Evaluation of Soil Amplification and Site Period for Yangon, Myanmar

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Abstract: *The effects of earthquakes are not only dependent upon the magnitude of the earthquake and the distance from the source, but also due to local geological conditions. Subsurface conditions play a major role in the damage potential of earthquakes and the seismic soil amplification of a site which is a critical factor affecting the level of ground shaking. The most widely used techniques for the study of one-dimensional amplification of vertically propagating seismic waves involve solution of the dynamic equations in the frequency domain with linearly viscoelastic material properties. The purpose of this study is to develop predominant period and amplification factor for Yangon city area. In this study, one dimensional equivalent linear approximation of nonlinear response analysis was performed by multiple refraction analysis and simulate with Matlab program. According to the evaluation results, Yangon city has been ranked from medium to relatively high hazard, and the soil amplification are ranged from (1.1-3.8) and predominant period values are ranged from 0.1 to 1.2 sec. The development of soil amplification and site period are reliable and applicable for seismic hazard analysis and earthquake resistant designs of structures.*

Key Words*: Dynamic Soil Properties, Multiple refraction analysis, Predominant Period, Amplification Factor, Yangon Region*

1. INTRODUCTION:

Myanmar is exposed to a major earthquake since a large part of the country lies in the southern part of the Himalaya and the eastern margin of the Indian Ocean. It is situated in the Alpide Earthquake Belt, one of the two main Earthquake Belts of the world. Yangon Region is one of the major regions of Myanmar and the former capital of Myanmar. It is located on low to medium seismicity region. It is tectonically bounded by the Indian-Burma plate's subduction in the west, Sagaing fault in the east, West Bago Yoma fault in the north-east and the Andaman rift zone in the south. According to the seismicity of the previous events, the main seismic sources to cause the earthquake potentials are subduction zone of Indian Plate beneath Burma Plate, Sagaing fault, and Kyaukkyan fault. Yangon is one of the major cities of Myanmar and is at risk of earthquake. Major earthquakes along the Sagaing Fault have a return period of 50 to 80 years. In 2012, a major earthquake (Thabeikkyin earthquake) with a magnitude of 6.8 attacked many residential housings and ground failures near Mandalay City. But Yangon area does not have any large earthquakes since 1930. In the previous year 2016, a major earthquake (Chauk earthquake) with a magnitude of 6.8 attacked Myanmar in the west of Chauk with a maximum Mercalli intensity of VI. Tremors from the earthquake were felt in Yangon and several temples in the ancient city of Bagan were damaged. The characteristics of earthquake shaking are affected by the local site conditions. The effects of the local soil conditions are often quantified via an amplification factor (AF), which is defined as the ratio of the ground motion at the soil surface to the ground motion at a rock site at the same location. Amplification factors can be defined for any ground motion parameter, but most commonly are assessed for acceleration response spectral values at different oscillator periods. Site amplification can be evaluated for a site by conducting seismic site response analysis, which models the wave propagation from the base rock through the site-specific soil layers to the ground surface. Predominant period indicates the frequency of the spectrum under which the near-surface soft sediment amplifies the earthquake ground motion, often referred as the site effects. When the predominant period of the sites appears near the period of the structure then the degree of damage caused by earthquake shaking would be larger. The purpose of this study is to provide predominant period and amplification factor maps for the study area.

2. SOIL AMPLICATION AND SITE PERIOD:

When an earthquake occurs, seismic waves are released at the source (fault), they travel through the earth, and they generate ground shaking at the ground surface. The characteristics of shaking at a site depend on the source characteristics and change as they travel through their path to get to the site. The wave amplitudes generally attenuate with distance as they travel through the bedrock in the crust and they are modified by the local soil conditions at the site. The important property of the local soil conditions that influence ground shaking is the shear wave velocity. Although seismic waves may travel a longer distance through the bedrock than through the local soils, the influence of the local soil conditions can be significant. The effects of the local soil conditions are often quantified via an amplification factor (AF), which is defined as the ratio of the ground motion at the soil surface to the ground motion at a rock site at the same location. The amplification of ground motions at a nearly level site is significantly by the natural period of the site. Both dynamic stiffness and depth are important. Other important seismic site response factors include the impedance ratio between the soil deposit and underlying bedrock, the material damping of the soil deposits, and the nonlinear response of soft a potentially liquefiable soil deposits. The effects of earthquakes are not only dependent upon the magnitude of the earthquake and the distance from the source, but also due to local geological conditions. Subsurface conditions play a major role in the damage potential of earthquakes and the seismic soil amplification of a site which is a critical factor affecting the level of ground shaking. The most widely used techniques for the study of one-dimensional amplification of vertically propagating seismic waves involve solution of the dynamic equations in the frequency domain with linearly viscoelastic material properties. The purpose of this study is to develop predominant period and amplification factor for the study area. In this study, one dimensional equivalent linear approximation of nonlinear response analysis was performed by multiple refraction analysis.

3. ONE DIMENSIONAL GROUND RESPONSE ANALYSIS:

Ground response analyses are used to predict ground surface motions and the soil plays a very important role in determining the characteristics of the ground surface motions. To perform in this study, borehole data are collected as much as possible from Yangon City Development Committee, Myanmar Engineering Society, and Construction Industry from Yangon city area. One-dimensional ground response analyses are based on the assumption that all boundaries are horizontal and that response of a soil deposit is predominantly caused by SH-waves propagation vertically from the underlying bedrock. For one-dimensional ground response analysis, the soil and bedrock surface are assumed to extend infinitely in the horizontal direction. Ground response analysis is also based on the use of transfer functions. Transfer functions can be used to express various response parameters such as displacement, velocity, acceleration, shear stress and shear strain to an input motion parameter such as bedrock acceleration. This approach is limited to the analysis of linear systems. A known time history of bedrock (input) motion is represented as a Fourier series using FFT (Frist Fourier Transform). Each term in the Fourier series of the bedrock (input) motion is then multiplied by the transfer function to produce the Fourier series of the ground surface (output) motion. The ground surface (output) motion can be expressed in the time domain using inverse FFT. Then, the transfer function determines how each frequency in the bedrock (input) motion is amplified, or de-amplified by the soil deposit. While the uniform elastic layer models are useful for illustration of the influence of soil conditions on several ground motion characteristics, they are suitable for analysis of practical ground response problems. Real ground response problems usually involve soil deposits with layers of different stiffness damping characteristics with boundaries at which elastic wave energy will be reflected or transmitted. Such conditions require the development of transfer functions for layered soil deposits. Nomenclature for layered soil deposit on elastic bedrock is shown in Fig.1.

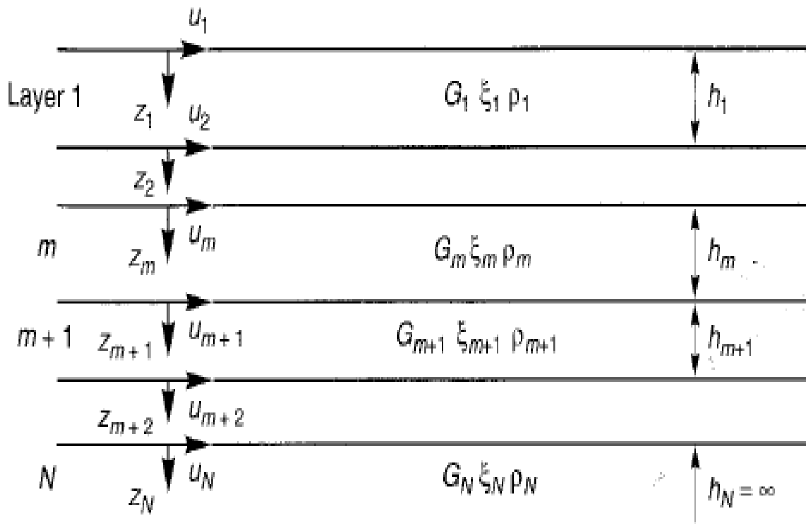

Figure.1. Nomenclature for layered soil deposit on elastic bedrock

In this study, 1994 Northridge earthquake, the moment magnitude 6.7, peak acceleration 0.734g, source to site distance 74.3m of Yorba Linda station (USGS) is used as bedrock (input) motion to predict surface motion for selected area and the recorded time history ground motion are presented in Fig. 2.

The Fourier series is complex valued; its one-sided Fourier amplitude spectrum. The Fourier amplitude spectrum is defined for frequency up to 10 Hz because most of the energy in the bedrock motion is at frequencies less than 5 to 10 Hz, (Steven L.Kramer, 1996). The Fourier amplitude spectrum for Northridge Earthquake is shown in Fig.3.

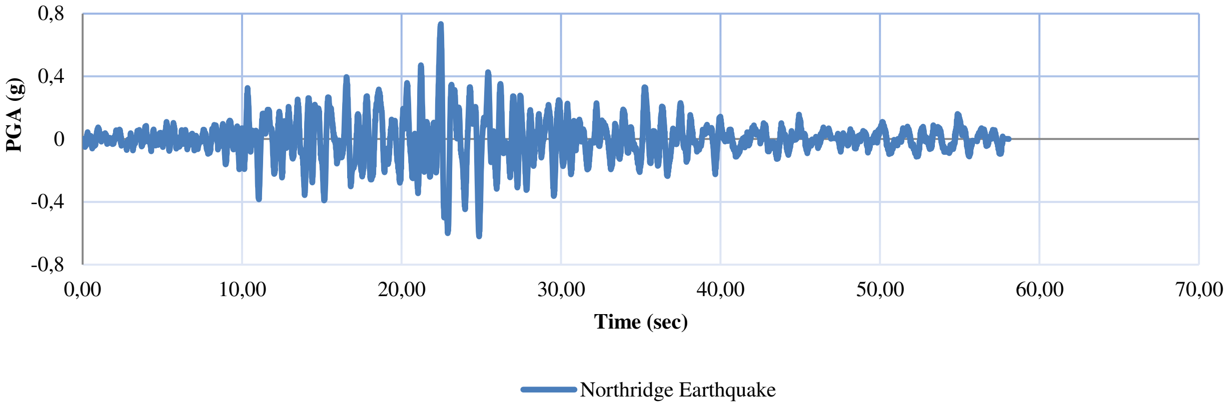

Figure .2. Recorded ground motion of Northridge Earthquake

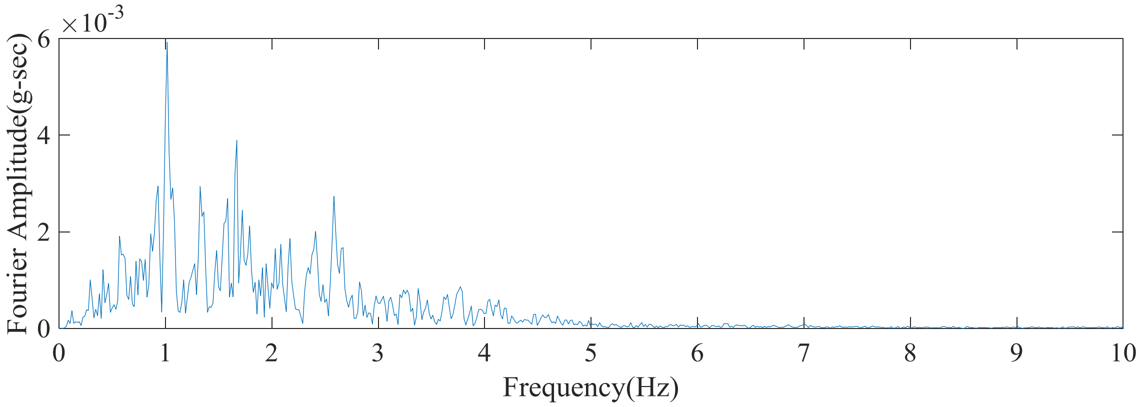

Figure.3. One-sided Fourier amplitude spectrum for Northridge Earthquake

The transfer function that relates the ground surface (output) motion to the bedrock (input) motion and soil characteristics parameters such as average shear wave velocity ($V_{s,30}$), unit weight of soil (ρ), soil layer thickness (H), soil damping (ε) are required to calculate transfer function. In this study, the transfer function of layered damped soil on elastic rock is considered.

4. SEISMOTECTONIS OF THE STUDY AREA:

Yangon is located between latitudes16º 45´ N –17º4´ N and longitudes 96º 1´E – 96º 20´E, on the southeastern corner of the Ayeyarwady Delta basin, at the mouth of three rivers: Yangon, Ngamoyeik and Bago rivers and 34km from the sea in the coastal area. It has a tropical monsoon climate with annual precipitation of 2366mm. The average temperature is 27ºC. It has population of about six million people. Owing to the annual increase in population, the size of the city has expanded several times than its prewar size. Yangon's pride: the Shwedagon Pagoda was built on the top of Singuttara Hill, on the southern spur of BagoYoma .The Yangon area is underlain by alluvial deposits (Pleistocene to Recent), the non-marine fluvialtile sediments of Irrawady formation (Pliocene), and hard, massive sandstone of Pegu series (early-late Miocene). Alluvial deposits are composed of gravel, clay, silts, sands and laterite which lie upon the eroded surface of the Irrawaddy formation at 3-4.6 m above mean sea level (MSL). Yangon is situated in the southern part of the Central Lowland which is one of the three major tectonic provinces of Myanmar. The Taungnio Range of the Gyophyu catchments area of Taikkyi District, north of Yangon, through the Thanlyin Ridge, south of Yangon forming a series of isolated hills probably resulted from the progressive deformation of the Upper Miocene rocks as the eastern continuation of the subduction or stretching and compression along the southern part of the Central Basin and regional uplifting of the Pegu Yoma. Most of the earthquakes are shallow focus earthquakes and major seismic sources are located within 250km in radius. Most of the earthquakes, which occurred in the central region of Myanmar, are related with Sagaing fault, and in the eastern part, the focal depth is not greater than 40 km. The right lateral, strike-slip Sagaing fault which caused the 5th July, 1917 event, the magnitude 7.3, May 5, 1930 Bago earthquake and December 3, 1930 (M7.3) earthquake, extends through the central part of the country for a length of more than 1,000 km. It runs from the Gulf of Mataban in the south through Bago, Pyinmana, Yamethin, Tharzi, and Sagaing till Putao in the north. The records of the previous significant earthquakes showed that some destructive earthquakes with the magnitudes ≥ 7 originated from this fault.

5. GROUND INVESTIGATION:

Firstly, collect (159) boreholes data in (23) townships in Yangon city area, and develop the correlation of shear wave velocity with SPT-N value for Yangon city. The correlation of shear wave velocity with SPT-N value for Yangon city area is:

$$V_s = 63.229\ N^{0.4298} \quad (1)$$

And then, the average shear wave velocity of soil up to 30m is calculated according to soil borehole data by the Eqn. (2).

$$V_{s,30} = \frac{\sum d_i}{\sum \frac{d_i}{V_{si}}} \quad (2)$$

Where, d_i is the thickness of layer i (feet, m) and V_{si} is the shear wave velocity in Layer i (feet/sec, m/sec).

The average shear wave velocity profile for 159 boreholes data are shown in Fig.4. In this study, the average shear wave velocity and density of engineering bedrock are considered as 400m/sec and 22 kN/m^3.

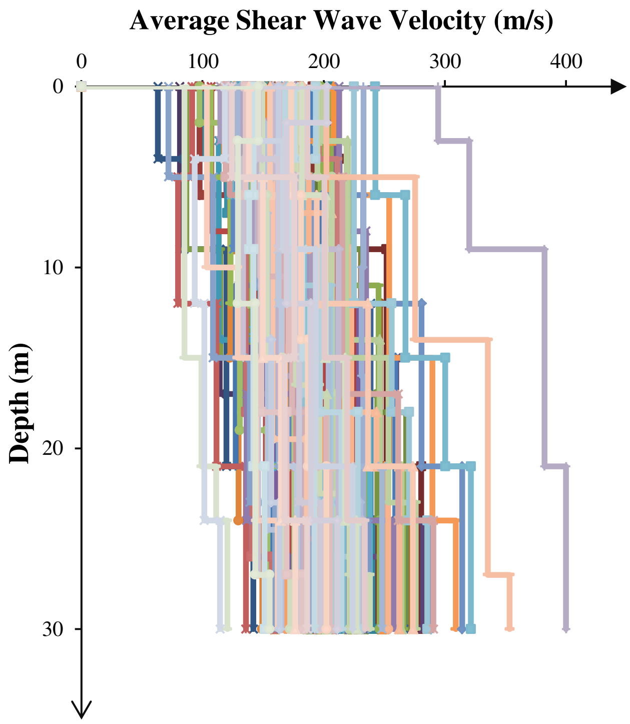

Figure.4. Average shear wave velocity, $V_{s,30}$ profile for Yangon Subsoil

6. EVALUATION OF AMPLICATION FACTOR AND PREDOMINANT PERIOD:

Firstly, one of the borehole data from YTU campus located in Insein Township is carried out. Borehole Log table for YTU-campus is shown in Table.1. By using the SPT-N value from the borehole data and a suitable relation between SPT-N and V_s values presented in equation (1), construct a shear wave velocity profile of the surface layer. And then, the average shear wave velocity of soil is computed according to equation (2). After that the soil layer is divided according to the different soil categories shown in Table.1. The soil profile type for YTU campus including layered thickness, the average shear wave velocity and density values for each layer and engineering bedrock are shown in Fig.5. Ground Response Analysis is the most important and reliable approach and one dimensional equivalent linear approximation of nonlinear response analysis were performed in this study. For the layered damped soil on elastic bedrock, the transfer function is evaluated by multiple refraction analysis and simulate with Matlab program based on the soil parameters of selected borehole, shear wave velocity structure and recorded bedrock motion. The damping for soil is assumed 5% and bedrock is assumed 2% in this study. The transfer function for selected borehole in YTU-campus is shown in Fig.6. Therefore, the estimated amplification factor and predominant period values for selected borehole in YTU-campus are 2.059 and 0.575 sec respectively.

Table1. Borehole Log for YTU-campus

Depth (m)	SPT N-values (Blows/30cm)	Soil Name	Unit Weight (kN/m^3)	$V_s = 63.229 N^{0.4298}$ (m/s)	$\bar{V}_s$ (m/s)
0.0	0	Lean Clay-I	0.00	0.00	0.00
1.5	11		19.50	177.22	177.22
3.0	17		19.50	213.68	194.35
4.5	14		19.50	196.57	195.07
7.5	8		18.11	154.55	176.44
9.0	8		18.11	154.55	172.24
10.5	8		18.11	154.55	169.55
12.0	12		18.11	183.97	171.28
13.5	9		19.05	162.57	170.30
15.0	10		19.05	170.10	170.28
16.5	23		19.05	243.33	174.91
18.0	60	Fat ClayII	19.94	367.42	183.17
19.5	109		20.60	474.90	191.96
21.0	130		20.60	512.26	201.25
22.5	111		20.60	478.63	209.08
24.0	76	Silty Sand	20.60	406.71	215.85
25.5	58		20.60	362.11	220.93
27.0	81		20.51	418.01	227.08
28.5	150	Fat ClayII	20.51	544.75	234.04
30.0	229		20.71	653.39	242.06

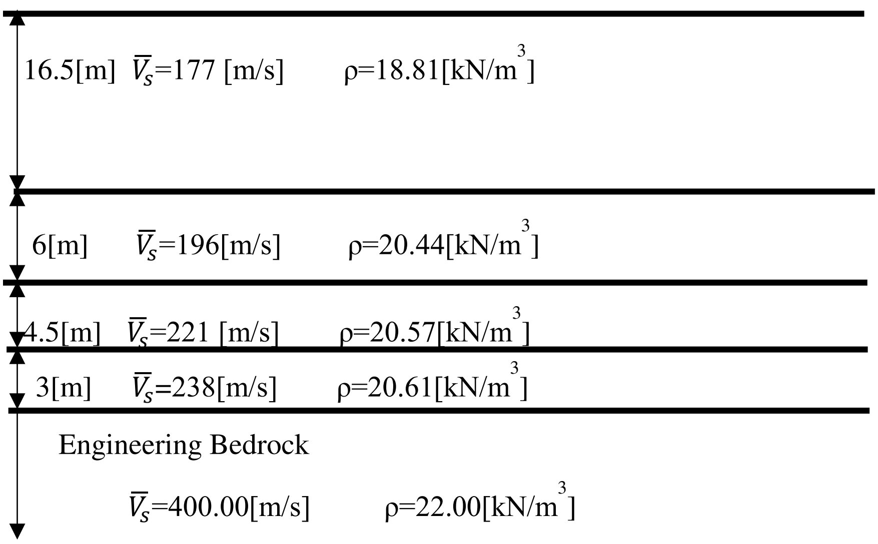

Figure.5. Soil Profile for YTU-campus

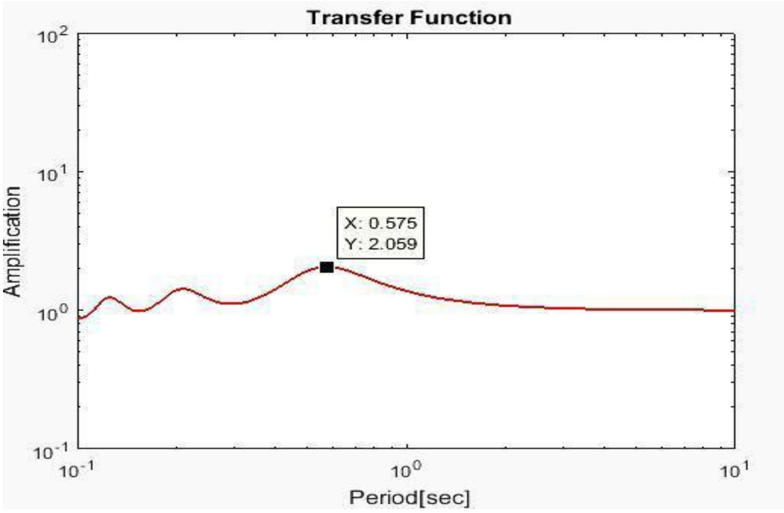

Fig.6. Transfer function for selected borehole in YTU-campus

On the other hand, Single station Microtremors measurement is carried in YTU-campus to estimate the predominant period and amplification factor for the subsurface soil. The microtremor technique has been employed to to verify the programed results using borehole data. Horizontal to Vertical spectral Ratio technique (H/V) consists of estimating the ratio between the Fourier amplitude spectra of the horizontal (H) to vertical (V) components of microtremors recorded at one single station. Micrtremor measurement observed data is shown in Fig.7. According to the microtremor measurement, amplification factor value for YTU-campus is 2.221 and predominant period value is 0.418sec.

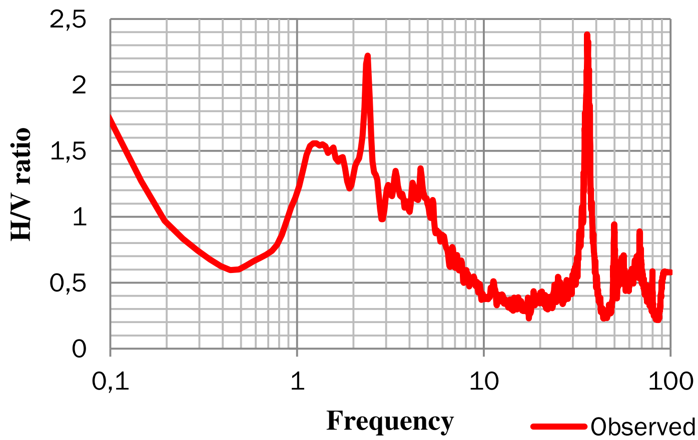

Figure.7. Observed data from microtremor measurements

Comparing the two results of amplification factor and predominant period for selected site soil presented in Fig.6 and Fig.7, the results are approximately equal. So, the amplification map and predominant period of this research study is reliable. Similarly, the amplification factor and predominant period values for Yangon area are developed the procedures mentioned in above. Then, evaluation of contour maps is drawn by IDW interpolation method using GIS software. Interpolation is the process of using points with known values or sample points to estimate values at other unknown points. It can be used to predict unknown values for any geographic point data, such as elevation, rainfall, chemical concentrations, noise levels, and so on. The IDW technique is used in this research. The IDW technique calculates a value for each grid node by examining surrounding data points that lie within a user-defined search radius. Some or all of the data points can be used in the interpolation process. The node value is calculated by averaging the weighted sum of all the points. Data points that lie progressively farther from the node influence the computed value far less than those lying closer to the node. The development of contour maps for amplification factor, and predominant period are shown in Fig.8 and 9 respectively. The correlation equation between amplification factor and average shear wave velocity up to 30m for Yangon city is shown in Fig. 10.

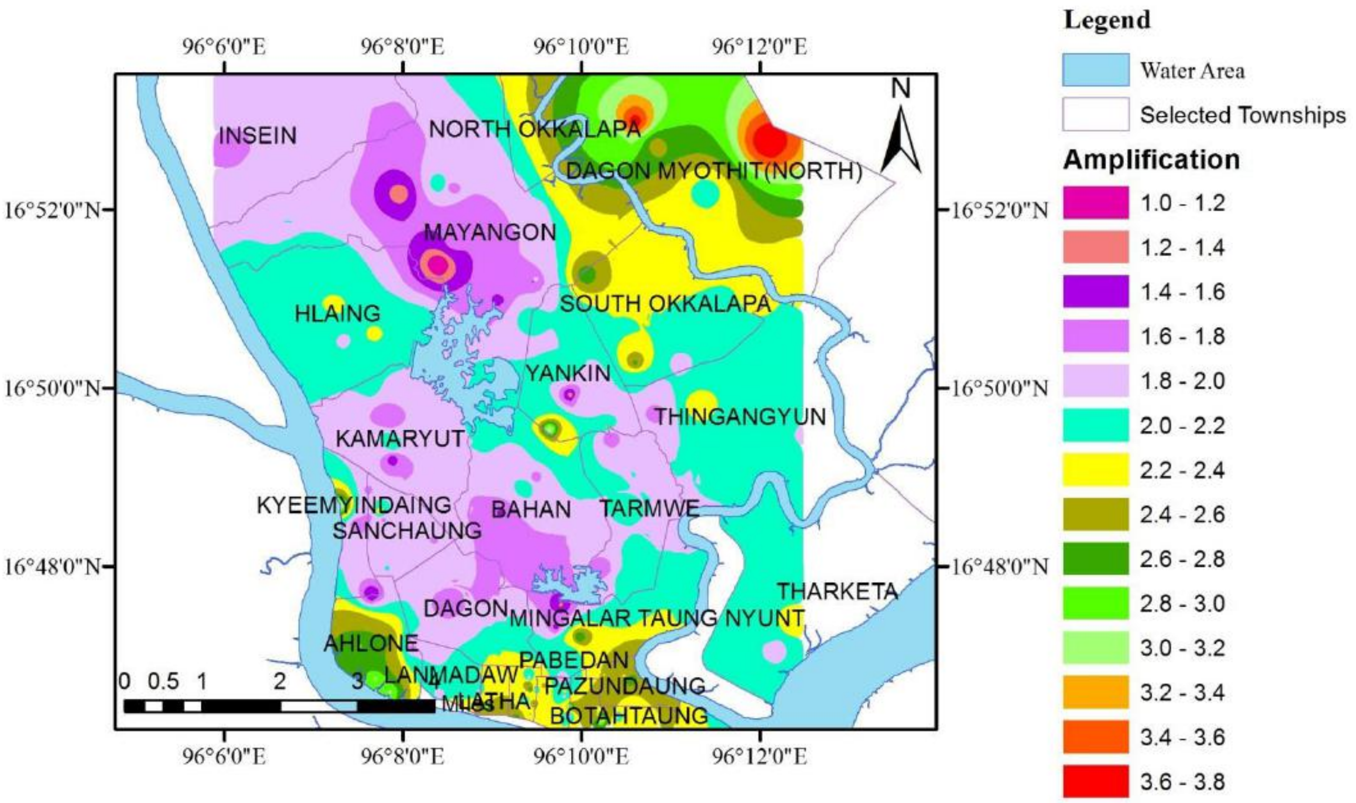

Figure.8. Amplification factor map for Yangon City

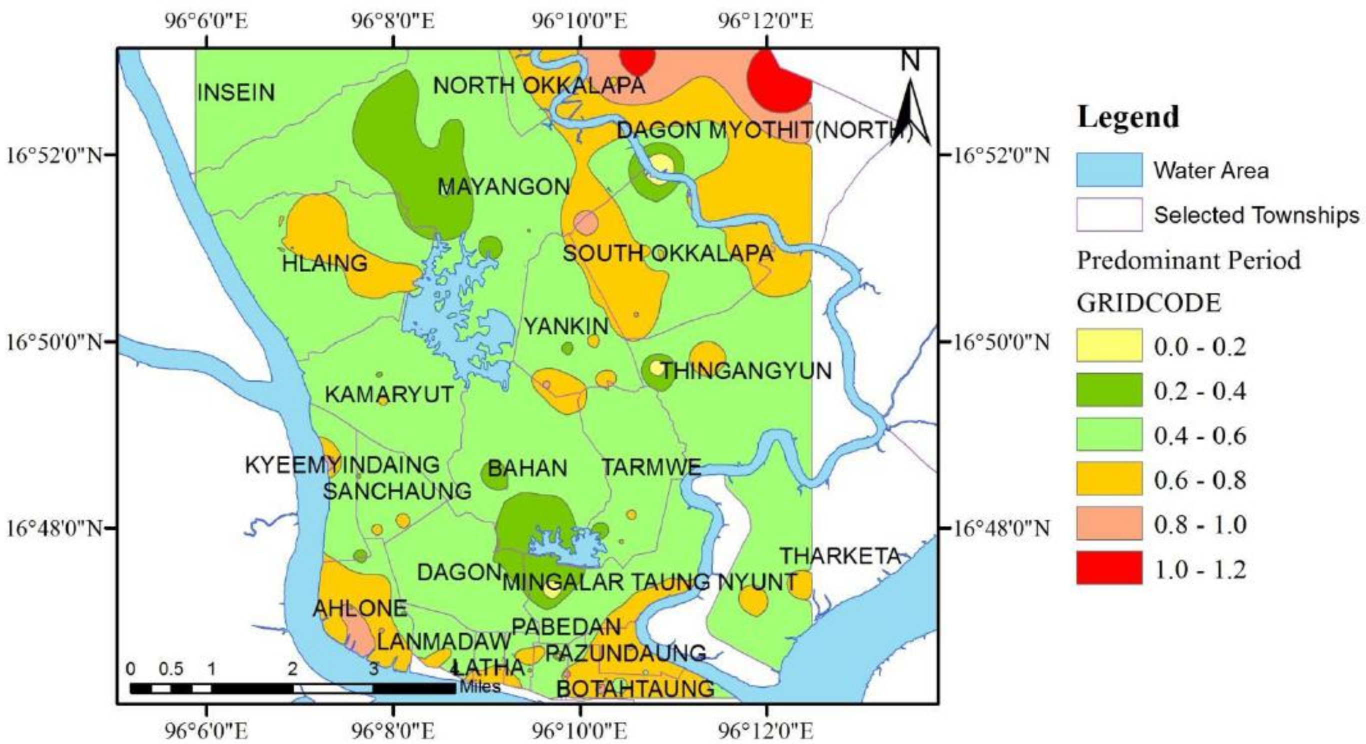

Figure.9. Predominant period map for Yangon City

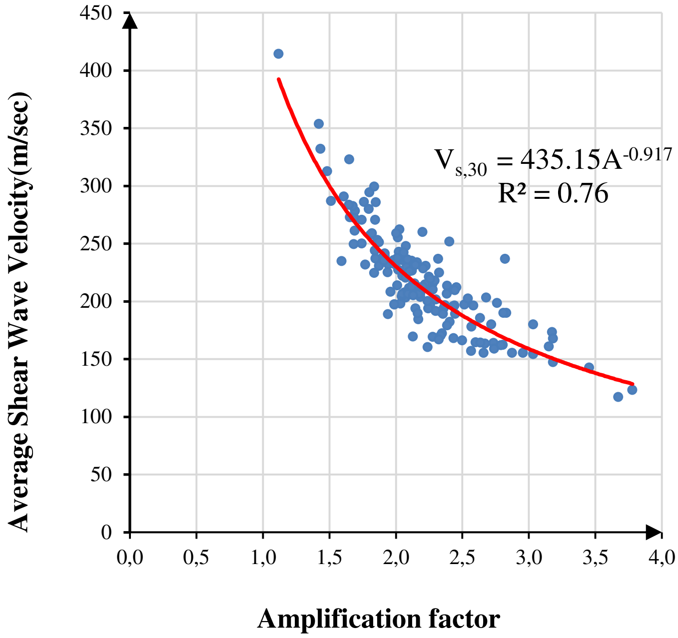

Fig.10. Correlation equation between amplification factor and average shear wave velocity up to 30m for Yangon city

8. DISCUSSION AND CONCLUSION:

In this research, ground motion parameters such as amplification factor and predominant period are calculated using multi-layered soil response analysis by Matlab program. Amplification factor values of Mayangone township is the lowest value (1-1.8).At Dagon(North), North Okkalapa, Kyee Myin Daing, Ahlone townships, amplification factor values is very high (2.8-3.8). Downtown area of Yangon city is 1.8 to 3.2 of amplification value. Predominant period values of Dagon (North) township is very height up to 1.2sec. Kamaryut, Mayangone, Insein Sanchaung, Bahan, Tarmwe, Dagon and Mingalartaungnyunt townships are predominant period of 0.4 to 0.6sec.Others of Yangon City are predominant period of 0.6 to 0.8sec. Amplification factor values for Yangon city is mostly (1.5-3.8).The greater the amplification factor values, the smaller the average shear wave velocity values. The correlation equation for the amplification factor and average shear wave velocity up to 30m is $\mathbf{V_{s,30} = 435.15A^{-0.917}}$. By applying Fig.9 and 10, we can easily get amplification factor and predominant period which are essential for seismic hazard assessment of Yangon Subsoil. And also, if the predominant period is known at the site of construction, engineer can design the structure in such that the natural period of the structure does not coincide with the predominant period for earthquake resistant designs of structures.

REFERENCES:

1. Myo Thant, Probabilistic Seismic Hazard Assessment for Yangon Region, Myanmar, in *ASEAN Engineering Journal Part C Vol.3 No.2,* December 2014.
2. S.L. Kramer, Geotechnical Earthquake Engineering, Prentice-Hall International Series in Civil Engineering and Engineering Mechanics, 653 pp, 1996.
3. Bernard R. Wair, Jason T. DeJong & Thomas Shantz, Guidelines for Estimation of Shear Wave Velocity Profiles, Pacific Earthquake Engineering Research Center, PEER, 2012/08 Dec 2012.
4. Bowles, Joseph E., Fourth Edition, 1992. Engineering Properties of Soils and their Measurement, By McGraw-Hill Book Companies, Inc.
5. Hla Hla Aung, Potential Seismicity of Yangon Region (geological Approach), in *Advances in Geosciences Vol. 26: Solid Earth,* 2010.