Development of Seismic Design Category Map of Aungmyaythazan and Chanayethazan Townships in Mandalay Region

Tun Tun Win*
Panglong University
geolttw73@gmail.com

Myo Thant
University of Yangon
myothant05@gmail.com

Myint Myint Yee
Panglong University
Meemee.geol@gmail.com

Abstract

In this study, the maps of fundamental frequency, shear wave velocity to a depth of 30m (V_s^{30}), soil thickness and seismic design category were determined based on MHVSR data. Soil samples were collected from 16 shallow boreholes and 26 microtremor points. The fundamental frequency value is inversely related to soil or sediment thickness. The low frequency may strongly influence the seismic site effect of tall building than short building. The V_s^{30} ranges from <220 to >420 ms^{-1}. The minimum Vs30 zones represent soft or recent alluvial soil, and these areas may be highly seismic site effect zones than other places. The seismic design category map of the study area was conducted based on V_s^{30} values using standard site class of Eurocode-8 (EC8). According to the resulted data, the western portion of the study area may suffer stronger ground shaking than other places during an earthquake.

Keywords: *microtremor horizontal-to-vertical spectral ratio (MHVSR), fundamental frequency, Shear wave velocity to a depth 30 m (V_s^{30})*

1. Introduction

Myanmar indeed lies in one of the two main earthquake belts of the world, known as the Alpide Belt. Moreover, the study area, Aungmyaythazan and Chanayetharzan townships in the Mandalay region are located on the eastern bank of Irrawaddy River and 8 km east of seismically active Sagaing Fault. Many destructive earthquakes in this region mainly come from this fault. By this evidence, the study area is an earthquake-prone in Myanmar. These townships are speedily developed in various fields such as economic, social, community and infrastructures. Therefore, the study area comes to experience a fast population growth at urban settlements accompanied by intensive construction activities in the seismic prone region. Due to the above situations, the seismic hazard vulnerability is threatening the study area. The values of fundamental frequency, thickness of soil layer and average shear wave velocity to a depth of 30 m (V_s^{30}) obtained from microtremor horizontal vertical spectral ratio (MHVSR) data are important parameters to estimate seismic local site effects of the study area. The HVSR data was resulted from the microtremor measurements. This paper can provide the estimation of local seismic soil response of the study area during earthquake.

2. Seismotectonic Setting and Seismicity of Mandalay Region

According to tectonic setting of Myanmar [1], the study area is tectonically bounded by several lateral strike-slip fault such as Moemeik fault, Shweli fault, Namma fault and Kyaukkyan fault etc., in the east, and the Sagaing fault and subduction zone of Indian plate beneath Burma plate in the west. 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 [2] [3] [4]. Due to these complex major faults, several earthquakes have impacted in and around Mandalay region. There have been 40 moderate earthquakes (M 6.0-6.9) and 15 large earthquakes (M≥7.0) within the territory of Myanmar in the past over 100 years.

The seismicity of Mandalay region is analyzed by using historical and instrumentally record. Figure (1) shows the distribution of seismicity around Mandalay region with different colors representing different earthquake depths. According to the historical and recent earthquakes data, Mandalay region can be impacted by very vulnerable earthquake for near future.

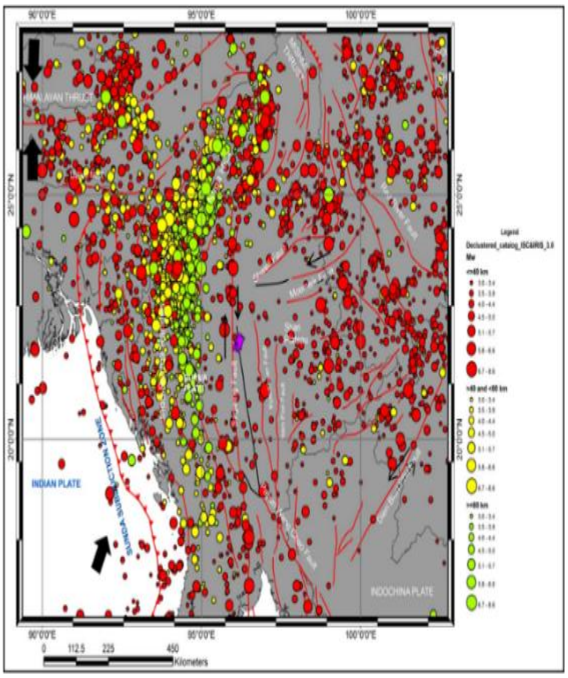

Figure 1. Regional seismicity map including Mandalay Region [5]

3. Methodology

3.1 Site Investigation

Microtremor survey instrument developed by Akashi Corporation, model SMAR 6A3P was used to calculate V_s^{30}value of the site investigation points. In this study, a total of 16 shallow boreholes and 26 microtremor points were investigated from various soil deposits at different locations (Figure.2). Survey location was 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 park, sewer or pipes, bad weather condition and noisy environments, since all of these structures can significantly influence the recordings. To minimize these effects, the recording duration vary as 15 min for normal condition and 30 min for noisy condition. 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.

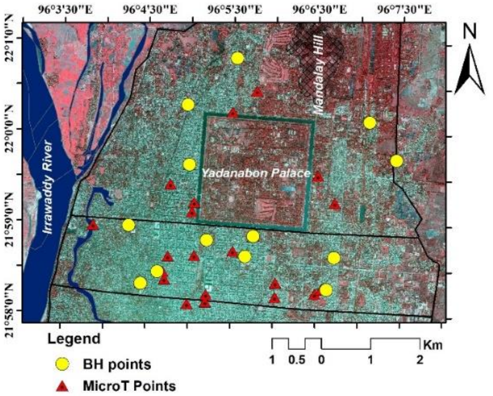

Figure 2. Map of the site investigated points in the study area

3.2 Evaluation of V_s^{30} Based on HVSR Data

Microtremor data was used to obtain HVSR ratio based on the following procedures (Figure 3). The H/V spectral ratio of microtremor measurement data was confirmed that the fundamental frequency and the amplification factor are able to be estimated [6]. Every data resulted from microtremor has 3 data types such as EW (East-West), NS (North-South) and UD (vertical) component data. Average spectral ratio of horizontal-to-vertical noise components (HVSR) at each frequency can be defined as

$$\frac{H}{V}(f) = \sqrt{\frac{H_{NS}(f)+H_{EW}(f)}{V(f)}} \quad (1)$$

Where, H and V are the spectra of the two horizontal (North-South and East-West direction) and vertical components, respectively [7].

To remove the artificial disturbance, all signals were band-pass filtered in a pass band of 0.1-10 Hz (Figure 4) and they were divided into 40.96 seconds long windows. 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.

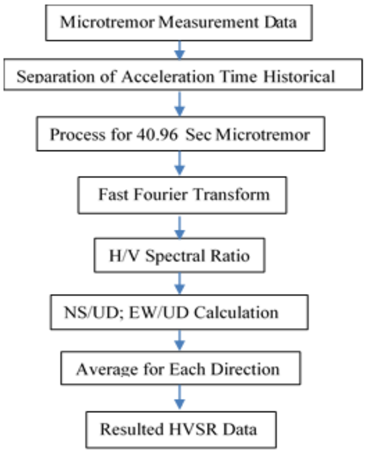

Figure 3. Flow chart of HVSR analysis procedures

In the present study, the following equation has been used for the estimation of shear wave velocity V_{sd} is computed for different depths [8]:

$$V_{sd} = \frac{d}{\sum_{i=1}^{N}\frac{h_i}{V_i}} \quad (2)$$

Where d is the depth in meters, and h_i and V_i denote the thickness and shear wave velocity of the i layer based on microtremor measurements, for a total of N layers [9].

The average shear wave velocity of the top 30m (V_s^{30}) is calculated as the following equation;

$$V_{S\,30} = \frac{30}{\sum_{i=1}^{N}\frac{h_i}{V_i}} \quad (3)$$

Where, Vs^{30} is the shear wave velocity of upper 30m, h_i and v_i denote the thickness (m) and shear wave velocity of the i-[th] layer, in a total of N, existing in the top 30m, V_s^{30}[10] [11] [12].

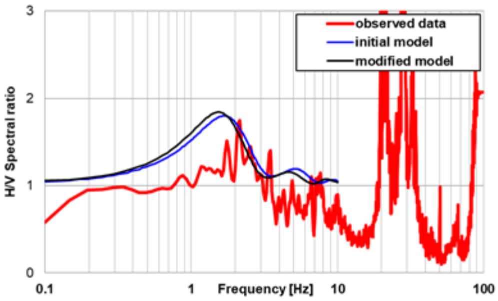

Figure 4. Example of H/V spectral ratios model of microtremor analysis at bet:27-28St-Thingazar Creek

4. Results and Discussion

In this study, the main aim is to estimate seismic site classification of various soils. The classifications of seismic design category become very important to solve seismic related hazard for the study area. The V_s^{30} value of subsurface soil is important to determine seismic design category of soil. To estimate the seismic local site effects of the present area, the fundamental frequency, thickness of soil layer and average shear wave velocity to a depth of 30 m, V_s^{30} values were used.

4.1 Development of Fundamental Frequency, Vs^{30} and Soil Thickness Maps

The ranges of the fundamental frequency in the study area lie between < 0.7 to >2.1 Hz as shown in Figure (5). The high frequency with the range >1.9 Hz can be observed in the eastern portion of Aungmyaythazan township especially eastern part of Mandalay hill. The low frequency range with <0.8 Hz represents western portions of Chanayethazan township. The high frequency may be thinner sediment whereas low frequency zone represents thicker sediment at the microtremor investigated points. The tall building on the low frequency zone may be strongly influenced the seismic site effect than short building. If the natural frequency of the building matches the frequency of ground at the study point, this structure may cause highly damage due to resonant frequency effect.

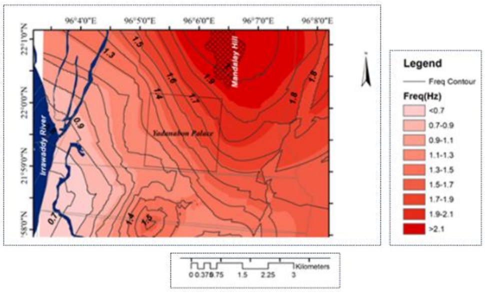

Figure 5. Fundamental frequency map of the study area

The V_s^{30} values have already calculated based on H/V spectral ratio of microtremor test compare with SPT-N value after inversion process. The V_s^{30} values of the study area are within the range of <220 to >420 ms^{-s} with the changes of the soil properties (Figure 6). The minimum V_s^{30} zone (<220 ms^{-s}) falls in the western part of Chanayethazan, and southwestern part of Aungmyaythazan townships. The maximum V_s^{30}zone (>400 ms^{-s}) can be observed in the northeastern part of the area especially around Mandalay hill. The minimum V_s^{30}zone may be suffered by stronger ground shaking during an earthquake and the maximum V_s^{30} zone may not be this effect. Moreover, if the V_s^{30}value is <220 ms^{-1}at an investigated point in the present area, this point may be liquefaction susceptibility.

For the study area, V_s^{30} value of bed rock (assuming soft rock) is placed 560ms^{-1} based on standard EC8 code. Soil thickness of the study area has estimated by the shear wave velocity structures resulted from MHVSR data by using inversion process. The soil thickness of the study area represents from <14 to >63 m (Figure 7). According to resulted data, the thickness of soil layer is decreasing from west to east in the study area. The maximum thickness of soil deposit is about >63 m and minimum soil thickness is about <14 m in the study area.

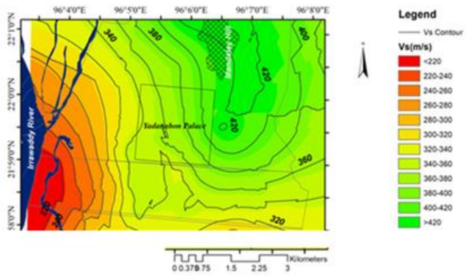

Figure 6. Shear wave velocity map of the study area

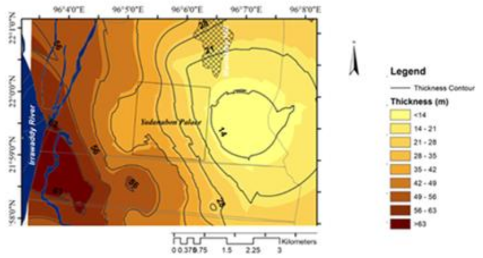

Figure 7. Soil or sediment thickness map of the study area

4.2. Development of Seismic Design Category Map

Seismic design categories map of the study area is conducted based on V_s^{30} value by using standard EC 8 codes site classification (Table 1). In this study, the site classes map is defined as seismic design category map of the study area as shown in Figure (8).

According to resulted data, the study area is characterized by 50% B soil type as very dense deposit, the 35% C-soil type class as deep deposits of dense or medium-dense sand, gravel or stiff clay and 15% D soil class as loose to medium, soft cohesionless soil (Figure 9). According to PGA map [10] and ground water level map [11], D soil type of this area lies in the zones of shallow depth ground water level and high PGA value. On the basis of previous and present resulted data, the D soil class area can be potentially high damage zone than the other parts of the study area during earthquake.

Table (4.3) Classification of subsoil classes according to EC8 (Eurocode.8) standards based on the V_s^{30} values [12][13].

Soil Class	Soil Description	$V_{s}30$ (ms^{-1})
A	Rock	>800
B	Soft rock, very dense sand, gravel or very stiff clay,	360–800
C	Dense or medium-dense sand, gravel or stiff clay	180–360
D	Loose-to-medium cohesionless soil or soft-to-firm cohesive soil	<180

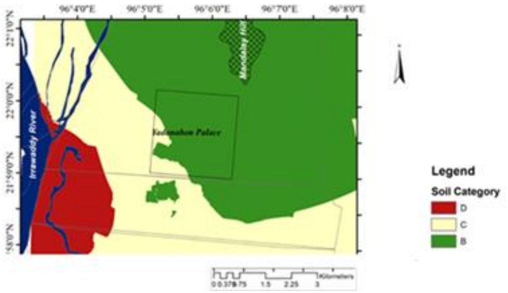

Figure 8. Seismic soil site class map of the study area

5. Conclusions

The main aim of the present research was to prepare seismic design category map of the study area based on fundamental frequency and shear wave velocity obtained from MHVSR data. The low fundamental frequency zone, maximum thickness of soil layer zone and the minimum V_s^{30}zone suffer more stronger ground shaking than the other zones during an earthquake. According to resulted data, these zones fall in D site class which can be observed at the western part of Chanayethazan township. The tall and large buildings should not construct on the D soil type of the study area. The present data will be very useful not only for seismic hazard mitigation programs but also for seismic safety plans. Moreover, these maps will help the structural designers or architect and city planners to assess the vulnerability of the area against seismic risk.

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References

[1] Soe Thura Tun & Ian M Watkinson (2017) The Sagaing Fault, Myanmar, Geological society London, Memoirs, Vol.48, Myanmar Geology, Resources and Tectonics, Ch-19, pp.413-441.

[2] Mitchell, A. H. G. (1981) “Phanerozoic Plate Boundaries in Mainland Southeast Asia, the Himalayas and Tibet”, *Journal of Geological Society London 138*: pp. 109-22.

[3] Win Swe(1981)“A Major Strike Slip Fault in Burma.” In Contributions to Burmese Geology, pp. 63-72

[4] Win Swe (2013) “The Sagaing Fault of Myanmar: a brief overview, Geology of Sagaing Fault, in Commemoration of 9th Anniversary of MGS”, Myanmar Geosciences Society, Yangon, Myanmar, pp.1–20.

[5] Myo Thant, New Le Nge, Soe Thura Tun, Maung Thein, Win Swe &Than Myint. (2012) Seismic Hazard Assessment of Myanmar, Myanmar Earthquake Committee (MES), Myanmar Geoscience Society (MGS).

[6] Nakamura, Y. (1989) “A Method for Dynamic Characteristics Estimation of Subsurface using Microtremor on the Ground Surface,” *Quarterly Report of RTRI*, 30:1, 25-33.

[7] Kawase, H., Francisco J. Sánchez-Sesma & Matsushima, S. (2011) “The Optimal Use of Horizontal-to-Vertical Spectral Ratios of Earthquake Motions for Velocity Inversions Based on Diffuse-Field Theory for Plane Waves”, *Bulletin of the Seismological Society of America*, Vol. 101, No. 5, pp. 2001–2014, doi: 10.1785/0120100263.

[8] CEN. (2004) EN 1998-1:2004, “Eurocode 8: Design of Structures for Earthquake Resistance – Part 1: General Rules, Seismic Actions and Rules for Buildings”, European Committee for Standardization.

[9] Bessason, B., and Erlingsson, S. (2011) Shear Wave Velocity in Surface Sediments, *JÖKULL No. 61, 2011,https://www. Research gate. Net/ publication/268384698*

[10] Myo Thant. (2013) Development of Seismic Microzonation Maps of Mandalay City, Mandalay Region, MES and MGS, Myanmar.

[11] Tun Tun Win (2020) Evaluation of Liquefaction potential of the Mandalay City, PhD Dissertation, University of Mandalay, Myanmar.

[12] Dobery, R. et al. (2000) “New Site Coefficients and Site Classification System Used in Recent Building seismic Code Provisions, Earthquake Spectra, 16, pp. 41-67.

[13] Sabetta, F. and Bommer, J. (2002) “Modification of the Spectral Shapes and Subsoil Conditions in Eurocode 8, 12th European Conference on Earthquake Engineering, Paper Ref: 518.