THE REVIEW OF THE STRONG GROUND MOTION OBSERVATION IN MALAYSIA AND PROPOSING IMPROVEMENT BASED ON THE IMPORTANCE OF THE LONG PERIOD GROUND MOTION

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ABSTRACT

Due to recent increase in human felt tremors in Malaysia, this study aims at proposal of an appropriate setting of strong motion observation, highlighting the importance of long period ground motion. Two ways are taken to emphasize the long period ground motion (LPGM) for the strong motion observation in Malaysia that is in the deterministic way and statistical way. Recorded Sumatra event on September 29, 2009 at IPM broadband station in Malaysia were selected and in Japan, three Kik-net stations recording four events, coded as S1, S2, S3 and S4, occupied with borehole and surface sensors, with depth ranging from shallow, intermediate and very deep were selected.

In deterministic way, the product of the transfer function, namely Fourier spectra ratio, obtained from S2 event with IPM true ground motion, will produce the synthetic waveform at each ground model. Next, from the synthetic waveform deterministic estimate of acceleration (S_a) and velocity (S_v) response spectra were calculated. For the statistical way, mean S_a ratio of four events were calculated. Then the product of mean S_a ratio with the estimated bedrock motion using the attenuation relation of Yuzawa and Kudo (2006) were obtained at each ground model.

Results show small amplitude of acceleration with long duration of motions about 20 minutes. The obtained deterministic estimate of S_a and S_v shows predominant periods around 0.7 to 0.8 second and 9 seconds respectively, which can still be observed with the appearance of other peaks that seems to be controlled by the thickness of the sediments or soil layers at each ground models. Statistical estimate of S_a shows three times higher than the deterministic estimate of S_a and might be due to the regionality in the attenuation characteristic of Malaysia and Japan. However, the trend is similar and thus the results are acceptable.

Considerable attention is paid to the long duration of motion about 20 minutes and some possible ways to set up strong motion are proposed. For the necessity of assisting a structural design and for hazard assessment, the measure should start with the data recording in all of the current installed strong motion stations in Malaysia.

Keywords: Long period ground motion, Kuala Lumpur, deterministic estimate, statistical estimate, Acceleration Response Spectra (S_a), Velocity Response Spectra (S_v).

1. INTRODUCTION

Malaysia is divided into two regions, separated by the South China Sea. West Malaysia consists of Malaysian Peninsula and east Malaysia consists of Sabah and Sarawak. It lies on the stable Sunda platform of the Eurasian plate and is bounded by two major seismically active plate boundaries, the Indo-Australian plate and the Philippine Sea plate. Kuala Lumpur, main capital city of Malaysia, where most of the high rise building is situated had experience tremors especially by the people in

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high rise building due to large events originating from the Sumatra region, the needs to study structure response, ground motion and risk analysis had becomes vital.

Malaysian Meteorological Department (MMD) has increased its seismic observation stations including ten strong ground motion observation networks placed in and around the Klang Valley area. However, there has been no recorded strong motion data obtained from this strong motion stations and ground motion on the surface of sediments at approximately 500 km to 600 km from the Sunda trench is still unknown and it is a necessary information in setting up the strong motion observation network in and around Klang Valley area.

This study aim to propose an appropriate setting of strong ground motion observation and to achieve this, examples of the estimated strong ground motion are shown, emphasizing the LPGM, 1 to 10 seconds or more in assisting the building and hazard risk study in Malaysia.

2. THEORY AND METHODOLOGY

Low frequency or long period waves are more robust to energy dissipation and hence can transmit more energy over much longer distance (Balendra et al. 2002). Two examples due to the effect of long period wave in a great distance from large earthquake events. One is during the Michoacán earthquake (September 19, 1985, Ms = 8.1), causing 20,000 fatalities in Mexico City, 400 km away from the epicenter (Koketsu et al. 2005) and another is September 26, 2003 Tokachi-Oki earthquake (M_w 8.3) 250 km away from Tomakomai city which had caused two oil tanks to catch on fire.

For the estimation of ground motion at the bedrock, the following two ways are taken: One is the deterministic way using the real earthquake and another is the statistical way using empirical attenuation relation of the acceleration response spectra (S_a).

For the deterministic way, broadband seismological station IPM (4.48°N and 101.03°E) recording the earthquake occurred at 10:16UTC September 30, 2009 with epicenter at 0.7°S 99.86°E and at the depth of 81 km are used. Their geographical configuration is shown in Figure 1. Tan et al. (2006) mentioned the similarity of geological condition for Ipoh and Klang Valley area, and it seems that the path effect from the source event to Klang Valley can be replaced with that to IPM station. IPM and Kuala Lumpur are located in almost similar azimuth from the epicenter of the event, whereas their epicenter distance differs slightly. Klang Valley has an epicenter distance of around 500 km and for IPM around 586 km. The data files of velocity waveform are downloaded from the Incorporated Research Institutions for Seismology (IRIS) earthquake database. The sampling rate of the seismogram obtained at IPM is 20Hz and then the frequency components higher then 10Hz are not included. Therefore, a direct comparison with existing attenuation relation of PGA or PGV cannot make sense. Next, the system correction and numerical differentiation to obtain the accelerograms are applied using the Seismic Analysis Code (SAC). Figure 3(a) and 3(b) shows the acclerograms and the velocity seismograms at IPM and Figure 4 shows the S_a and the velocity response spectra (S_v) respectively. Hereafter, these are called "observed S_a and S_v at IPM" respectively.

For the statistical modeling of the bedrock motion, the attenuation relationship of S_a proposed by Yuzawa and Kudo (2008) is used that is obtained for the bedrock motion of LPGM recorded at all around Japan by Kik-net. Any other formula cannot be found for LPGM at bedrock that also is applicable for the epicentral distance as far as about 500 km.

The site effect with a pair of three component sensors at the ground surface and another at the bottom of borehole that reaches to hard rock are used and among them, AICH09, AICH20 and AICH22 in Toyohashi Plain having different depths. Toyohashi Plain has the similar lateral extent and the similar opening towards the subduction zone to those of Klang Valley and is not located on a deep tectonic basin, same as Klang Valley. Depths range from shallow, intermediate to deep structure and it seems convenient to use all three different depths in discussion of amplification effect of Klang Valley of which velocity structure is unknown.

The transfer function, namely, Fourier spectral ratio of the records obtained at the surface to that at borehole are calculated for AICH09, AICH20 and AICH22 that are named as Ground Model 1 (G1), Ground Model 2 (G2) and Ground Model 3 (G3) respectively. These are used in place of the local site effect for the deterministic estimation. Earthquake events are selected, shown in Figure 2, by taking into account the recorded duration of waveform and the magnitude. The former is to consider the possible long response time function due to basin induced surface waves and the latter for the capacity of generating LPGM. Each event is named as S1, S2, S3 and S4 respectively. For deterministic estimation, only S2 is used to calculate the transfer functions at three ground models.

Figure 1. The location of Kuala Lumpur, IPM station, Sumatra earthquake event and the subduction zone.

Figure 2. Map showing AICH09, AICH20 and AICH22 and Four Seismic events along the trench.

For the deterministic way, accelerograms at each ground are derived by the convolution of the acclerograms of IPM with the transfer function of each ground in the frequency domain and then the waveforms are reconstructed using the reverse Fast Fourier Transform (FFT). Then S_a and S_v are calculated from these synthetic ground motion in the time domain using the View Wave software developed by Kashima (2009).

For the statistical way, at each station, the ratio of S_a at surface and borehole, for four events are calculated. Then, the mean S_a ratio is obtained by averaging out all the four S_a ratio at each ground that will suppress the features of S_a ratio that are the properties of each event. Next, the product of these mean S_a ratio to the estimated S_a at bedrock using the attenuation relationship proposed by Yuzawa and Kudo (2006) will provide us S_a estimated at ground surface. Hereafter, the S_a estimated at ground surface is called statistical estimate of S_a.

3. RESULTS OF THE ANALYSIS

IPM waveforms as depicted in Figure 3(a) show small amplitude of acceleration, main part is about 300 seconds and at the end of the record amplitude is still bigger than the noise level observed before P-onset. Figure 3(b) in velocity waveforms show the long duration obtained on this hard rock site more clearly. The calculated S_a and S_v for IPM of both damping factor, 1% and 5% shows predominant periods around 0.7 to 0.8 second in north-south (NS) component and 9 seconds in up-down (UD) and east-west (EW) component respectively as shown in Figure 4.

Figure 5 show small peak acceleration at all ground model with long duration of ground motion and clearly depicted in velocity seismograms. A comparison of Figure 12 and Figure 13 with Figure 6(a) and (b) shows that the long duration takes place in the absence of a deep tectonic basin and that this LPGM is observed in the bedrock ground motion. The cause of LPGM may be due to the earth crust that is different from the cases of Tomakomai City and Mexico City where amplification in deep basin occurred resulting in higher amplitude of acceleration at ground surface.

The deterministic estimate of S_a at each ground shows the predominant period of 0.7 to 0.8 second. However, by comparing Figure 7, Figure 8 and Figure 9 to that of Figure 4, following observation can be noted where other peak also appears in the relatively short period at G1 and two peaks in short period component for G3, whereas for G2, similar results were obtained with that of the observed S_a at IPM. As for the deterministic estimate of S_v, long period peak at IPM around 9 seconds can still be observed at each ground. However, at G1 and G3, other peaks also appear at short period and relatively short period, while G2 shows nearly similar results with the obtained S_v at IPM. These peaks seem to be controlled by the thickness of the sediments.

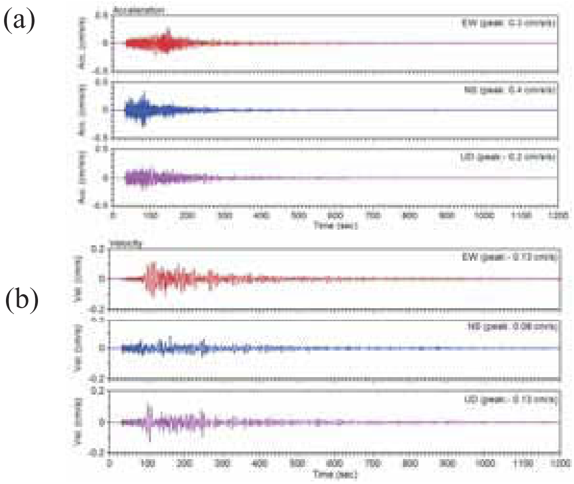

Figure 3. (a) Accelerogram and (b) velocity seismogram of true ground motion at IPM station bedrock.

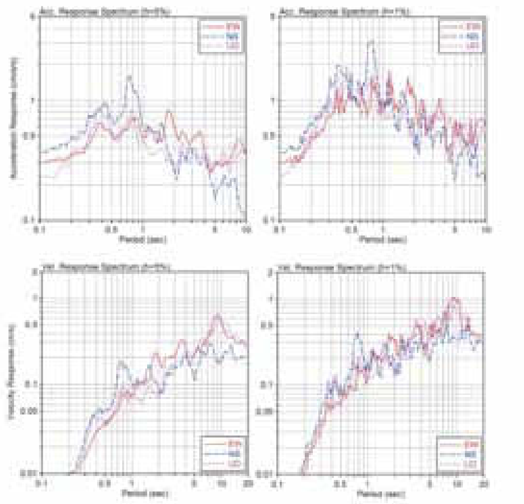

Figure 4. Observed respond spectra at IPM. Top left) S_a with h=5%, top right) S_a with h=1%, bottom left) S_v with h=5% and bottom right) S_v with h=1%.

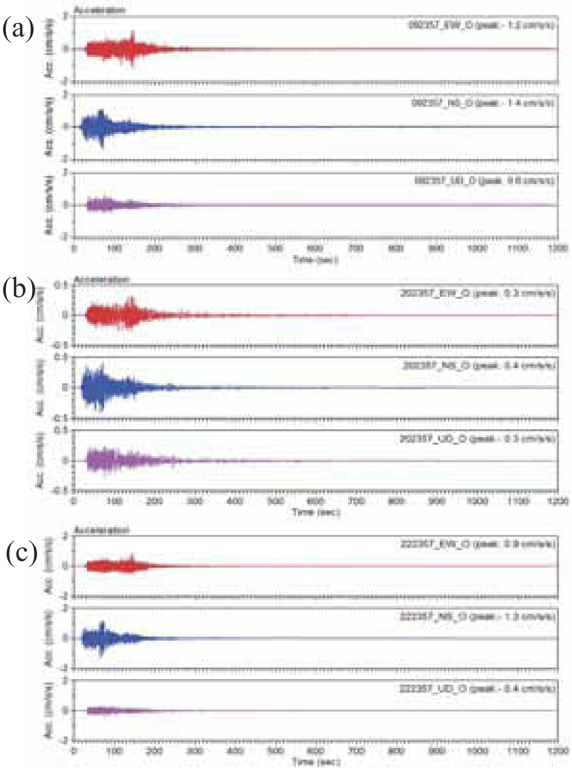

Figure 5. Three component of acceleration waveform obtained at (a) G1, (b) G2 and (c) G3 ground surface.

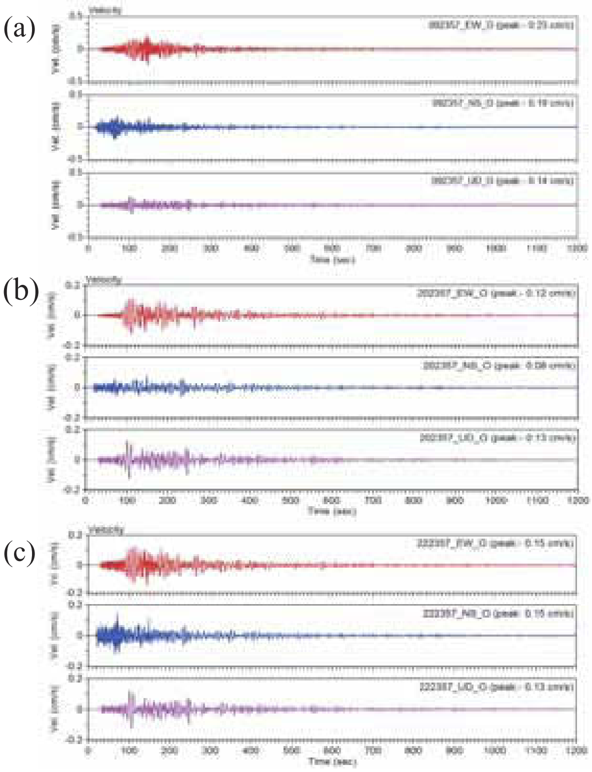

Figure 6. Three component of velocity waveform obtained at (a) G1, (b) G2 and (c) G3 ground surface.

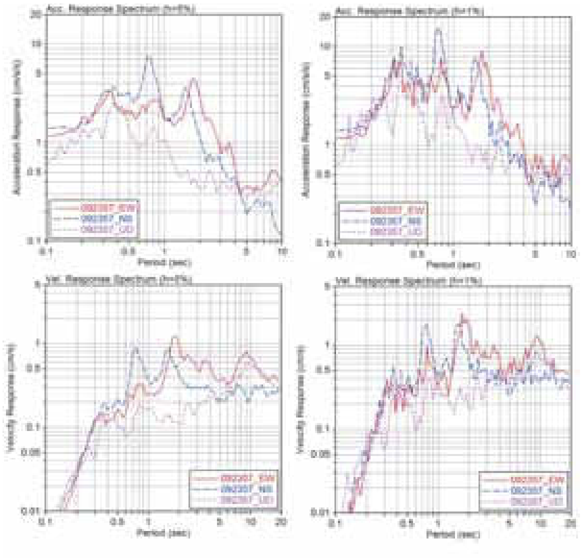

Figure 7. Three components of S_a and S_v at ground surface of G1. They are made from the bedrock motion observed at IPM and the transfer function calculated for G1. Top left panel) S_a with h=5%, top right panel) S_a with h=1%, bottom left panel) S_v with h=5% and bottom right panel) S_v with h=1%

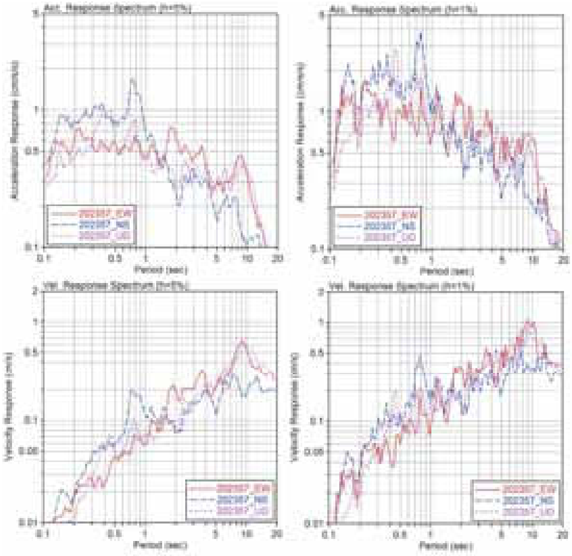

Figure 8. Three components of S_a and S_v at ground surface of G2. They are made from the bedrock motion observed at IPM and the transfer function calculated for G2. Top left panel) S_a with h=5%, top right panel) S_a with h=1%, bottom left panel) S_v with h=5% and bottom right panel) S_v with h=1%

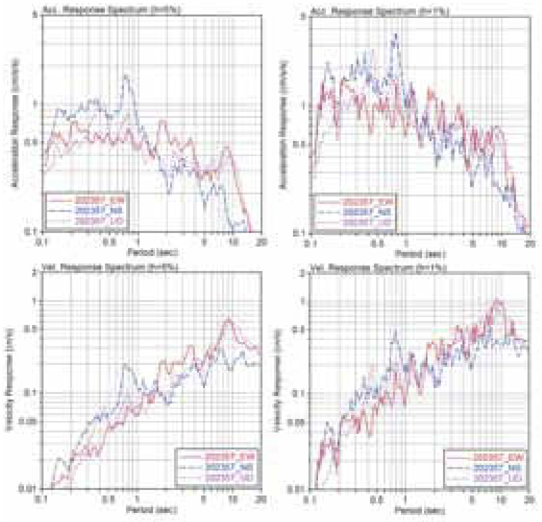

Figure 9. Three components of S_a and S_v at ground surface of G3. They are made from the bedrock motion observed at IPM and the transfer function calculated for G3. Top left panel) S_a with h=5%, top right panel) S_a with h=1%, bottom left panel) S_v with h=5% and bottom right panel) S_v with h=1%.

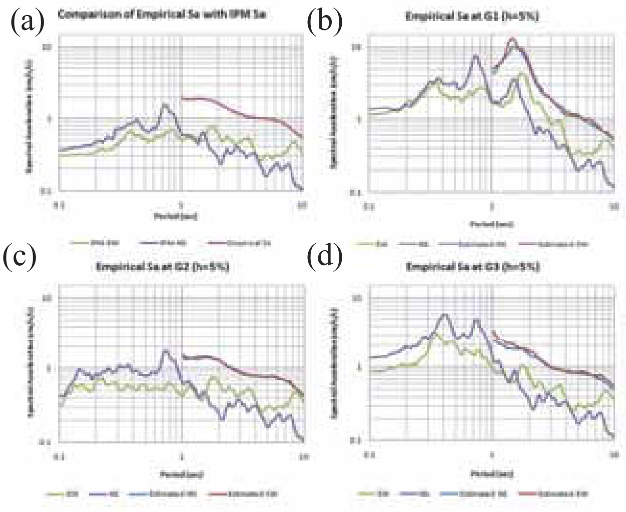

Figure 10. Comparison of Empirical Sa at (a) IPM and the ground surface of (b) G1, (c) G2 and (d) G3 for the damping of 5%.

In Figure 10(a), the comparison of the statistical estimate of S_a given by the attenuation relation of Yuzawa and Kudo (2006) with the observed S_a on IPM hard rock is shown. Figures 10(b), (c) and (d), show the comparison of the deterministic estimate of S_a to the statistical estimate of S_a at each ground surface for the period of 1 to 10 second. In all of these four cases, the latter show the amplitude about three times higher than the former. Nevertheless, this difference, which is less than ten times, is still acceptable and comparatively good in estimating the ground motion compared to the estimation done by Miyake and Koketsu (2010). This difference can be due to the regionality of attenuation characteristics of Japan and Malaysia that can have differences to big scale structure, heterogeneity and then scattering characteristics. Moreover, neither radiation pattern of the event S2 nor local amplification of IPM is considered in this paper. Although this is a rough estimation, the deterministic estimate of S_a falls in the same order with the statistical one and then is acceptable.

The distance between IPM station and Kuala Lumpur is approximately 180 km. The epicentral distances to Kuala Lumpur and IPM are about 500 km and 586 km respectively. Therefore, Kuala Lumpur will experience a larger amplitude of ground motion acceleration compared to IPM station. The geometrical spreading factor of body waves $1/r$ and that of surface wave is $1/\sqrt{r}$ giving the estimation of the amplitude ratio of Kuala Lumpur to IPM about 1.2 and 1.1 respectively. The difference between them is not considerable.

4. CONCLUSIONS

Based from the result obtained, Kuala Lumpur can experience ground motion that has long duration of motion with small amplitude. Considering the cost efficiency and to optimize the hardisk data storage, setting up of the current strong motion observation into triggered base system is proposed. However, the small amplitude and long duration of motion is difficult to obtain using the usual setting of strong motion triggering system. As an alternative, seismic signal received at MMD observatory center that is sent from the Agency for Meteorology, Climatology and Geophysics (BMKG), Indonesia, via satellite communication will then be used to launch a triggering signal to the strong motion sites in Malaysia. Signal being transmitted via radio communication is faster than P-wave, which will take approximately two minutes to arrive at the station for 500 km of epicentral distance. After receiving the triggered signal, the accelerograms will start recording for example one minute before the P-wave arrival at the site. Configuring the recording duration about 20 minutes, based on the duration of simulated synthetic ground motions, is also necessary to acquire important information. The duration should be from the time an earthquake occurs until it returns to the level of background noise. However, it is best that more accurate and desirable value is to be decided from time to time highlighting the characteristic of ground motion with small amplitude and long duration. An efficient seismic risk study and structural design shall start from the recorded data at the strong motion stations in Malaysia.

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