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ATTENUATION FUNCTION RELATIONSHIP OF SUBDUCTION MECHANISM AND FAR FIELD EARTHQUAKE

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ABSTRACT

An attenuation relationship for far field earthquakes considered by subduction has been developed. The attenuation relationship function was developed using regression analysis. The database consisting of more than 130 peak ground accelerations from seven earthquake sources recorded by Seismology Station in Malaysia have been used to develop the relationship. This study aims to investigate the new relationship attenuation to gain exact peak ground acceleration at the location on site. Based on this study, the location is a structure located at Terengganu seaside. Referring to that data provided by Malaysia Meteorological Department Malaysia, an attenuation function was developed and that function can be used for earthquake prediction.

Keywords: attenuation, earthquake, subduction.

INTRODUCTION

Attenuation is when the seismic waves move farther away from the epicenter which is they grow smaller as they are attenuated by the ground. The energy with which an earthquake affects a location depends on the running distance. The attenuation in the signal of ground motion intensity plays an important role in the assessment of possible strong ground shaking. This phenomenon is tied in to the dispersion of the seismic energy with the distance. There are two types of dissipated energy which is geometric dispersion caused by distribution of the seismic energy to greater volumes and dispersion as heat.

ATTENUATION FUNCTION

Introduction of Attenuation Function

Attenuation is when the seismic waves move farther away from the epicenter which is they grow smaller as they are attenuated by the ground. The energy with which an earthquake affects a location depends on the running distance. The attenuation in the signal of ground motion intensity plays an important role in the assessment of possible strong ground shaking.

This estimation is carried out using a ground motion relation. This relation, that is commonly referred to in engineering as an attenuation relation, is a simple mathematical model that relates ground motion parameters (i.e. acceleration, velocity and displacement) to earthquake source parameters (i.e. magnitude, source to site distance, mechanism) and local site conditions (Campbell, 1985).

A large number of attenuation relations have been developed by different investigators since the record of ground motions become more available. In general, they are categorized according to tectonic environment and site condition (i.e. rock, soft soil, or stiff soil). A seismic wave loses energy as it propagates through the earth (attenuation). This phenomenon is tied in to the dispersion of the seismic energy with the distance.

Subduction Earthquake

Subduction is the process that takes place at convergent boundaries by which one tectonic plate moves under another tectonic plate and sinks into the mantle as the plates converge. Regions where this process occurs are known as subduction zones. Subduction zones mark sites of convective downwelling of the Earth's lithosphere (the crust plus the top brittle portion of the upper mantle).

Subduction zones exist at convergent plate boundaries where one plate of oceanic lithosphere converges with another plate.

Strike Slip Earthquake

Strike-slip earthquakes commonly occur along vertical fault plane as one side of the fault slides horizontally past the other. If the far side of the fault shifts to the right it is termed a right-lateral fault and if it shifts to the left, it is left-lateral fault. With dip-slip earthquakes, the fault is usually at an angle with the earth's surface and the movement is up or down. For faults that make an angle with the earth's surface, names are given for the two sides of the fault. The top side of the fault is known as the hanging wall and the bottom side is the footwall.

On a normal-slip fault, the hanging wall moves down and the footwall up and on a reverse-slip fault, the reverse happens with the hanging wall moves up and the footwall moves down. A common feature along normal-slip faults is for the hanging wall to collapse and create a secondary fault that dips into the main fault. The area downdropped between these two faults is called a graben. If a fault has both strike-slip and dip-slip movement, it is known as an oblique-slip fault.

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ATTENUATION RELATIONSHIP FOR SHALLOW CRUSTAL MECHANISM

An essential element in both deterministic and probabilistic seismic hazard analyses is the ability to estimate strong ground motion from a specified set of seismological parameters.

This estimation is carried out using a ground motion relation. This relation, that is commonly referred to in engineering as an attenuation relation, is a simple mathematical model that relates ground motion parameters (i.e. acceleration, velocity and displacement) to earthquake source parameters (i.e. magnitude, source to site distance, mechanism) and local site conditions (Campbell, 2003). A large number of attenuation relations have been developed by different investigators since the record of ground motions become more available. In general, they are categorized according to tectonic environment and site condition (i.e. rock, soft soil, or stiff soil).

A state of the art assessment of the attenuation relationships could be found in a special issue of Seismological Research Letters. The brief summary regarding some attenuation relations have also been listed by Engineering Seismology and Earthquake Engineering (ESEE) report No. 01-1 which presented a comprehensive worldwide summary of strong-motion attenuation relationships since 1969 until 2000. Some of the attenuation relations are summarized in Table-1.

Table-1. Summary of attenuation functions.

Model	Calculated	Site Condition	Ranges	
			R (km)	M_w
Western North America				
Abrahamson and Silva (1997)	PHA, PVA, S_{ah}, S_{av}	Rock, Deep Soil	0-100	4.0-8.0
Boore *et al.* (1997)	PHA, S_{ah}	Vs in upper 30m	0-80	5.5-7.5
Campbell (1997)	PHA, PVA, PHV PVV, S_{ah}, S_{av}	Hard Rock, Soft Rock Soil	0-100	4-9.5.0
Sadigh et al. (1997)	PHA, S_{ah}	Rock, Deep soil	0-100	4.0-8.0
Sadigh and Egan (1998)	PHA, PHV, PHD	Rock, Soil	0-100	4.0-8.0
Central and Eastern North America				
Atkinson and Boore (1997)	PHA, S_{ah}	Rock	10-300	4-9.5.0
Toro et al. (1997)	PHA, S_{ah}	Rock	1-100	5.0-8.0
Campbell (2003)	PHA, S_{ah}	Rock	1-1000	5.0-8.0
Subduction Zones				
Atkinson and Boore (1997)	PHA, PHV, S_{ah}	Rock	10-400	4-9.5.0
Youngs *et al.* (1997)	PHA, S_{ah}	Rock, Soil	0-100	4-9.5.0

Most commonly, the attenuation relationships were derived using empirical method based on historical earthquake data. There are several inherent strengths in this method that make it most popular method to obtain the relationship. The first strength is its simplicity because a lot of method in mathematic statistic that can be used to develop the relationship such as regression analysis or artificial neural network. The second strength is that it relies on the actual earthquake data.

Therefore, this method has accounted aleatory of variability or the randomness variability due to the unknown or unmodelled characteristics of the underlying physical process (Campbell, 2003). The empirical method requires numerous strong motion data in order to obtain reliable results. The limitation of the function will depend on the quality of strong motion data such as quantity and the distribution of parameters of attenuation function such as magnitude, depth, distance and peak acceleration. Usually attenuation relationships are derived for near source earthquakes; consequently, most of the attenuation relationships have a distance limit about 80 km to 400 km away from hypocentral or epicentral distances.

Peninsular Malaysia is located near Sumatra, which is one of the islands in Indonesia that experiences earthquakes frequently. Due to its location, Peninsular Malaysia is affected by earthquakes from Sumatra in which the nearest distance of earthquake epicentre from Malaysia is approximately 350km.

RESEARCH METHODOLOGY

Site specific seismic hazard evaluation studies require estimation of strong ground motion from probable earthquakes. The estimation of peak ground acceleration in terms of magnitude, source-to-site distance, tectonic environment and source type using attenuation relationships has been a major research topic in seismic hazard estimation studies. Such relationships are developed in the past for various regions and comprehensive reviews have been published for such relationships (Boore *et al.* 1982), (Campbell, 1985), (Joyner *et al.* 1988), (Abrahamson *et al.* 1989), (Fukushima and Tanaka, 1990).

Most of the relationships are developed using worldwide acceleration data acquired through the strong motion arrays. The general form of regression models have been described by (Campbell, 1985).

For the regions where strong motion data is not available for such analysis, the attenuation relationships developed for other regions are used based on the resemblance of the characteristics of the both regions. In some of the cases, where lesser data is available the empirical relations are developed by pooling some of the data from other regions (Fukushima and Tanaka, 1990).

The vertical accelerations are generally smaller than horizontal accelerations for strong motion data from earthquakes recorded at shorter distances. An attenuation relationship for peak ground vertical acceleration is developed in the present study (Kramer, 1996). This relationship is then compared with the attenuation relationship developed on the same data set for peak ground horizontal ground acceleration and the ratios of vertical to horizontal peak ground acceleration are then compared with the actual ratios recorded by the stations.

An attenuation relationship for far field earthquakes considered by subduction mechanism has been developed. The attenuation relationship function was developed using regression analysis by part of researchers. In this research, the new attenuation function for subduction mechanism is followed a typical forms of attenuation relationship proposed by previous researchers (Young *et al.* 1997), (Ergin Ulutas and Mithat Firat Ozer, 2010).

ANALYSIS OF DATA

Peak Ground Accelaration (PGA) Data

Peak ground acceleration (PGA) is very important for earthquake hazard assessments and emergency response operations. One of the earthquake hazard assessments is the determination of earthquake effect and type of ground motion at the site. Typically, this is done by means of an earthquake ground motion attenuation relationship which provides the estimation of ground motion for an earthquake of a given magnitude at a different distance through a curve fitted to the observed data. The development of an attenuation relationship is based exclusively on the recorded seismic events.

From more than 200 available ground motion records, 130 data were selected for analysis of PGA. This is because waveforms with background noises have been excluded and only records, which are applicable to support a distance range recommended by selected attenuation relationships and also subduction fault only have been accounted for. Furthermore, insignificant waveforms, which exist within the available dataset, have been removed by applying resolution values for PGA.

Between Year 2004 and Year 2012, a few interpolate earthquake events of magnitude Mw ≥ 3.5 recorded. Out of these 21 events, 11 were from subduction zone, which occurred along the Sumatran, Peninsular Malaysia, Sabah and Sarawak fault, while the remaining 10 events occurred within the strike slip zone.

The magnitude of the events were adopted from the Malaysian Meteorological Department (MMD) and National Earthquake Information Center (NEIC) of the United States Geological Survey (USGS). The data based used for the study has been made available by the Malaysian Meteorological Department located in Petaling Jaya which has deployed a few of stations in Malaysia Region. Table-2 presents the summary of the selected subduction earthquake that occur from Year 2004 to Year 2012. The earthquake occur surrounding Malaysia and the event map presented in Figure-1. On the maps also mark the location of the event using identity name.

Table-2. Summary of subduction selected earthquake.

Event	Identity Name	Date	Time
Southern Sumatera Indonesia	SB 1A	12/09/2007	23:49:00
Southern Sumatera Indonesia	SB 1B	25/02/2008	08:36:00
Southern Sumatera Indonesia	SB 1C	30/09/2009	10:09:09
Sumatera Acheh	SB 2A	11/04/2012	08:38:00
Sumatera Acheh	SB 2B	11/04/2012	10:43:00
Northern Sumatera Indonesia	SS 3A	01/12/2006	03:58:00
Northern Sumatera Indonesia	SS 3B	06/04/2010	22:15:06
Off West Coast Northern Sumatera Indonesia	SS 4A	28/03/2005	16:09:00
Sulu Archipelago	SS 5A	02/05/2012	12:32:00
Belaga (Bakun) Sarawak Malaysia Belaga (Bakun) Sarawak Malaysia	SS 6A SS 6B	09/05/2012 12/05/2012	21:02:00 03:55:00

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Sarawak Malaysia

Figure-1. Selected subduction earthquake location on maps.

RESULT AND DISCUSSIONS

Developing New Attenuation Function

This study aims to investigate the new relationship attenuation for subduction earthquake to gain exact peak ground acceleration at the location on site. Based on this study, the location is a structure located at Terengganu seaside (Longitude 5.6079 N, Latitude 103.9052 E). In the Southern Asia region (Indonesia, Philippine and Malaysia) for example, there is significant hazard from earthquake along the subduction fault. From the obtained result, the new attenuation function is :

$$\ln Y = 3.24857 - 2.27216\, M_w + 2.7529\, M_w^{1.12783} - 2.21827 \ln(R + 360.46122\, e^{-1}(-0.05307\, M_w)) - 0.0484\, H \quad (1)$$

Where ;

- Y = Mean of ground motion (PGA) in gals
- M_w = Magnitude of the earthquake (moment magnitude)
- R = Distance from the source to the site being considered (hypocentral distance)
- H = Focal depth of site characteristics function (km)

PGA Data from Different Event Using Attenuation

Using the attenuation function in equation 1 that generated from regression analysis, list of PGA value in gals obtained. The required data fill up using the real data that provided by the MMD and NEIC of the United States Geological Survey (USGS). Table-3 shown a summary of peak ground acceleration in unit gals. The PGA value was very small and the result was very logic because of far field distance.

Table-3. Summary of PGA analysis.

Identity Name	Magnitude	Distance (km)	Focal Depth (km)	Peak Ground Acceleration (gals)
SB 1A	7.9	996.5	35	0.000431
SB 1B	7.2	1025	25	0.000214
SB 1C	7.2	996.8	25	0.000254
SB 2A	7.71	1242	25	0.000289
SB 2B	7.61	1383	10	0.000220
SB 3A	6.6	204	10	0.000100
SB 3B	7.24	829.7	31	0.000292
SB 4A	8.6	835.4	30	0.001170
SB 5A	7.8	1720	4.47	0.000008
SB 6A	3.78	1137	20.9	0.000009
SB 6B	3.53	1155	40.63	0.000007

CONCLUSIONS

An attenuation function was developed and this equation can be used to determine or predict peak ground acceleration for far field earthquake. At the same time, people can make ready whether the condition is going to be worst or safe if an event of earthquake occur.

This attenuation function should be compared to the other function but same consideration must be take for the consideration. The most important thing are that regression analysis were based on subduction mechanism and also referring to far field earthquake.

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