Estimation of Shear Wave Velocity to a Depth of 30 Meters (V_S 30) Using Microtremor HVSR Method in Mandalay City

Tun Tun Win[1]*, Myo Thant[2], Pyi Soe Thein[3] and Win Min Than[4]

Abstract

Mandalay city lies in seismic hazard zone of Myanmar due to its very close to the seismically active Sagaing fault. Shear wave velocity to a depth of 30 meters (Vs30) have been conducted in the Mandalay city using microtremor HVSR method. The average shear-wave velocity (Vs) is a widely used parameter for evaluating the dynamic behavior of soil in the shallow subsurface. The shear wave velocity has been determined from microtremor data and comparing with exiting borehole data (SPT-N value). Site characterizations of Mandalay City are mainly estimated based on the subsurface shear-wave velocity (Vs30). Shear wave velocities are depend upon the stiffness and density of a soil. Nearly all of the sites comprise the Vs30 range of <176 – >412 m/s, the lateral changes of the soil properties, in terms of Vs30 values are in East-West direction. The minimum Vs30 range, 176-209 m/s, constitutes in the western part of the city. The maximum Vs30 values can be observed in the northeastern part of the city, with the range of 378 – 412 m/s. Lower shear wave velocity can be longer period of vibration and more dangerous.

Keywords: Horizontal to vertical spectral ratio (HVSR), Shear wave velocity, Vs30, microtremor

Introduction

The research area, Mandalay city is a seismically hazard prone in Myanmar because it is very close to the highly dangerous active Sagaing Fault (Fig. 1). According to historical record, several earthquakes have impacted in and around Mandalay region since 1400yrs. These earthquakes caused not only a large number of causalities but also huge economic loses. Many damages were mainly caused by ground shaking amplified of the past earthquakes in this region. Shear wave velocity is an important parameter to study the dynamic properties of soils and site characterization. Shear wave velocity to a depth of 30 meters (Vs30) have been conducted in the Mandalay city using microtremor HVSR technique. The average shear wave velocity based on the measure time-travel at the top 30m is known as Vs 30. Shear wave velocity of soils result from microtremor data compare with borehole (mainly SPT) data is used for estimation the site effect of ground motion. The microtremor horizontal-to-vertical spectral ratio (HVSR, or H/V spectral ratio) method is an effective tool for detecting sediments' resonant frequency and then shear wave velocity of subsurface soil. The main objective of this paper is to compute Vs30 value for the preparation of Vs30 map in Mandalay City.

Regional Geologic and Tectonic Setting

The study area is situated between the latitude 21º 52' 00" to 22º 01' 00"N and the longitude 96º 01' 34" to 96º 08' 13" E. Mandalay region is predominantly covered by Paleozoic rock in the east and Cenozoic rock in the middle and west . In the west of the study area, Sagaing metamorphics (Paleozoic), Minwun metamorphic (Paleozoic? or Mesozoic?), Irrawaddy Formation (Upper Miocene-Pliocene), Fanglomerate (Pleistocene) and alluvium (Holocene) are exposed along the Sagaing fault. In the east of the study area, Paleozoic rocks

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are extensively wide spread throughout the Eastern Highland Province. The regional structural trend is nearly N–S direction.

Tectonically, Mandalay region is bounded by the Shan Plateau in the east in which several lateral strike-slip faults are included such as Moemeik fault, Shweli fault, and Namma fault etc., and the subduction zone of Indian plate beneath Burma plate in the west as shown in (Fig. 2) and these tectonic environments are the main seismic sources of causes rather than Sagaing fault. The Sagaing fault is a major strike-slip right-lateral continental fault that extends over 1200 km and connects to the Andaman spreading center at its southern termination. The rate of subduction of Indian plate under Burma plate are about 36 mmyr^{-1} and the Benioff zone dips in varying degree in each segment of the subduction system (Myo Thant, 2013). In the northern-most part of the subduction zone of Indian-Australian Plate under Burma plate, the Burma Trench system links with the eastern end of the collision zone of Indian plate with Eurasia plate. The India Plate collides with Asia at the rate of 50 mm/yr (GIAC, 2002). The another important tectonic feature is the Andaman extension basin that spreads with the rate of 3.72 cm a^{-1} since Middle Miocene and the spreading axis is nearly in NE-SW direction, it extends northwards and connect the Sagaing fault (Hutchison, 2007).

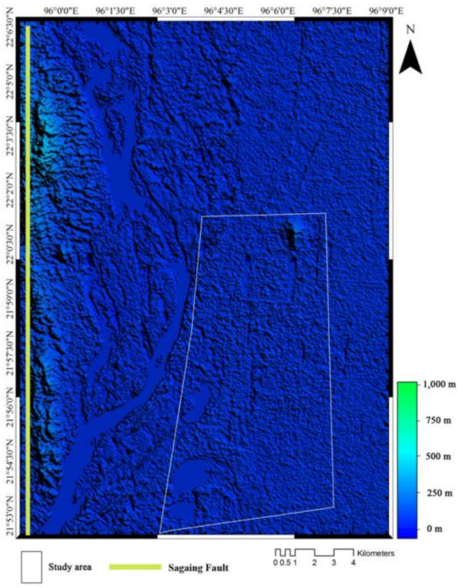

Figure (1). The Study area and Sagaing Fault

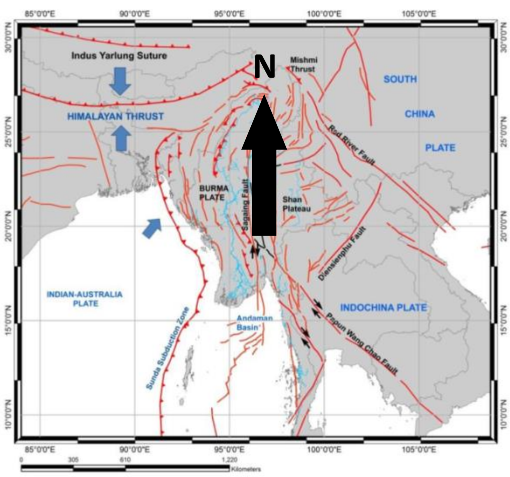

Figure (2). Regional tectonic setting map of Myanmar (Myo Thant, 2013)

Methodology

Our research is to update the preparation of shear wave velocity (Vs30) map of the study area by using borehole data and microtremor (HVSR) technique. Totally 50 boreholes and 187 microtremor data were collected in Mandalay City. From 187 microtremor data, only 50 data were carried out for the calculation of shear wave velocity value. The 50 microtremor data were nearly selected from 50 borehole points (Fig. 3).

Microtremor Observation

Microtremor observation prepared by Akashi Corporation, portable SMAR-6A3P seismometer ((Fig. 4) was used to estimate shear wave velocity (Vs30) of Mandalay city .The microtremor horizontal-to-vertical spectral ratio (HVSR) data has been carried out to estimate the predominant frequency and shear wave velocity (Vs30) at 50 representative sites in the Mandalay City. Survey locations were chosen on the basis of previous existing geological information together with the reconnaissance field trip, but the sites should be away from the buildings or underground structures, traffic car parks, sewer or pipes, bad weather condition and noisy environments, since all of these can significantly influence the recordings. To minimize these effects, the recording duration vary based on all of the above conditions, if the site is very quiet location, the sampling duration is set up as 15 min but if the environment condition is noisy, the measurement is carried out at least 30 min. Due to traffic and industrial noise in the study area, the ambient vibration measurements were conducted for about 30 minutes at each point and the sampling frequency was 100 Hz.

The position of SMAR-6A3P instrument calibrates automatically by using 4 satellites and then the observation is started. If SMAR do not find 4 satellites, we can't use this function. After clock calibration, SMAR starts recording. When we switch on the amp, we don't have to carry SMAR to other place. Raw data is recorded difference value of acceleration. So, we should converse the format of observed raw data to real data using Cygwin program. Every data resulted from microtremor has 3 data types such as EW (East-West), NS (North-South) and UD (vertical) component data. The SPT data is used to correlate subsurface profiles for the averaged shear wave velocity (Vs30).

Calculation of Shear Wave Velocity Based on HVSR Data

Nogoshi and Igarashi (1970 and 1971) firstly introduced the H/V technique and then well known by Nakamura *et al.*, (1983). The microtremor Horizontal-to-Vertical spectral ratios (HVSR) technique becomes an important tool to estimate the natural vibration frequencies of soil for seismic microzonation studies (Nakamura, 1989). The natural frequency value is known from the peak value of Microtremor H/V ratio data (Fig. 5). This maximum value ratio is highly corresponds to the ground characteristics (Nakamura et al., 1983). However, it was found true only for the fundamental resonance peak of the transfer function. The results supported the idea that Nakamura's technique effectively compensated for the site effect .The amplitude spectra of the vertical component were computed first and the H/V spectral ratio is then computed, and after that the best signals were chosen visually. The average spectral ratio of horizontal-to-vertical noise components (HVSR) at each frequency can be defined as

$$\frac{\mathrm{H}}{\mathrm{V}}(\mathrm{f}) = \sqrt{\frac{\mathrm{H_{NS}(f)} + \mathrm{H_{EW}(f)}}{\mathrm{V(f)}}}$$

Where, H and V are the spectra of the horizontal (North-South and East-West direction) and vertical components, respectively (Kawase *et al.*, 2011).

In the present study, empirical equation has been used for the estimation of shear wave velocity $V_{S,d}$ is computed for different depths (CEN, 2004):

$$V_{S,d} = \frac{d}{\sum_{i=1}^{N} \frac{h_i}{V_i}}$$

where d is the depth in meters, and h_i and V_i denote the thickness and shear wave velocity of the i-th layer based on microtremor measurements, for a total of N layers. The average shear wave velocity of the top 30m (Vs30) is calculated as the following equation;

$$V_{S\,30} = \frac{30}{\sum_{i=1}^{N} \frac{h_i}{V_i}}$$

Where, Vs^{30} is the shear wave velocity of upper 30m, hi and vi denote the thickness (m) and shear wave velocity of the i-th layer, in a total of N, existing in the top 30m.

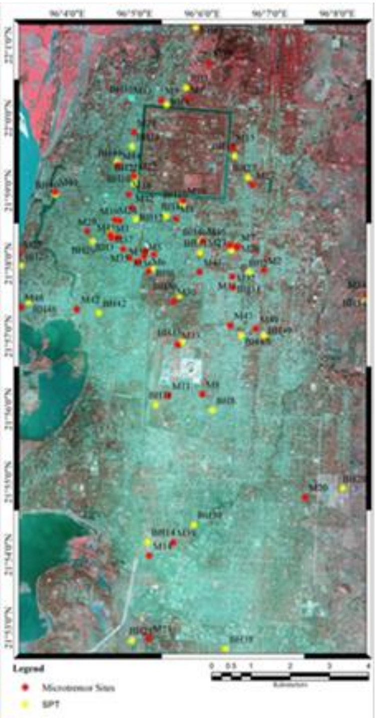

Figure (3). Location of the shear wave velocity measurement sites in Mandalay City

Figure (4). Microtremor measurement in Mandalay City

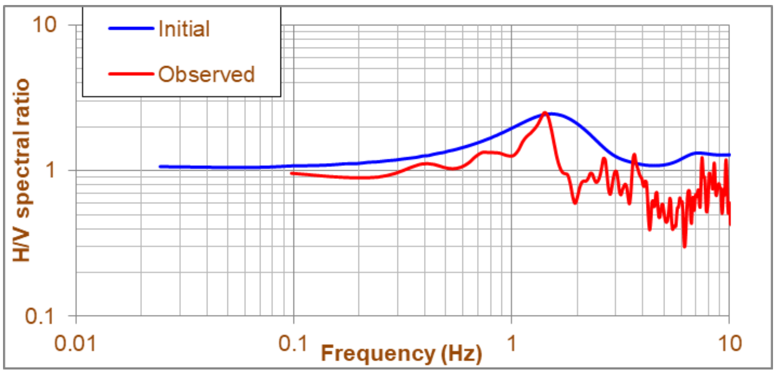

Figure (5). Initial model of H/V spectral ratio of Mandalay City at M-01-Lat 22.00771& Long 96.09638

Results and Discussion

The present results are to prepare shear wave velocity of upper 30 m (Vs30) map by using microtremor (HVSR) data. At each point, observation duration is about 30 minutes for the estimation of average shear wave velocity (Vs). In the present study, the spectral ratios are presented in the range between 0.001 to 10 Hz, which includes the natural frequencies of building in the study area. For site parameter studies, the average shear wave velocity in the top 30 m (Vs30) is estimated using the compare of SPT-N values obtained from borehole drilling and microtremor recording data (Fig. 6). The formulars of Seed & Idriss (1981), Tsiambaos & Sabatakakis (2011) and Hanumantharao & Ramana (2008) are used for this purpose. The variation of average shear wave velocity of upper 30 m in Mandalay City as shown in table (1) was determined from microtremor measurements conducted with approximately selected borehole points.

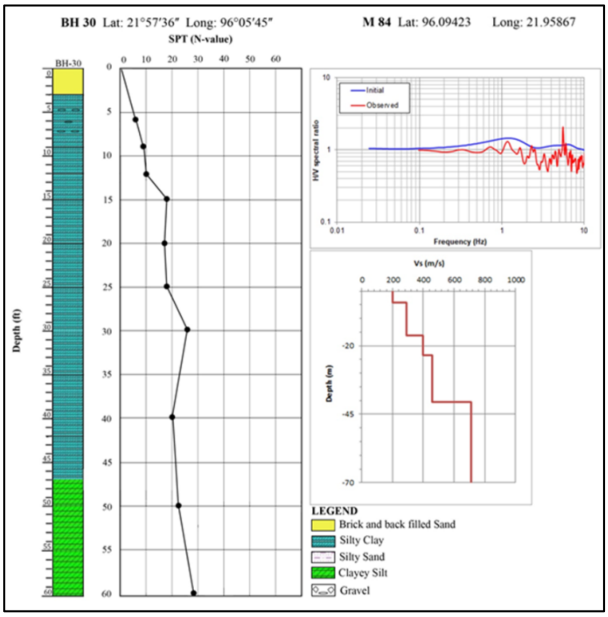

Figure (6). Example of (a) soil profile and (b) SPT-N value of borehole BH-30; (c) predominant frequency and (d) shear wave velocity profile of M-84 at Mahaaungmye Township

Table (1). Shear wave velocity values of some microtremor points in Mandalay City

Site	Latitude	Longitude	Vs_{30}(ms^{-1})		Site	Latitude	Longitude	Vs_{30}(ms^{-1})
M1	96.09638	22.00771	310		**M13**	96.08284	22.00501	254
M2	96.11277	21.96568	329		**M14**	96.08898	21.90354	302
M3	96.07874	21.97295	259		**M15**	96.10866	21.99233	317
M4	96.09212	21.97826	301		**M24**	96.07941	21.97717	255
M5	96.08684	21.96885	291		**M29**	96.0741	21.97212	236
M6	96.08889	21.96614	293		**M34**	96.14178	21.96117	342
M7	96.10984	21.97143	336		**M38**	96.10874	21.87944	318
M8	96.10437	21.93396	352		**M40**	96.06458	21.98273	176
M9	96.09165	22.00377	333		**M42**	96.07593	21.95578	221
M10	96.0961	21.98111	311		**M45**	96.0985	22.02157	377
M11	96.09043	21.93496	330		M48	96.05859	21.95796	186
M12	96.08458	21.97737	316		M50	96.08532	21.96775	261

The reliability of the observed V_s^{30} data is corroborated with recorded HVSR data at 50 selected microtremor points (Fig.3). Based on the current measured V_s^{30} data, we have presented a V_s^{30} map of Mandalay City as shown in figure (7). The estimated Vs30 range vary <176 – >412 ms^{-s}, the lateral changes of the soil properties, in terms of Vs30 values are nearly East-West direction. The minimum Vs30 range, 176- 209 ms^{-s}, constitutes in the western part of Aungmyethazan, Chanayethazan, Mahaaungmye and Chanmyathazi, Townships. The maximum Vs30 values can be observed in the northeastern part of the city, with the range of 378 – 412 ms^{-s}. This portion includes north eastern and eastern parts of Aungmyethazan Township, and eastern part of Chanayethazan Township. Shear wave velocities are depend upon the stiffness and density of a soil. Lower shear wave velocity can be longer period of vibration and more dangerous. According to Vs30 results, the north western parts of the Mandalay region, located in the recent alluvial soil and exposed to high levels of damage during the earthquake, have the low shear wave velocity distribution. So, north-western parts of the research area characterized by higher level of damage than other parts. The north-eastern part of the city suffered the low level of damage during earthquake.

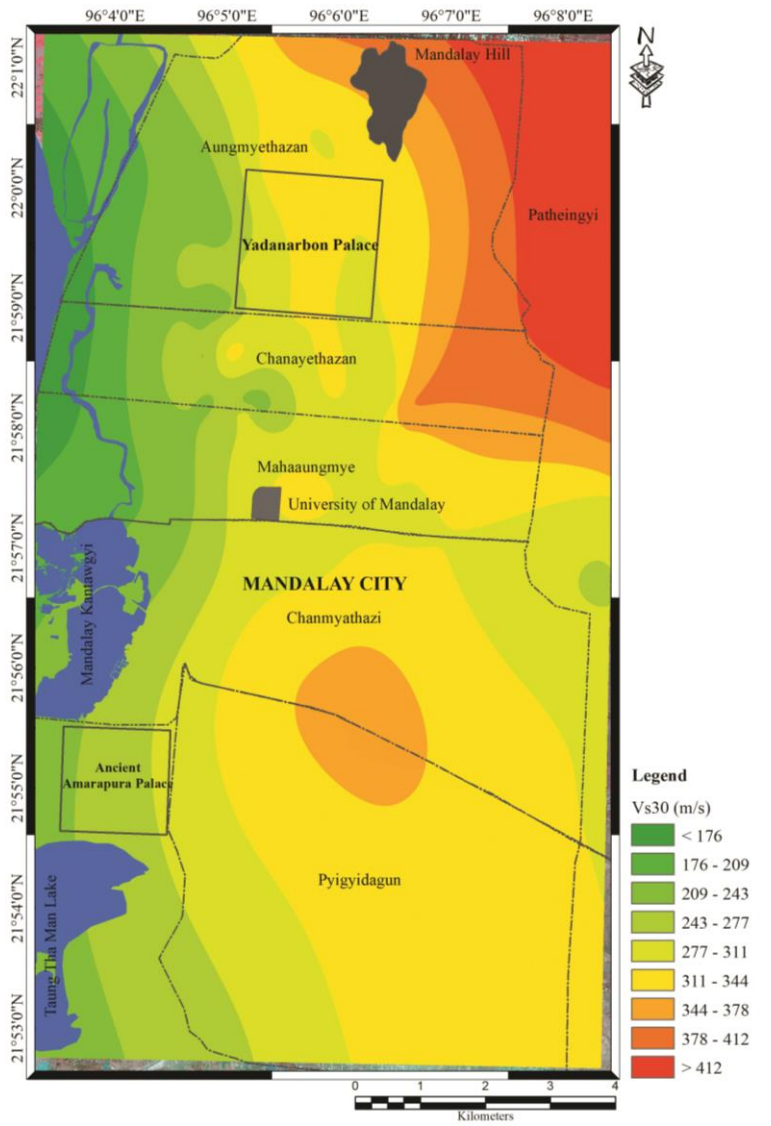

Figure (7). Average shear wave velocity to the depth of 30 m (Vs30) map of Mandalay City

Conclusions

The mainly purpose of the present research has been carried out the shear wave velocity of the top 30 m of the soil profile (Vs30) map in Mandalay City .This map was constructed based on Vs30 value resulted from microtremor data . We have compared the results of SPT (N-value) and Vs30, which are used for the preparation of Vs30 map in the study area. On the basis of the subsurface geology, shear wave velocity to the depth 30 m (Vs30) values vary from <176 to >416 ms $^{-1}$ in the Mandalay City. Lower shear wave velocity can be longer period of vibration and more dangerous. According to this map, north-western parts of the research area characterized by higher level of damage than other parts. This suggests that the Vs30 values obtained from microtremors HVSR data are used to evaluate the seismically vulnerable zones and to develop future plan for disaster risk mitigation of the Mandalay city.

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