J. Myanmar Acad. Arts Sci. 2021 **Vol. XIX. No.5A**

GEOPHYSICAL APPORACH TO THE DETERMINATION OF LOCAL SITE EFFECT IN DAGON TWONSHIP, YANGOM REGION FOR SEISMIC HAZARD

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Abstract

Determination of local Site effect had carried out at 43 sites in Dagon Township, Yangon, Myanmar. Yangon area is located in moderate to high seismic prone area and high damage can be expected because the soil conditions in the city vary from alluvial soil to soft rock. The potential damage effects can be estimated on the basic of local soil effects. To determine the local soil conditions and its effects, analysis of the ratio of horizontal to vertical (H/V) spectra of microtremor was performed. The microtremor measurements were conducted by the SMAR-6A3P seismograph with LS-8800 data logger and GPS time composition at 200 Hz sampling rate. Finally, sediment thickness, shear wave velocity structures and potential soil amplification were determined. The potential frequency is ranging from 1.25Hz to 2.65Hz and the amplitude is ranging from 0.2 to 3.8. The potential soil thickness is ranging from 52 m to 106 m and average shear wave velocity of upper 30m depth, V_s^{30}, is ranging from 200 m^{-1} to 540 m^{-1} in general. Microtremors analysis show that southeastern and northwestern part of the Dagon Township is covered by thick and soft sediments (low frequency and high peak amplitude) while the central part of the Dagon Township is generally covered by thin and soft sediments (high frequency and high peak amplitude). These results can be used for urban seismic hazard assessments and risk mitigations in future.

Keywords: microtremors, spectral ratio, fundamental frequency, sediment thickness, shear wave velocity, site amplification

Introduction

Yangon is the capital city of Myanmar and this city has great density of the population, high concentration of residential buildings and public buildings, and a large number of old buildings in downtown Yangon. It had experienced several earthquakes in the past including Bago Earthquake with 7.3M on May 5 in 1930 because it is near to the Sagaing Fault. In addition to that, most of its townships are located in soft alluvial plain which is mainly composed of gravel, sand, silt and clay where strong ground motion and high amplification of local sediments can be expected. Nakamura (1989) proposed a method inferring site amplification factors to incident seismic shear waves using microtremor H/V ratio at a single site. This method is allowed detailed mapping of local site effects in an urban area without knowing precise subsurface geological and S-wave structure (Tun Naing et.al., 2013). According to this method, it is found that the microtremor H/V ratios coincide with amplification factors of near-surface structures to incident shear waves (Nakamura, 1989). The single station microtremor observation is measured about 20 (or) 30 minutes to determine horizontal to vertical Fourier amplitude spectral ratio from unknown sources. The sources of microtremor can be man-made or natural. Microtremors with frequencies above 1Hz are generally associated with man-made such as road traffic, trains, machinery while those below 1Hz are associated with natural phenomena such as wind, wave action and variations in atmospheric pressure.

Location and Size

Dagon Township is the major part of downtown area of Yangon as shown in Figure (1) and it has the population of 25,082 according to 2014 Myanmar Population and Housing Census.

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The total area of Dagon Township is 4.92 km^2. This township has many historical buildings and cultural heritage as well.

Seismicity of Yangon

Yangon region can be regarded as a moderate seismic prone. It is tectonically bounded by Sagaing Fault in the east, West Bago Yoma fault in the north, and the Andaman rift zone in the south (Win Swe & Win Naing, 2008). The seismogenic Sagaing Fault is passing through about 40 km away from Yangon and it had experienced several earthquakes in the past. The most significant earthquake occurred around this region is the Bago earthquake of 5th May, 1930 with the magnitude of 7.3 M_w, as shown in Figure (2). This earthquake caused 500 casualties and large destruction in Bago while 50 casualties and some damages in Yangon.

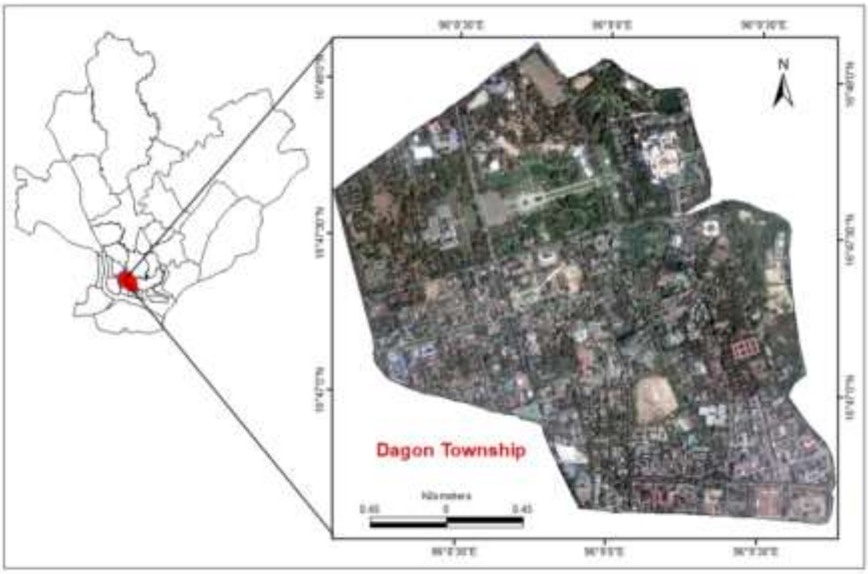


Figure 1 Location map of the study area

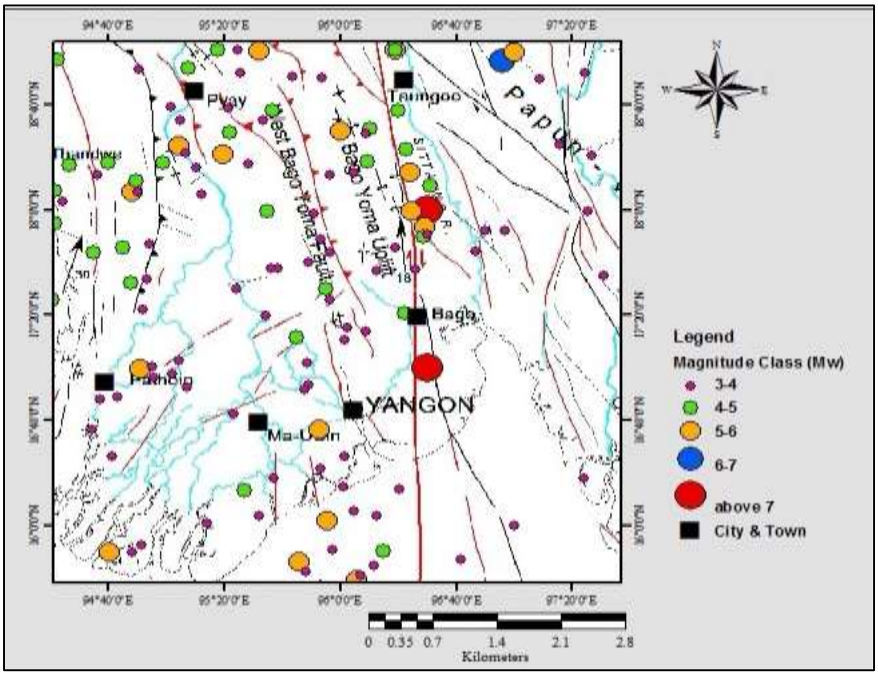


Figure 2 Seismic activities of Yangon area and its environs (ANSS catalog of 1900–2019 complement with MEC data)

Materials and Methods

The methodology mainly includes four portions: desk study, preliminary site investigation, detailed site investigation, and data analysis and processing. The desk study mainly includes literature reviews. The preliminary investigation performs initial site investigation. Detailed subsurface investigation program throughout the Dagon Township, including field measurements and laboratory tests are included in detailed investigation stage. Modeling analyses by using different software will be the main task in data analysis and processing. Figure (3) showing the scheme for the method of study of the whole research.

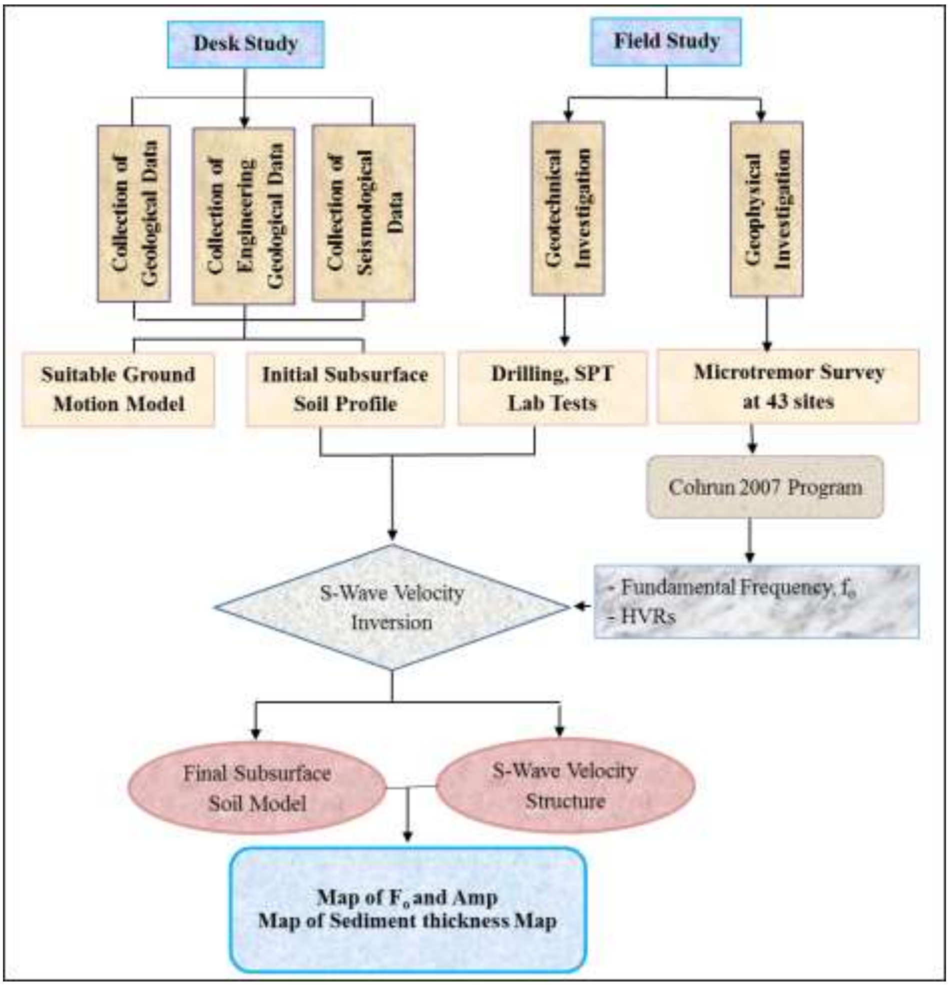


Figure 3 Scheme for the method of study of the whole research

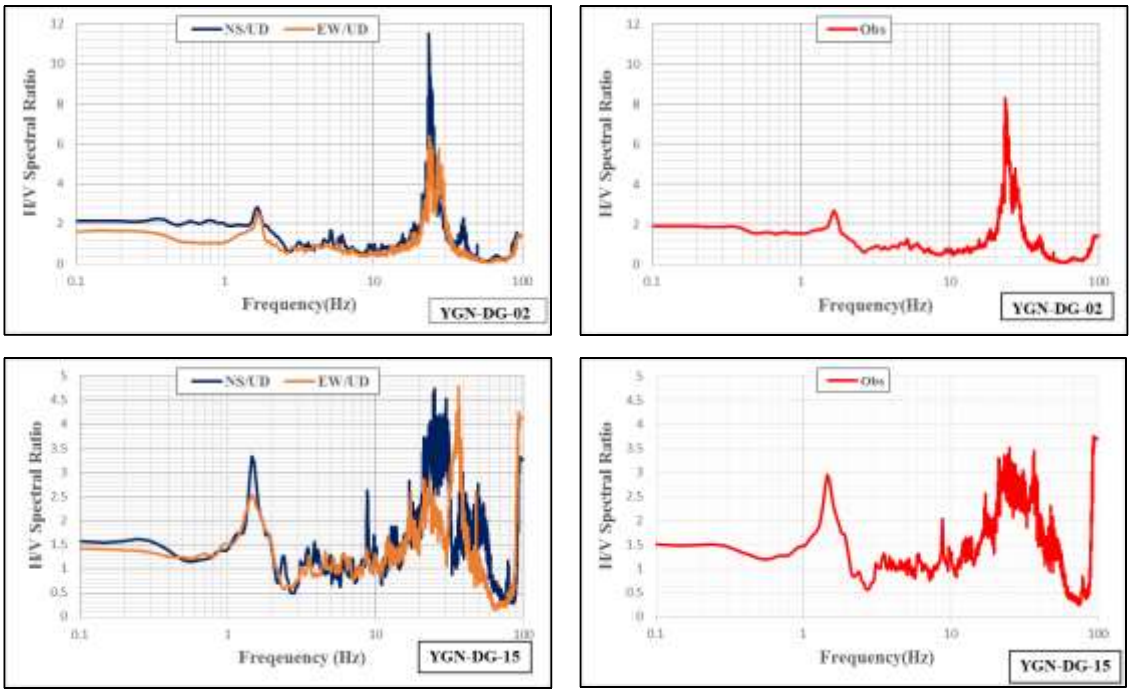
Geophysical Measurement (Microtremor Survey)

The microtremors, ambient seismic noises, generating low amplitude vibrations by natural disturbances have been used as a tool to estimate seismic response of underlying soil layers (Kanai and Tanaka, 1954). Based on the diffuse field theory (Sesma et.al., 2011), the microtremor H/V spectral ratios correspond to the square root of the ratio of the imaginary part of horizontal displacement for a horizontally applied unit harmonic load and the imaginary part of vertical displacement for a vertically applied unit load. The microtremor single station measurements had been conducted at 43 sites throughout the Dagon Township as shown in Figure (4). These measurements were conducted for 20 minutes at each site at the sampling rate of 200 Hz/s by using SMAR-6A3P seismometer shown in Figure(5).

Figure 4 Geophysical Measurement of the research area, (a).Locations of microtremor measurements in Dagon Township, Yangon, (b) SMAR-6A3P Microtremor Equipment and Microtremor Surveying

Determination of Microtremor (H/V)

The horizontal-to-vertical spectral ratio (HVRs) together with fundamental frequency of each site had been determined. HVRs of NS/UD and EW/UD were determined first and then the final observed microtremor spectrum has been determined by averaging the spectra of NS component and EW component (by averaging NS/UD, EW/UD) Figure (5).The observed microtremor HVRs show the two peaks; one at low frequency and one at high frequency. The peak at low frequency is related to deeper soil layers while the peak at high frequency is more related to shallow soil layers. The low peak amplitude suggests that the impedance contrasts between the underlying layers are small. And the high peak amplitude suggests that the impedance contrasts between the underlying layers are large.



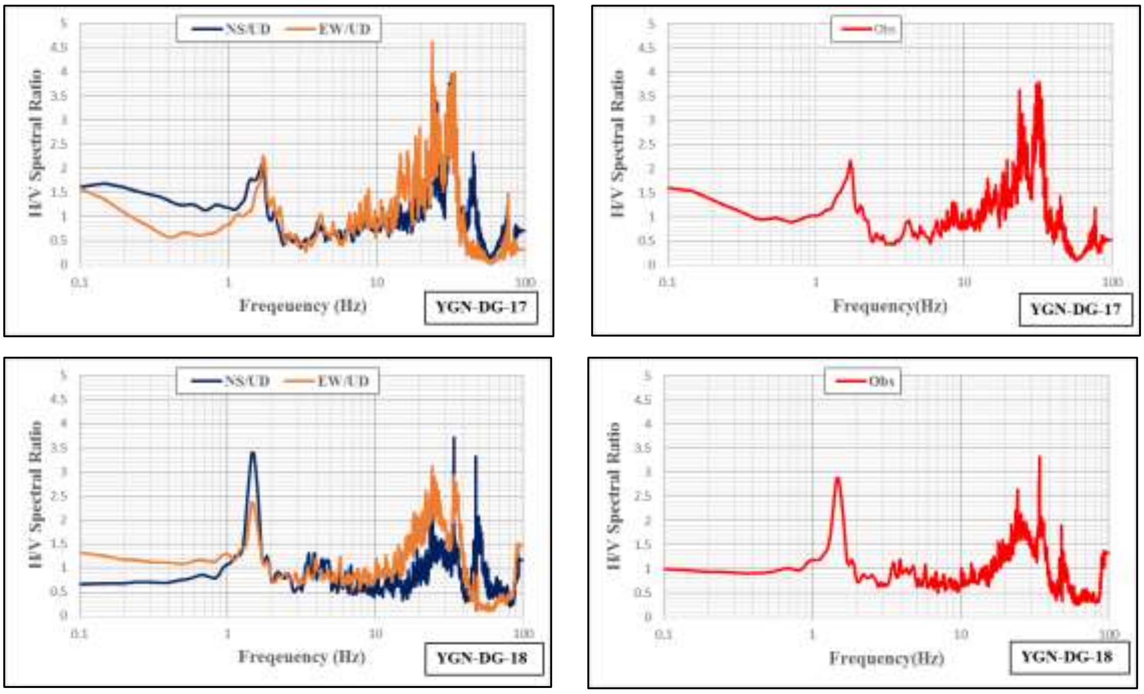


Figure 5 NS/UD, EW/UD and Observed Microtremor Spectra (Obs) of Some Selected Sites YGN-DG 2, 15, 17, 18 in Dagon Township; (YGN-DG-2) at the ancient church, corner of Pyihtaungsu Yeiktha street and Myoma Kaung street, (YGN-DG-15) at the corner of U Wisara Road and Shin Saw Pu Road, (YGN-DG-17) at the corner of Ahlone Road and Myoma Kyaung Road near the Pyihtaungsu Yeiktha, (YGN-DG-18) at the Dagon Park, junction between Shwedagon Pogoda Road and U Wisara Road.

Shear wave Velocity (S-wave) Inversion

The model 6-layer is used as an initial model and the S-wave velocity contract between each layer in the model is not high because the amplitude of observed mean HVRs is low. Based on observed HVRs and calculated HVRs, the velocity and thickness of each layer in initial model is modified by the increase or decrease in percentage until observed the best fit in terms of peak amplitude and frequency. The horizontal to vertical ratio (HVRs) of observed microtremor is in red colour, theoretical or final one is in dark blue colour and green for initial model is shown in Figures (6) with the tables using by trial and error inversion process and final soil model. The elastic half spaces of the Tables represent the seismic bedrocks as shown in Table (1).

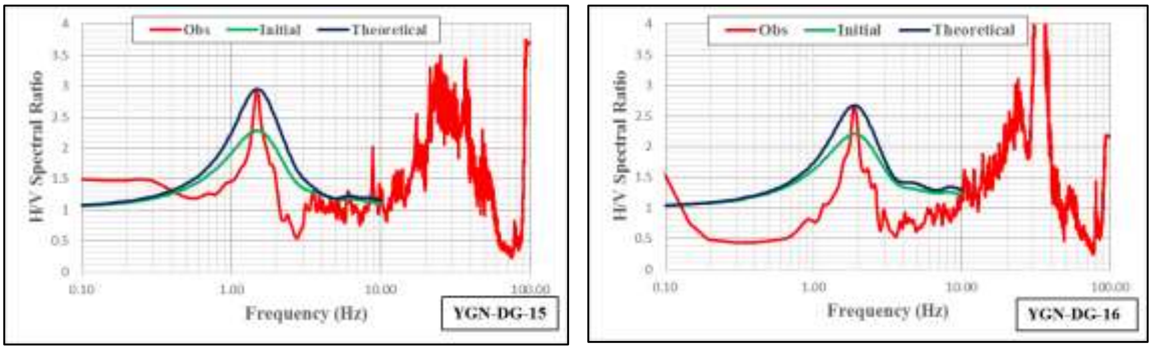


Figure 6 Initial, Modified Spectra and Observed H/VSpectra of Some Selected Sites (YGN-DG-15, 16) in Dagon Township, Yangon

Table 1 Initial and Modified Soil Model of YGN-DG-15 in Dagon Township

Layer	Thickness (m)		Vp*		Vs**		Unit Wt.	
	Initial	Modi	Initial	Modi	Initial	Modi	Initial	Modi
1	2	4	1502	1329	250	200	1.93	1.87
2	9	10	1536	1417	300	250	1.94	1.90
3	12	14	1633	1502	350	300	1.95	1.93
4	16	15	1695	1695	400	400	1.99	1.99
5	24	16	1957	1815	500	500	2.06	2.02
6	25	18	2091	1844	600	520	2.09	2.03
Elastic Half Space	88888	88888	2219	2219	800	800	2.12	2.12

* Primary Wave Velocity ** Shear Wave Velocity

Identification of Shear Wave Velocity (S-Wave) Structure

The shear wave velocity structure was constructed based on final modified soil model derived from inversion process of each site where microtremor measurement was conducted and identified S-wave velocity structure in some selected sites at Dagon Township. Shear wave velocity (V_s) is an essential parameter for evaluating the dynamic properties of soils. The S-wave velocity (V_s) structure of sedimentary deposits can control site dependent strong ground motions and resulting geotechnical problems and structural damage. The shear wave velocity structure of individual site was constructed based on final modified soil model from inversion process of each site where microtremor measurement was conducted as shown in Figure (7). In the Shear wave velocity profile, the blue line represents the S-wave velocity structure of initial model and the red line represents the S-wave velocity structures of modified of final one.

Determination of V_s^{30}

The most important parameter in the classification of the seismic design categories is the shear wave velocity of the topmost 30m of sediment depth, the V_s^{30}, and it had also been calculated based on the following equation (Borcherdt, 1970).

$$V_s^{30} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} d_i / v_{si}}$$

Where,

d_i = thickness of ith soil layer

v_{si} = shear wave velocity in ith soil layer

n = number of soil layer

The Shear wave velocity structures are obtained together with subsurface soil layers, their thickness and unit weight at each site where microtremors measurement was conducted. The sediment thickness can be obtained after the trial and error inversions are being focused on fundamental peak of horizontal to vertical ratio (H/V).

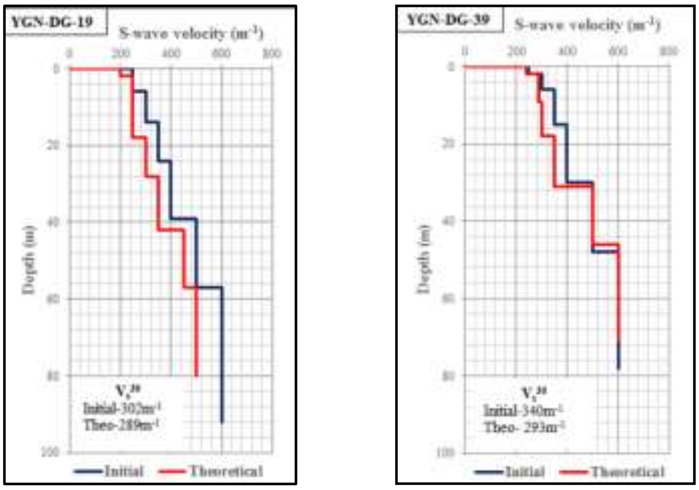


Figure 7 S-wave Velocity Structures of YGN-DG-19, 39 in Dagon Township

Results and Discussion

Based on fundamental peak, the peak amplitude of H/V and fundamental frequency of all measured sites in Dagon Township had been determined. These results show that the peak amplitude of H/V (potential soil amplification) are ranging from 0.2 to 3.8 as shown in Figure (8), while the fundamental frequencies are ranging from 1.25 Hz to 2.65 Hz as shown in Figure (9).

Peak Amplitude (Amp)

The peak amplitude of microtremor H/V is in five red coloured zones as shown in Figure(8): the first zone is between southern part of Pyay Road and southern part of Myoma Kyaung Road; the second zone is around B.E.H.S No (1) Dagon, Ahlanpya Pagoda Road; the third zone is near National Theater, U Wisara Road; the fourth zone is western part of Pyidaungzu Yeiktha street; and the fourth zone is northern part of Pyay Road, near Yangon Region Parliament which are remarkably higher than the other parts. It can be regarded that these zones are generally composed of softer sediments and higher amplification of ground motion can be expected during a future earthquake than other places. In the meantime, lowest amplitude is observed in Purple colored where the dense sediments and lower amplification of ground motion can be expected during a future earthquake.

Fundamental Frequency (Freq)

The Fundamental Frequency map as shown in Figure (9), the lowest fundamental frequency is in four purple colored zones: the first zone is around Ministry of Construction; the second zone is between Khay Pin Street and Taw win street; the third zone is around Alan Pya Pagoda; and the fourth zone is northern Part of Yangon Region Parliament. These zones can generally be regarded that the sediment in this zone is thicker than the other area. Meanwhile, the highest fundamental frequency is observed in red colored zone where the thinner sediment can be expected. The medium thick sediment can be observed in green colored zones.

Predominant Period

The predominant period is inversely proportional to fundamental frequency and it is one of the most important parameter. The buildings with similar or coincide natural period to predominant period of underlying soil layers will be suffered stronger shaking and likely to be serve damage during an earthquake. The predominant period of the short period appears on a very thick soft ground, because such ground consisted of plural layers and the influence of the uppermost layer is remarkable. The predominant period on fresh rock, bed rock and sand hill, show very long period, but amplitude is always very small. In Figure (10), predominant period between 0.78-0.8 were noted that at the Min Ye Kyaw Zwa street. The period map shows how many stories should be constructed in this area because 0.1s is equal to the one-story structure as a rule of thumb.

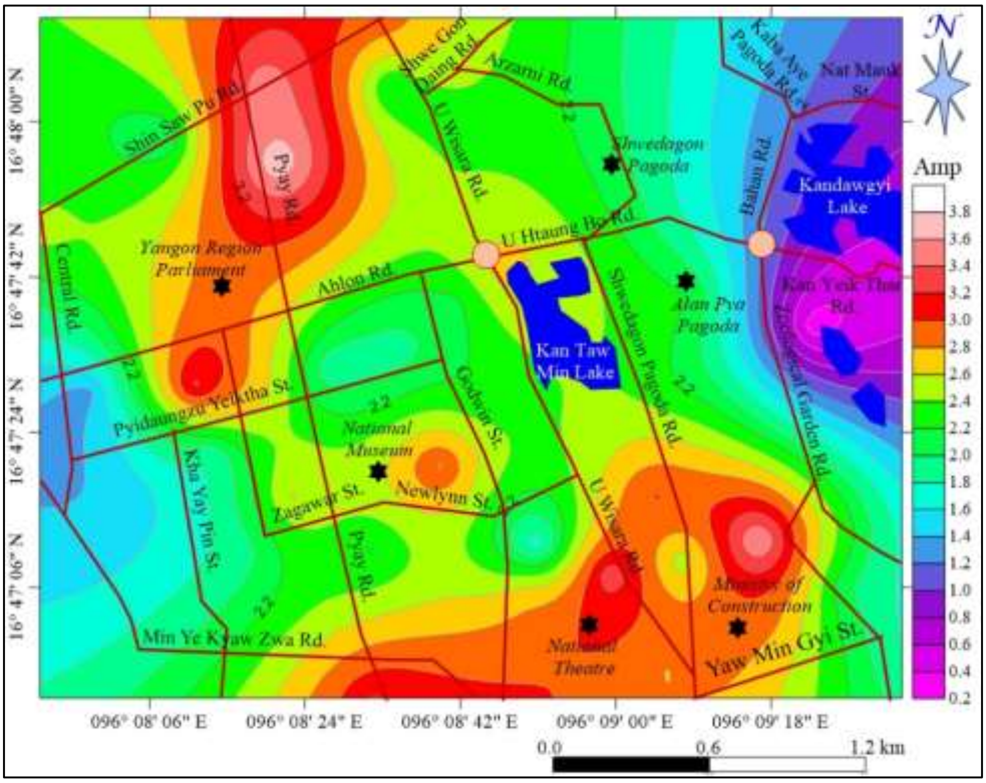


Figure 8 Peak Amplitude (Amplification) Map of Dagon Township in southern Yangon

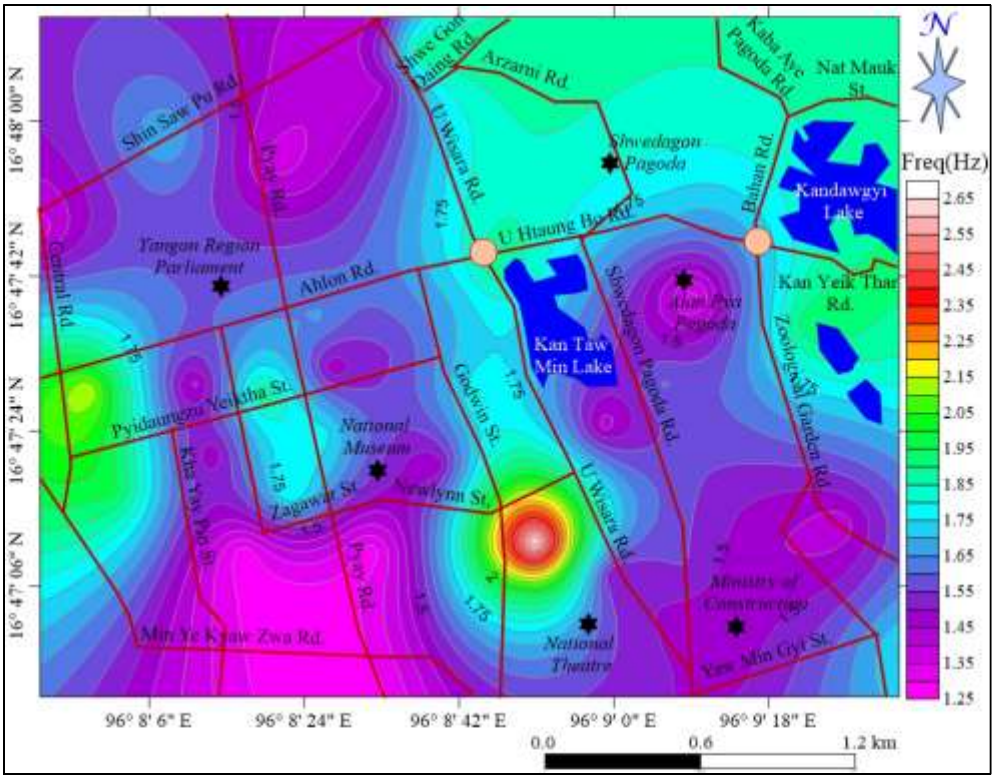


Figure 9 Fundamental Frequency Map of Dagon Township in southern Yangon

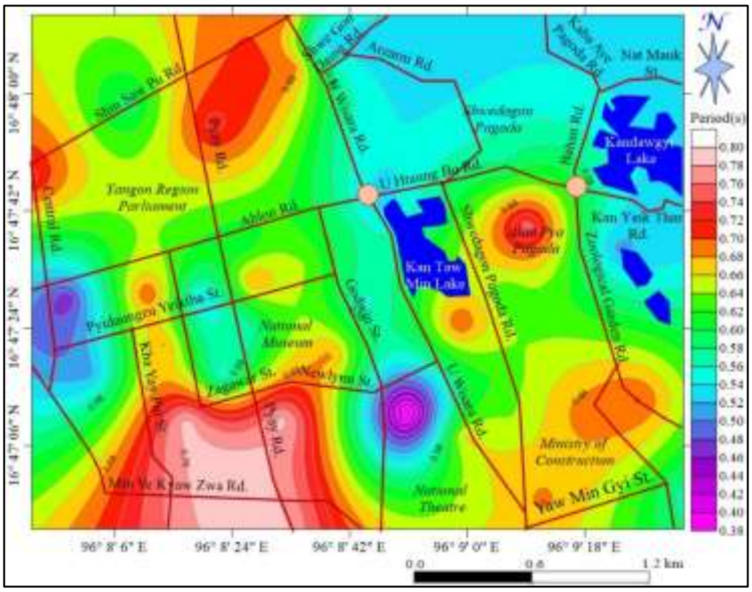


Figure 10 Predominant Period Map of Dagon Township in southern Yangon

Sediment Thickness

The shear wave velocity structures are obtained together with subsurface soil layers, their thickness and unit weight at each site where microtremors measurement was conducted. The sediment thickness can be obtained after the trial and error inversions are being focused on fundamental peak of horizontal to vertical ratio (H/V). In Figure (11), the thinner sediment zones (the purple color) are mainly observed in central portion of the Dagon Township, especially the area Road between U Wisara Road and Shwedagon Pagoda Road; around Yangon Region Parliament; U Htaung Bo Junction. These portions are not suitable for low rise building because the buildings can be fallen due to the equal frequency of underlying soil layers and buildings. The thicker sediment zones (the red color) are mainly observed the road between Pyay Road and Myoma Kyaung Street, Northwestern part of Dagon Township, near Shin saw Pu Road, and around the Alan Pya Pagoda. These portions are unsuitable for high rise building. In addition to the Dagon Township are mainly composed of medium thick sediment zone, these zone are sediment depth between 70m - 90m.

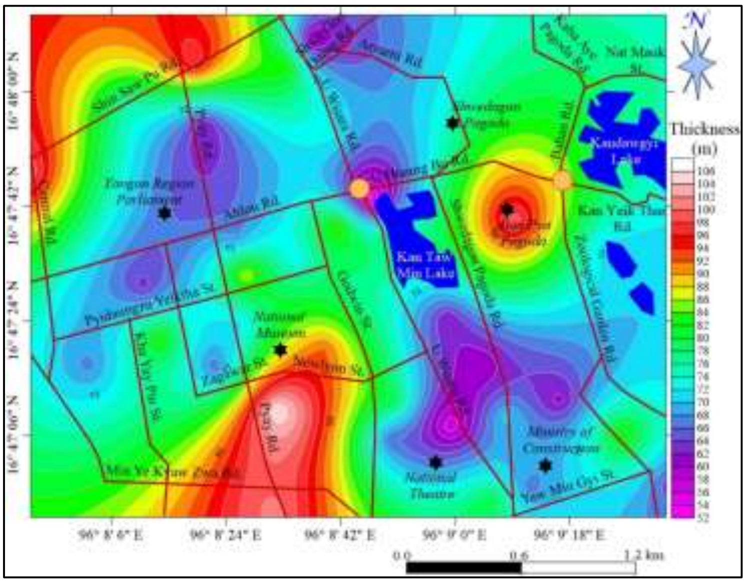


Figure 11 Soil Thickness Map of Dagon Township in Yangon

Average Shear Wave Velocity (V_s^{30})

The average shear wave velocity of upper 30 m depth (V_s^{30}) is calculated from velocity structure of final soil model and map of V_s^{30} is as shown in Figure (12). The purple colour represents the softer sediment zone (relatively low velocity) and the red colour represents the dense sediment zone (relatively high velocity). The lowest shear wave velocity zones (purple color) can be observed along the southern portion of the Dagon township; and northern portion of Pyay Road near Yangon Region Parliament and Pyidaungzu Yeiktha street, where the soft sediments are occupied. According to these results, the strong ground shaking can be expected including Yangon Region Parliament, National Therater and Ministry of Construction office compound. The highest shear wave velocity zones (red colour) can be observed in the eastern part and western part of Dagon Township where the dense sediments are occurred.

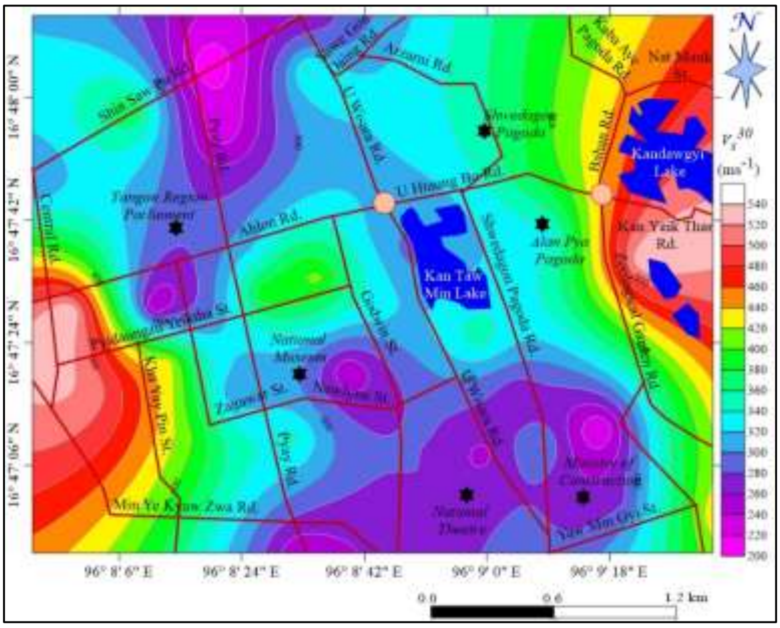


Figure 12 V_s^{30} Map of Dagon Township in Yangon

Concluding Remarks

This research mainly focused on the acquisition of ground information for future liquefaction hazard analysis in southern Yangon (Dagon, Mingalar Taung Nyunt, Ahlone, Lanmadaw, Latha, Kyauktada, Papedan, Botataung, Pazundaung Townships) where Dagon township is included. The microtremor survey had been applied as the main tool for research activities in the field and available secondary boring data were combined to microtremor data during the data processing and analysis. Based on results of overall research works, the following facts are concluded.

1. The fundamental frequency of underlying soil layers is ranging from 1.25 Hz to 2.65 Hz and the lowest frequency zone is encountered in most part of the Dagon Township especially and highest frequency zone in south-western part of U Wisara Road and moderate zones in the rest area.
2. The peak amplitude microtremor H/V ratio or potential soil amplification factor is between 0.2 and 3.8 in general and the places between southern part of Pyay Road and southern part of Myoma Kyaung Road; around B.E.H.S No (1) Dagon, Ahlanpya Pagoda Road; near National Theater, U Wisara Road; western part of Pyidaungzu Yeiktha street; and northern part of Pyay

Road, near Yangon Region Parliament can experience higher soil amplification effect during an earthquake than other parts.

3. The highest predominant period between 0.78-0.8 s were noted that the Min Ye Kyaw Zwa street.
4. Based on determined subsurface soil profiles and related engineering properties, it is revealed that the thickness of sediment is ranging from 52 m to 106 m, and relatively thicker sediment zones are observed in road between Pyay Road and around Alan Pya Pagoda. These portion are not suitable for high rise building.
5. The average shear wave velocity of upper 30m depth, V_s^{30}, is 200m^{-1} and 540 m^{-1} in general. The lowest shear wave velocity zones; along the southern portion of the Dagon township; and northern portion of Pyay Road near Yangon Region Parliament and Pyidaungzu Yeiktha street, Yangon Region Parliament, National Therater and Ministry of Construction office compound, where strong ground shaking can be expected.

Acknowledgements

The authors thank the Ministry of Education, Department of Higher Education for the permission to carry out this research and financial support. I acknowledge Dr. Nu Nu Yee and Dr Nay Thwe Kyi, Pro-Rectors of Dagon University for their kind permission to submit this research paper. I would also like to express my sincere gratitude to Professor Dr. Kyi Kyi Maw, Head of Department of Geology, Dagon University for her encouragement, suggestions and Discussions.

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