DEVELOPMENT OF PREDICTION EQUATION ON LONG PERIOD GROUND MOTION FOR EARTHQUAKE EARLY WARNING IN BANGKOK

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1. INTRODUCTION

Long Period Ground Motion (LPGM) refers to ground motion with period larger than one second and can induce great destruction to high-rise buildings locate far from earthquake source. During August 2016 M_w 6.8 earthquake in Burma, people in high-rise buildings with epicentral distance 1,000 km in Bangkok scurried out in panic. In this study, Ground Motion Prediction Equation (GMPE) for Absolute Velocity Response Spectra (AVRS) is constructed with aim for providing Earthquake Early Warning (EEW) of LPGM in Bangkok city as AVRS provides suitable expression of indoor situation compared with other strong motion indices. However, due to lack of observation data in Bangkok, regression analysis is done by applying data observed in Japan to check the applicability to situation in Thailand. In addition, an estimation equation is proposed in this study to calculate AVRS for Bangkok using Relative Velocity Response Spectra (RVRS) and Peak Ground Velocity (PGV) which might be estimated under the existence of regression models proposed in previous studies that evaluated to be suitable for condition in Thailand.

2. DATA COLLECTION

Acceleration time history records are collected from 6 earthquakes of M_w 5.1 or greater from November 22, 2016 to March 13, 2020 at 950 JMA observation sites in total in three directions (NS, EW and UD direction). Distribution of data with respect to magnitude and hypocentral distance is plotted in Fig. 1. Velocity time histories are calculated by integration of acceleration time histories in frequency domain and PGV is obtained by taking maximum of absolute values. Relative velocity response time histories with damping ratio of 5% are calculated by linear acceleration method. Velocity time histories are added in time domain to calculate absolute velocity time histories for corresponding natural period, and AVRS is obtained by taking peak of absolute value for each natural period. High-pass filter is applied to remove long-period noise. Soil condition is examined by V_{S30} values by finding nearest K-NET and KiK-net stations which is classified as stiff and dense soil.

3. ESTIMATION OF AVRS IN BANGKOK

Due to limited number of earthquake observation data in Thailand, it is difficult to establish regression model applying AVRS directly. On the other hand, large amount of strong-motion data is available in Japan and various ground motion indices can be obtained such as Peak Ground Acceleration (PGA), PGV, AVRS, Relative Velocity Response Spectra (RVRS) etc. Therefore, in this study one method is proposed in estimation of AVRS in Bangkok by using data in Japan.

3.1 Establishment of regression model

Regression model in this study is based on Dhakal et al. (2015) shown in Eq. (1). Two-stage regression analysis based on least square criterion is used to eliminate systematic errors due to correlation of magnitude and distance.

$$log_{10}Y_{ij} = c + aM_i - bR_{ij} - log_{10}R_{ij} + \varepsilon_{ij} + \eta_i \quad (1)$$

where Y_{ij} is maximum absolute velocity response in cm/s from event i at station j, M is magnitude, R is the hypocentral distance in km, ε is intra-event error, and η is inter-event error; c, a and b are regression coefficients for constant, magnitude, and inelastic attenuation, respectively.

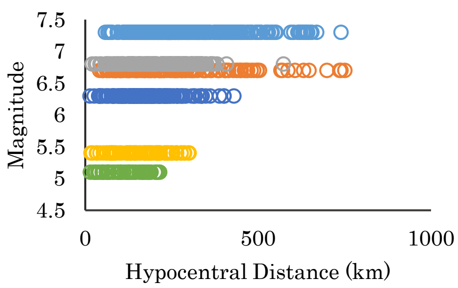

Fig. 1 Distribution of data.

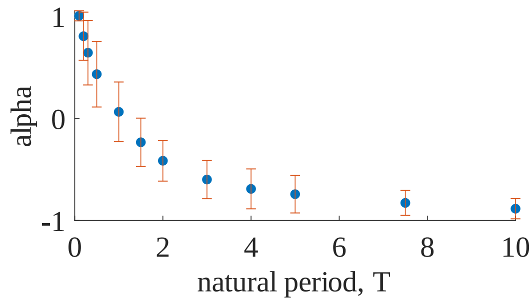

Fig. 2 Coefficient, $\alpha(T)$.

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3.2. Establishment of estimation equation

Considering the existing procedure to calculate AVRS, we proposed an estimation equation in Bangkok in absence of observation data by using RVRS and PGV shown in Eq. (2).

$$AVRS(T) = RVRS(T) + \alpha(T)PGV \quad (2)$$

where $\alpha(T)$ is coefficient for corresponding natural period. In calculation of $\alpha(T)$, in the first step, regression analysis is done on AVRS, RVRS, and PGV respectively. In the second step, random values are generated from probability density function of magnitude and hypocentral distance data collected from JMA observation sites which follows Lognormal and Weibull distribution respectively. 10,000 trails for each natural period are generated and $\alpha(T)$ is obtained by taking mean value for corresponding natural period. Coefficients, $\alpha(T)$, obtained based on estimation equation Eq. (2) is shown in Fig. 2.

4.RESULTS

In this study, we obtained acceleration time histories in three directions for only two earthquakes from one Thai Meteorological Department (TMD) observation site. One is the 2011 M_w 6.8 Tarlay earthquake in Myanmar, and the other one is the 2014 M_w 6.1 Mae Lao earthquake in Thailand with hypocentral distance 785.54 km and 673.66 km respectively. Applicability of regression curve for AVRS directly using Eq. (1) is examined for Bangkok. Fig. 3 shows example plot with natural period at 1.5 s, 3 s and 7.5 s. For the sake of comparison, maximum and geometric mean (GM) of AVRS in NS and EW directions are calculated. The result shows that observed AVRS at all periods for both earthquakes are larger than the estimated values. As Bangkok located on central part of a large lower plain known as Chao Phraya Basin, previous study shows that soft clay underlying this area might show high potential of amplification of ground motions in Bangkok (Plengsiri et al. (2017)) which is one possible reason for the underestimation.

Due to absence of appropriate attenuation equation on RVRS and PGV in Thailand, the applicability of estimation equation is evaluated with observed data in Bangkok. In other words, estimated AVRS is calculated by observed RVRS and PGV obtained from TMD station and $\alpha(T)$. The result is shown in Fig. 4 which indicates relatively in good agreement. However, further evaluation is needed for the availability of suitable attenuation model for Bangkok in the future.

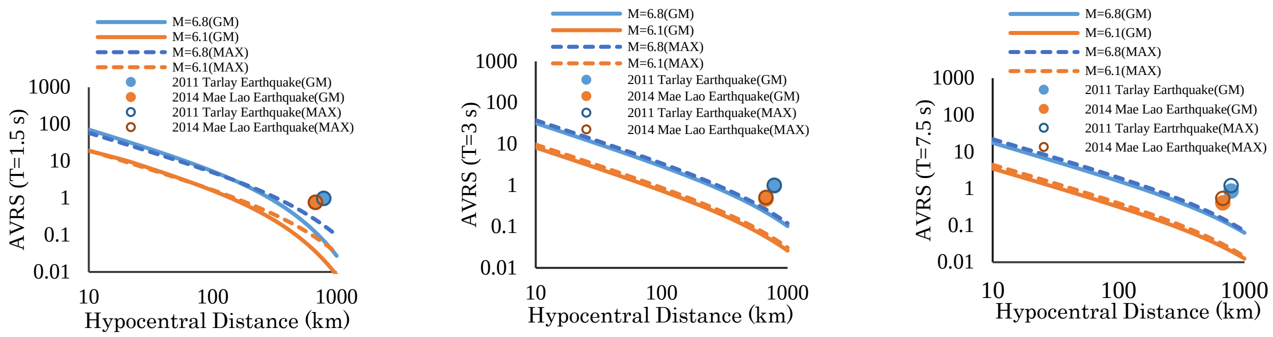

Fig. 3 Regression curve and observed AVRS using maximum (MAX) and geometric mean (GM).

5.CONCLUSIONS

We propose GMPE for AVRS using Japan data and check its applicability to Bangkok. The results show that the regression model proposed in this study might underestimate situation in Bangkok. Possible reasons might be limited observation data and amplification effect in basin area during earthquake.

Estimation equation proposed in this study to calculate AVRS in Bangkok might be applicable but future evaluation is indispensable for the existence of attenuation model on PGV and RVRS in the future.

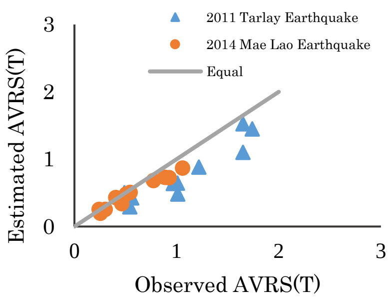

Fig. 4 Estimated and observed AVRS.

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