Deep Shear Wave Velocity of Southern Bangkok and Vicinity

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Abstract: Bangkok is located on the soft marine clay of the Lower Chaopraya Basin which can amplify seismic wave and affect building shake. Shallow shear wave velocity to depth 30 m. (V_s30) is widely studied recently but data of deeper layer to bedrock are still absent. The missing data are useful for earthquake engineering design and ground shaking estimation.
This study aims to measure deep shear wave velocity profile down to bedrock of southern Bangkok region. Microtremor measurements with 2 seismographs using Spatial Autocorrelation (2-SPAC) technique done at 8 sites. The data was collected during a day time on linear array geometry varied between 5-2,000 m. Long natural wavelength at the frequency 0.2-0.6 Hz. was detected at many sites. The results show that shear wave velocity function of the Southern Bangkok is between 100-2,000 ms^{-1} and indicate that the bedrock depth is about 600-800 m, except at Bang Krachao Very deep shear wave data of many sites are ambiguous due to noise and survey limitation.

1. Introduction

Shear wave velocity to 30 meters depth (V_s30) were studied widely which aims to prove the better elastic constant of Bangkok area for earthquake engineering purpose and ground motion research. (Poovarodom, 2014) These studies revealed relative low shear wave velocity on shallow layer of the entire area. However, the certain shear wave velocity profile down to the bedrock still absent. There is no certain evidence of the bedrock depth. Although, Sin Sinsakul (2000) indicates that the bedrock should be at depth between 500-2,000 m. Poovarodom and Jirasakjamroonsri (2014) suggest that the bedrock depths were between 400-800 m using microtermor measurement with maximum array distance 589 m. This study aims to measure the deeper shear wave velocity in Southern Bangkok.

SPAC (Spatial Autocorrelation) technique is considered to provide better resolution on dispersion image in the low frequency and generating a large range of dispersion curve, comparing to F-K technique (Zhao and Li, 2010). In this study the two microtremor array (2-SPAC) technique was selected to measure the shear wave velocity profile to depth 2 km at eight sites in the southern Bangkok and vicinity. The final results are displayed as shear wave velocity models.

2. Theories and techniques

Long period wave from natural noise or microtremor are generated by natural phenomena such as ocean wave, atmospheric change and can be measured by microtremor observation. Spatial Autocorrelation was introduced by Aki (1957) using 4-7 sensors on triangle array and one in its center. Assuming that microtremor propagates from all direction equally, Cho et al. (2006) Margaryan (2009) showed that two-sensor SPAC yields almost identical phase velocities as those using 4 or 7 sensors. Hayashi and Underwood (2012) demonstrated that S-wave velocity profiles down to depth 2-3 km can be measured by using 2 only sensors. The phase velocity is calculated from the ambient noise using a formula:

$$SPAC(\Delta x,\omega) = J_0(\frac{\omega}{c(\omega)}\Delta x)$$

whereas x is a distance between receivers, ω is an angular frequency, c(ω) is a frequency-dependent phase velocity and J_0 is a zero order Bessel's function

The fundamental concept of SPAC is to record the vertical microtremor composition in several positions of the target sites to collect varied azimuthally angle propagation of Rayleigh wave identity. The data pair is then calculated to compare its wave coherency spectrum, determine correlation, phase velocity and to generate SPAC coefficient which fits to the formula above. The phase velocity model displays correlation of a velocity of each frequency. Then, it will be converted to velocity-depth profile model by inversion analysis for the final result.

3. Data Acquisition and Processing

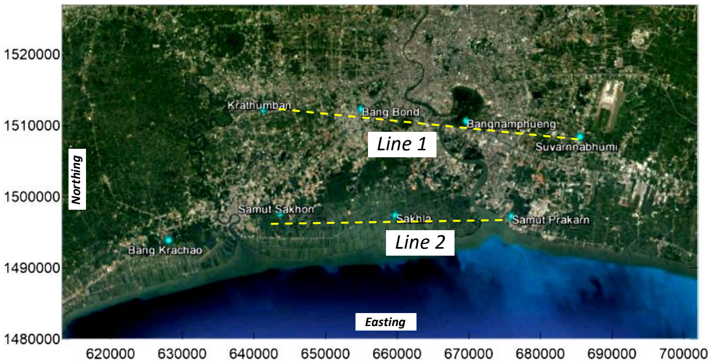

Figure 1. UTM WGS84 map displays survey locations around Southern Bangkok and 50 km. The cross-section of velocity profiles are shown in Figures 5-6.

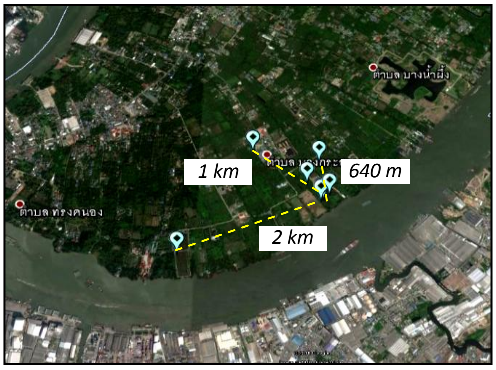

Figure 2. Example of a geometry of 2-SPAC methods at Bang Namphueng.

The survey locations were designed as line points to cover the southern Bangkok and its vicinity in quiet environment and less human activity. Inter-station location distance was about 15-18 km. Most observation areas are in parks, near abandoned buildings or agricultural lands. The data acquisition was done in day times during local winter period when the microseism from the Gulf of Thailand are strongest. Two MT-Neo seismographs (Geometrics Inc.) were placed as a linear array. One seismograph was fixed and acquired the data for entire time at each survey location. The second seismograph was measured at separation of 5, 10, 20, 40, 80, 160, 320, 640, 1,000 and 2,000 m with data recorded time between 20-90 minutes or 2 hours. The acquiring time were extended when the separation of two seismographs was increased. We used 2 ms sampling interval in this survey.

The obtained data was divided into many blocks with about 160 seconds of data for each block. Fast Fourier Transform (FFT) was used to convert these waveforms to frequency domain for calculating coherence of each data group. Summation of average complex coherence defined SPAC coefficient, resulted in phase-velocity model and inversion model respectively.

Figure 3 and 4 show phase-velocity of Samut Sakhon and Samut Prakarn. Their biggest coherence frequencies are between 0.5 and 0.2 Hz, respectively. Red dots represent maximum coherence which are manually picked for inversion model.

4. Results and Discussion

The phase velocity models display minimum frequency of 0.2 - 0.6 Hz to maximum frequency at 5 Hz. Interference of the local long wavelength reduced clarity of deep shear wave function in phase velocity image although generally, the longest wavelength obtained through the SPAC is 2 to 4 times of receiver separation (Koichi, 2013). Joint Inversion (Suzuki and Yamanaka, 2010) were applied to all observed dispersion curves to generate final fit velocity-depth models.

For the top 50 m depth, shear wave velocities are between 80-180 ms^{-1}. Next shear wave velocity range from 200-800 ms^{-1} which could be sand and saturated clay layer, was found at depth between 100-500 m. On line 1, we found shear wave velocity of 1,000-2,000 ms^{-1} at depth between 600-800 m, 600 m at Krathumban and 800 m at Bang Bond, Bang Namphueng and Savannabhumi.

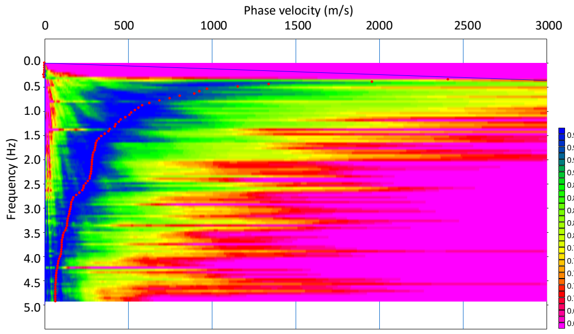

Figure 3. Phase-velocity of Samut Sakhon

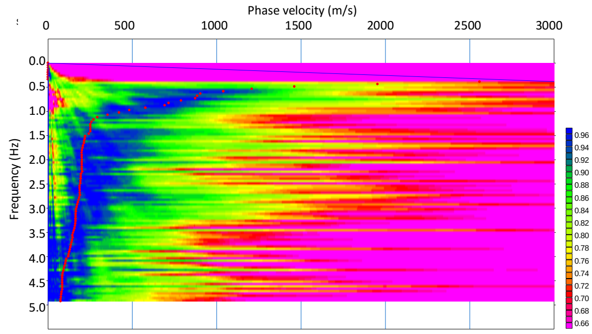

Figure 4. Phase-velocity of Bang Namphueng

On line 2, the shear wave velocity of 1,000-2,000 ms^{-1} was found at depth of 400 m at Bang Krachao, 700 m at Samut Sakhon, 800 m at Sakhla and 1,000 m Samut Prakarn. This velocity layer can be interpreted as sandstone and claystone bedrock which corresponds to Bangkok's geological structure. (Sinsakul, 2000)

At the deeper level of some sites, we found the layer of shear wave velocity 2,000-3,200 ms^{-1} at depth 1,500-1,900 m. It is expected to be quartzite basement layer. This shear wave velocity range was found in Krathumban at about 1,500 m depth. The same shear wave velocity range is also found in Bang Namphueng, Samut Sakhon and Sakhla at 1,700 m depth and 1,900 m depth in Samut Prakan. This information conforms to the well drilling data (Department Mineral Fuels, 1988)

There are some survey locations that the low frequency coherences are noisy due to location limitation of seismograph installation and surrounding activities. It affects the detection ability at deeper part, especially at basement level. The unclear deep velocity profiles are at Bangbon, Suvannabhumi and especially at Bang Krachao. The surface condition on these sites are soft soil, salt farm and near estate developing area.

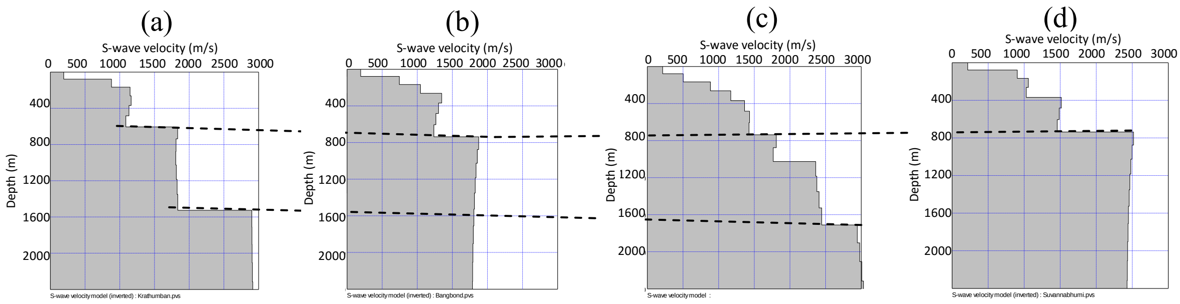

Figure 5. Velocity models of W-E transect line 1 (a) Krathumban (b) Bangbon (c) Bang Namphueng and (d) Suvannabhumi respectively. The upper dashed line indicates the depth of the bedrock with shear wave velocity of 800-2,000 ms^{-1} at 700-800 m. The lower dashed line is basement velocity 2,000- 3,000 ms^{-1} showing at depth of 1,500-1,700 m.

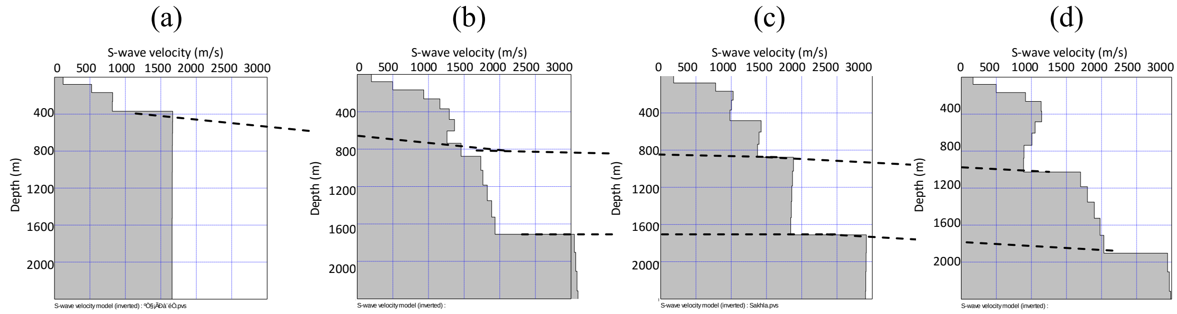

Figure 6. Velocity models of W-E transect line 2 (a) Bang Krachao (b) Samut Sakhon (c) Sakhla and (d) Samut Prakarn respectively. The upper line indicates bedrock depth level of shear wave velocity 800-2,000 ms^{-1} found at 400, 700-1,000 m depth and the second lower line is basement velocity 2,000- 3,200 ms^{-1} at depth 1,700-1,900 m.

5. Conclusion

Shear wave velocity profiles of the Southern Bangkok can be determined by a SPAC technique using 2-measurement station array (2-SPAC). This technique provides reliable data at depth shallower than 500-800 m of maximum 2,000 m array practically. Minimum 0.2 Hz phase velocity frequencies were found largely in most sites. The shear wave velocities of the topmost layer 50 m is about 80-180 ms^{-1} from surface to 50 m depth. The shear wave velocities of the lower layers are interpreted as saturated sand, claystone and sandstone which is considered bedrock. Its depth varies from 600-800 m in Southern Bangkok, except at Bang Krachao. Basement depth with velocities of 2,000-3,200 ms^{-1} are found between 1,500 to 1,900 m which corresponds to the well drilling data.

One of the limitations of the data acquisition is strong noise interference of long wavelength which appeared in many areas. This interference reduces accuracy of the analysis or even tampers with all bedrock depth information. In the future, the 2-SPAC survey should be conducted throughout the Greater Bangkok with appropriate sites, spacing and correlate the result with data from other geophysical methods in order to create accurate bedrock map of the entire Greater Bangkok.

Acknowledgement

We would like to thank the Faculty of Science, Kasetsart University for their financial support and Geometrics Inc. for supporting the seismographs. Lastly, thanks to all mates for fieldwork assistance.

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