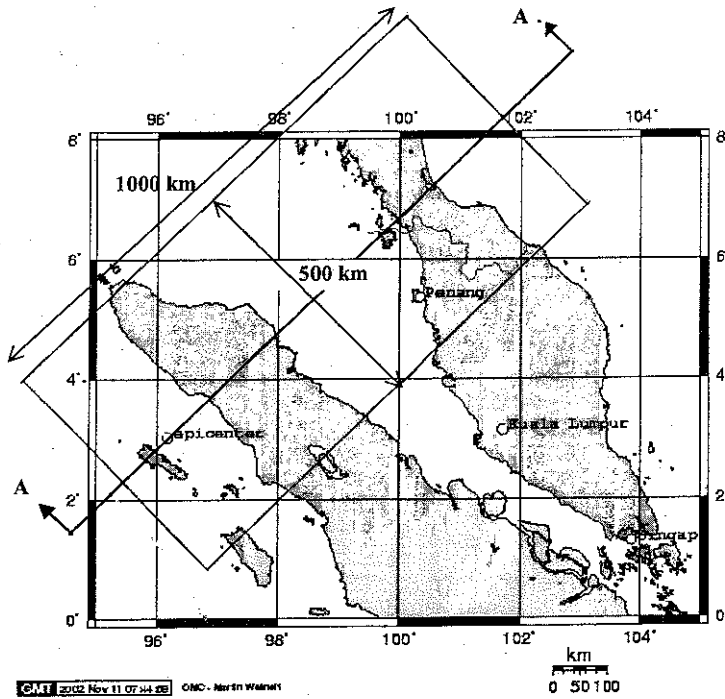


Figure 4. Location of earthquake data

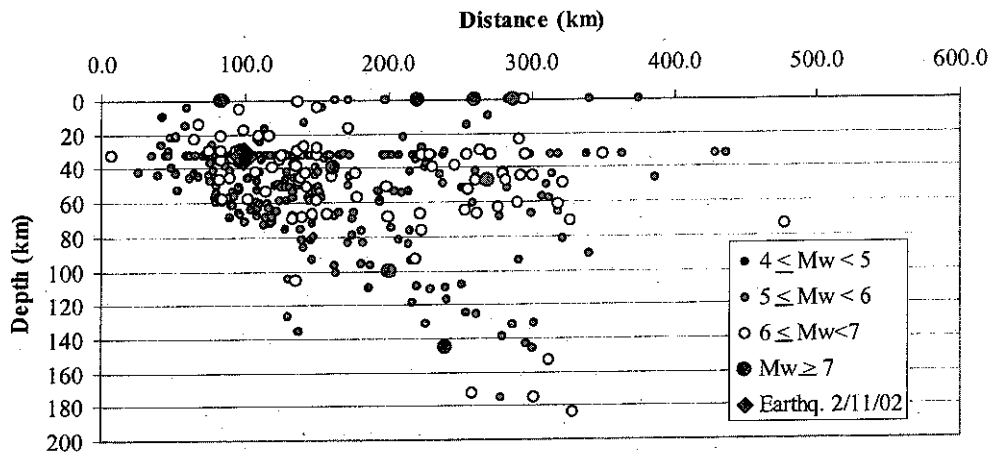


Figure 5. Hypocentral profile at segment A-A (Source: USGA-NEIC)

According to The Malaysian Meteorological Service Department, the earthquake caused tremor in several cities in the Malaysian Peninsular such as Penang, Port Klang, and Old Klang. The tremor caused panic among residents of the high-rise

buildings in Penang. Thousands were running out of their buildings. In Port Klang, Selangor, the tremor was felt in several offices and in Old Klang Road, Selangor, it was felt by residents in the high-rise buildings. Based on the data, it can be predicted that the local size of earthquake effect in Penang is approximately V on MMI scale. There was no report regarding the effect of the earthquake on Kuala Lumpur City Centre.

SEISMIC ANALYSIS

Seismic analysis is performed in order to obtain Peak Ground Acceleration (PGA) at the bedrock of Penang and Kuala Lumpur. Analysis is carried out using deterministic method and using several appropriate attenuation relationships.

Attenuation Relationship

One of the critical factors in seismic analysis is selecting appropriate attenuation relationship. Since there is no attenuation relationship was derived for Malaysian region as well as no adequate ground motion recording to develop attenuation formula, several attenuation functions from other countries are taken.

An attenuation relation derived in a certain region may not be necessarily employed in other region. Therefore the selection of attenuation function is conducted based on similarity of faulting mechanism between site region and that in which attenuation formula was derived. After selecting an attenuation formula, one may verify whether it is appropriate with local site condition. As there are many uncertainties involved in local site condition, it is safer to use attenuation relation for estimating expected ground motion at bedrock. Most investigators derived their formula using peak ground motion recordings at the surface. Hence, it is too conservative if one applies for corresponding relation at bedrock necessarily. Since there are only a few attenuation relations derived at true bedrock sites, a correction factor should be determined to compensate for site condition difference. It takes much consideration and engineering judgments in determining the coefficient.

Generally, the attenuation formula can be categorized according to tectonic environment (i.e. subduction zone and shallow crustal earthquakes) and site condition. Most relations use qualitative measure to represent site condition, except for Boore *et. al.* (1997), which utilizes average shear velocity over the upper 30 m (V_s) to represent site condition. Based on information from USGS, NS2002 was occurred on subduction zone. Hence in this analysis attenuation relationship for subduction zone earthquake were used. There are several attenuation relationships derived for subduction zone earthquake such as Crouse (1991), Youngs (1997),

Atkinson and Boore (1997), Petersen (2002). In this analysis, only attenuation relationships for bedrock are used. Therefore, only attenuations from Youngs (1997) Atkinson and Boore (1997) and Petersen (2002) are taken. Crouse (1997) attenuation relationship is omitted because it was derived for shallow firm soil site in the Pacific Northwest. The attenuations from Youngs (1997) Atkinson and Boore (1997), and Petersen (2002) are described briefly as follows :-

Youngs et al. Attenuation Relationship (1997)

This relation considers two types of subduction zone earthquakes, i.e. interface earthquakes and intraslab earthquakes. Subduction zone interface earthquakes are shallow angle thrust events that occur at the interface between the subducting and overriding plates, while intraslab events occur within subducting oceanic plate and are typically high angle; normal faulting events responding to downdip tension in the subducting plate. Attenuation relations for rock is given as follows:

$$\ln(y) = 0.2418 + 1.414M - 2.552 \cdot \ln(r_{rup}) + 1.7818 \cdot e^{0.554M} + 0.00607 \cdot H + 0.3846 \cdot Z_t$$

Where y is PGA in g's, M is moment magnitude, r is the source to site distance and Z_t is type of earthquake mechanism. This formula is valid to be applied only for epicenter distance less than 200 km.

Gail M. Atkinson and David M. Boore Attenuation Relationship (1997)

This attenuation relationship is derived using a stochastic model to develop preliminary ground motion relations for eastern North America (ENA), for rock sites. Attenuation relations for rock is given as follows:

$$\ln(y) = 1.841 + 0.686(M - 6) - 0.123(M - 6)^2 - \ln(r_{hyp}) - 0.00311 \cdot r_{hyp}$$

Where, y is PGA in g, M is moment magnitude; r_{hyp} is the source to site distance. This equation is proposed to use for epicenter distance less than 400 km.

Petersen et al. Attenuation Relationship (2002)

Petersen et al. (2002) had modified the attenuation relationships in order to calculate PGA for epicenter distances beyond 200 km. They used data from IRIS DMC and Singapore Network to identify the characteristics of ground shaking at large distances. The modification of the Youngs et al. (1997) equation for peak ground acceleration for distances beyond 200 km is given as follows:

$$\ln y_{\text{modified}}(M,x) = \ln y_{\text{youngs}}(M,x) + [-0.0038 \cdot (x-200)]$$

Where y is the peak horizontal ground motion in units of g, M is moment magnitude, and x is distance in kilometers as defined by Youngs et al. (1997).

Results of Analysis

The results of the analyses showed that PGA at bedrock for Penang in accordance with the attenuation relationships from Youngs (1997), Atkinson and Boore (1997) and Petersen et al. (2002) are 3.89 gal, 4.84 gal, and 1.14 gal, respectively as shown in Figure 6, Figure 7, and Figure 8. The effect of the earthquake in Kuala Lumpur is lower about 25% to 31% than Penang. According to the attenuation relationships from Youngs (1997), Atkinson and Boore (1997), and Petersen et al. (2002) the PGA at bedrock for Kuala Lumpur are 2.90 gal, 3.32 gal, and 0.63 gal, respectively.

In order to compare the effect of epicenter distance using those three attenuation functions, relationship between distance and PGA are calculated. The result can be seen in The Figure 9. The first vertical line in the figure indicates the distance limitation for Youngs (1997) and the second line for Atkinson & Boore (1997). Based on the figure, it can be seen that attenuation formula form Atkinson and Boore (1997) gives a higher value than the others. For longer distance (more than 400 km) attenuation Youngs (1997) tends to attenuate more slowly than the others. This attenuation is saturation faster than another because the formula was derived only for small distance earthquake (less than 200 km). In contrast, after modification by Petersen (2002), the acceleration of the earthquakes decreased significantly at the distance beyond 200 km. The value of the difference increases as the distance increase. The range of the difference is between 17% and 82%. These comparisons show the critical point of selecting an appropriate attenuation function. This step will influence the results of seismic risk analysis significantly. Therefore, comprehensive studies in order to select the attenuation function are needed.

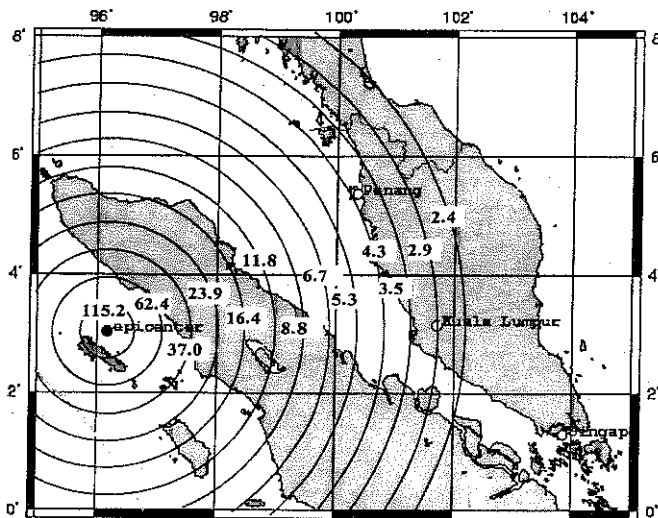


Figure 6 : PGA Contour using Youngs (1997) attenuation relationship

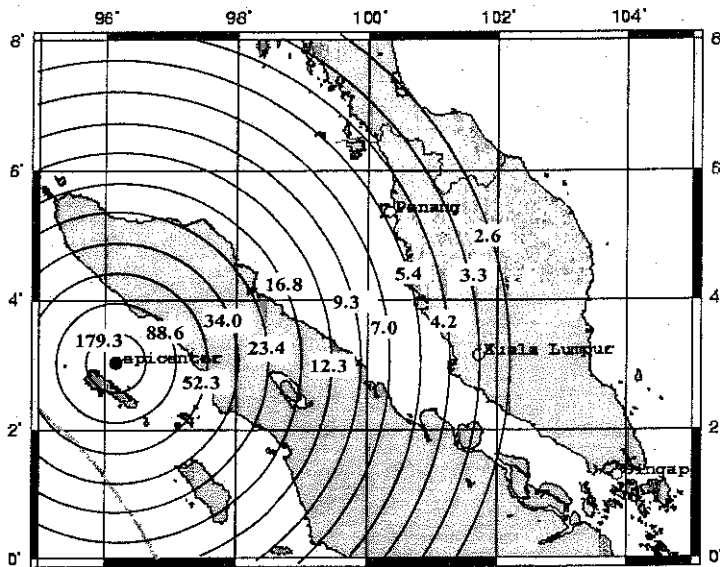


Figure 7 : PGA Contour using Atkinson & Boore (1997) attenuation relationship

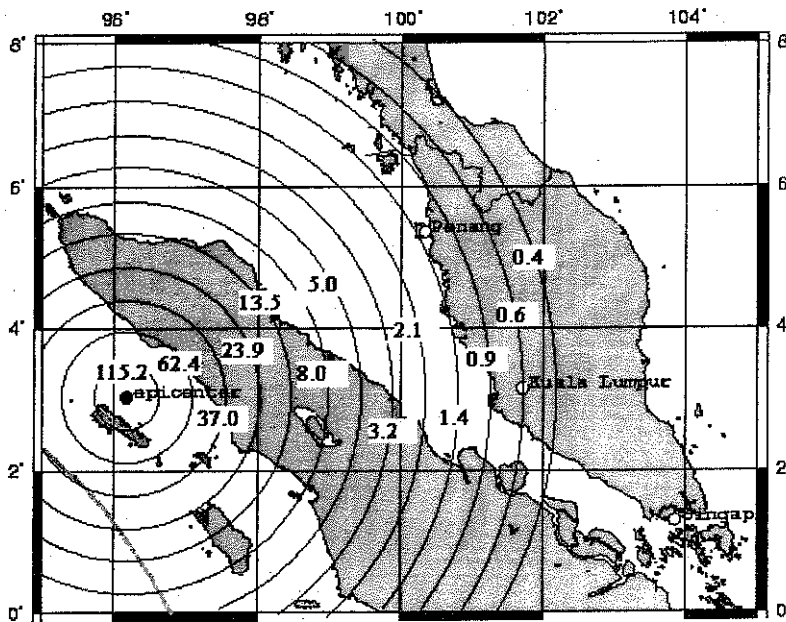


Figure 8 : PGA Contour using Petersen et al.(2002) attenuation relationship

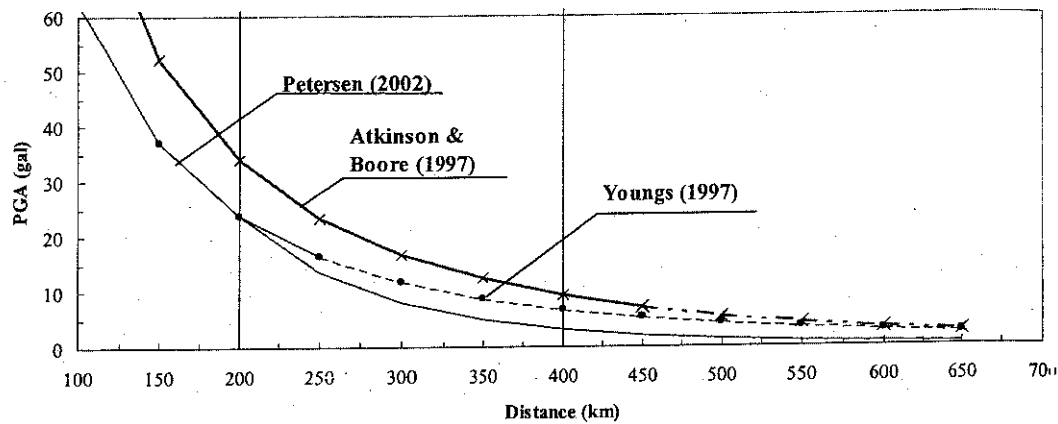


Figure 9 : Comparison of three attenuation relationships

CONCLUSION

Seismic analysis had been performed in order to obtain Peak Ground Acceleration (PGA) at the bedrock of Penang and Kuala Lumpur. Analysis is carried out using deterministic method and using attenuation relationships proposed by Youngs (1997) Atkinson and Boore (1997) and Petersen (2002). Those attenuation relationships were chosen due to the similarity of the tectonic environment (subduction zone) and site condition where the formula was derived.

The results of the analyses showed that PGA at bedrock for Penang in accordance with the attenuation relationships from Youngs (1997), Atkinson and Boore (1997) and Petersen et al. (2002) are 3.89 gal, 4.84 gal, and 1.14 gal, respectively. The effect of the earthquake in Kuala Lumpur is lower about 25% to 31% than Penang. According to the attenuation relationships from Youngs (1997), Atkinson and Boore (1997), and Petersen et al. (2002) the PGA at bedrock for Kuala Lumpur are 2.90 gal, 3.32 gal, and 0.63 gal, respectively.

Comparison study using those three attenuation functions had been conducted. The results of analysis show the difference value of those three attenuation functions range between 17% and 82%. These comparisons illustrate that selection of appropriate attenuation function is one of the critical factors in seismic analysis. This step will influence the results of seismic risk analysis significantly. Therefore, comprehensive studies in order to select the attenuation function are needed.

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