Evaluation of Shear Wave Velocity Profiles and $V_{s,30}$ Map for Yangon Subsoil

[1]Chit Su San, [2]KyawKyaw, [3]Thet MyatThawdar Win
[1]Ph.D Student, [2]Professor, [3]Ph.D Student
[1, 2, 3]Civil Engineering Department,
[1, 2, 3]Yangon Technological University, Yangon, Myanmar
Email – [1]chitsusan3@gmail.com, [2]kyaw.u.kyaw@gmail.com, [3]thetmyatthawdar@gmail.com

Abstract: *Site effect has been known as the major cause of large ground amplifications during several recent catastrophic earthquakes. Consequently, the evaluation of site effect is an important factor that must be considered in mitigation of earthquake hazards. Shear wave velocity is a key parameter that controls seismic response of a site. Hence its profile must be identified down to the seismic bedrock and are used in a variety of earthquake engineering applications, such as site response studies, liquefaction analyses and soil-structure interaction evaluations. The average shear wave velocity of the top 30 m of the subsurface profile ($V_{s,30}$) as the primary parameter for characterizing the effects of sediment stiffness on ground motions. In this research, evaluate the shear wave velocity (V_s) profile of Yangon subsoil and average shear wave velocity ($V_{s,30}$) map by using standard penetration tests (SPT-N) value. To perform in this study, firstly collect the boreholes data including SPT-N value, soil density (ρ), moisture content, and soil description for Yangon city area. The SPT-N value (vs) V_S correlation equations for all soils from previous researcher are considered and shear wave velocity profile for Yangon subsoil are developed by using regression analysis. Finally, a mapping of average shear-wave velocity of Yangon subsoil has been developed by Arc GIS-10 software. From this study, It is found that the average shear wave velocity ($V_{s,30}$) values of Dagon (North), North Okkalapa, Ahlone, Botahtaung, Pazundaung, KyeeMyintDaing are low value (150-200 m/sec), and Mayangone, Insein, Bahan townships are high value (250-350) m/sec. Most of the Yangon subsoil area are average shear wave velocity ($V_{s,30}$) value of (200-250) m/sec.*

Key Words: *Boreholes data, SPT-N Values, Shear wave velocity (V_s) profile, $V_{s,30}$ map, Regression analysis*

1. INTRODUCTION:

Site effects have been known to be the most influencing factor causing large amplifications of ground motion and hence intensive damage during several past destructive. Therefore, the evaluation of site effects is one of the key factors that must be considered when discussing prevention or mitigation of seismic hazards. The importance of characterization of the initial (or small-strain) shear modulus (G_o) is recognized because of its applications in nonlinear seismic ground response analysis, such as site response analysis and soil-structure interaction (SSI) analysis. Shear wave velocity is one of the input parameter for seismic ground response analysis and can be expressed in terms of elastic modulus and material density as follows:

$$G_o = \rho V_s^2 \qquad (1)$$

Where ρ = mass density of soil (total unit weight of the soil divided by the acceleration of gravity).In the most relationships, $V_s$is considered as a function of SPT-N values. The SPT is one of the effective tests in quick and low cost assessment of the soilmechanical properties; hence it has received the greatest attention from both academic researchers and professional geotechnical engineers. In this paper, a new empirical equation for the SPT-N value with depth for Yangon subsoil is proposed using linear regression analysis. The SPT-N value (*vs*) V_S correlation equations from previous researcher are considered to evaluate shear wave velocity profile for Yangon subsoil. The shear wave velocity profile of Yangon subsoil is evaluated using new proposed SPT-N value (*vs*) V_S correlation equation. Finally, average shear wave velocity is calculated and develop the shear wave velocity map for Yangon subsoil. Table (1) presented the relation of SPT-N value and V_s for all soil type from different researcher.

Table 1. The Relation of SPT-N value and V_s for all Soil Types

No.	Author	V_s
1	Athanasopoulas (1995)	$V_s = 107.6\ N^{0.36}$
2	Sisman(1995)	$V_s = 32.8\ N^{0.51}$

3	Iyisan(1996)	$V_s = 51.5\ N^{0.516}$
4	Jafari et al (1997)	$V_s = 22\ N^{0.85}$
5	Kiku et al (2001)	$V_s = 68.3\ N^{0.292}$
6	Hasancebi and Ulusay(2006)	$V_s = 90\ N^{0.309}$
7	Dikmen (2009)	$V_s = 58\ N^{0.39}$
8	Uma Maheshwari et al.(2010)	$V_s = 95.64\ N^{0.301}$
9	Fauzi et al (2014)	$V_s = 105.03\ N^{0.286}$

2. SOIL INVESTIGATION:

In this study, soil investigation are carried out from (23) townships in Yangon city area. Most of the borehole data are provided from Yangon City Development Committee (YCDC) and some are collected from construction industry. The collected borehole data are up to 50 m depth and including the soil parameters such as SPT-N value, soil density, moisture content, specific gravity and soil description.More than 500 boreholes data are obtained from Yangon city area. Among them, the suitable (159) boreholes data from (23) townships in Yangon city area are selected for this study. Selected townships and location of collected borehole data points are shown in Fig(1).

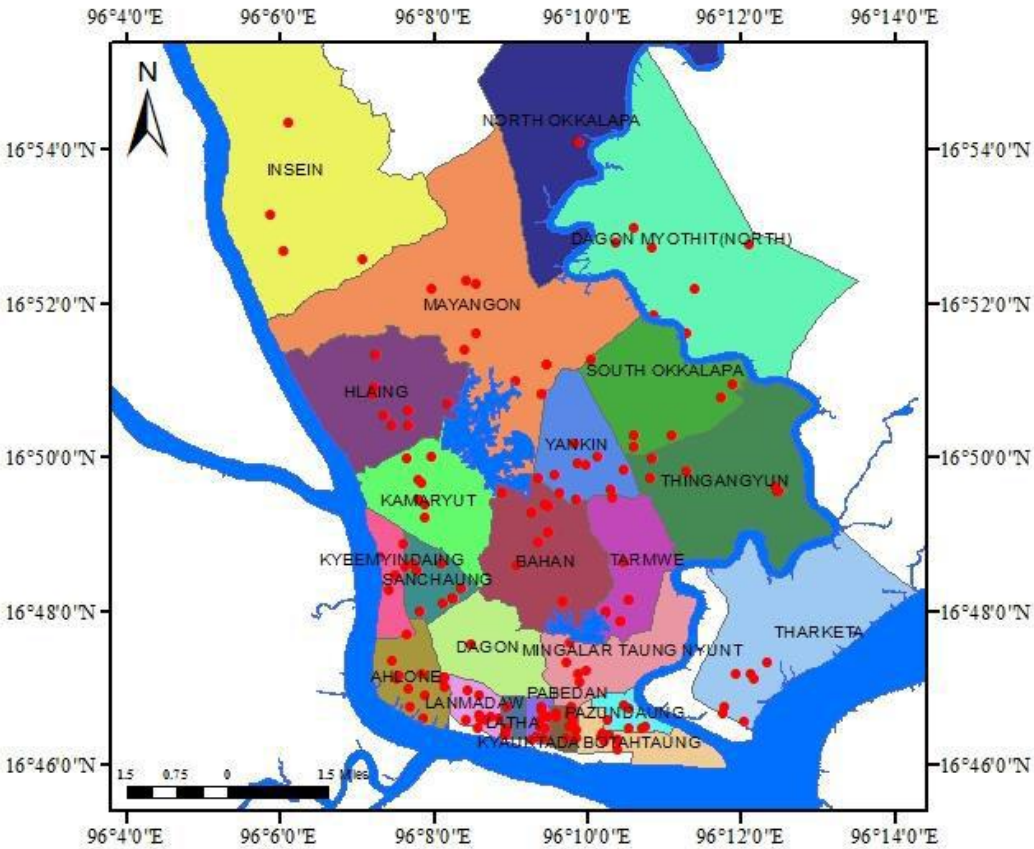

Figure 1. Selected townships and location of collected boreholes data point

3. EVALUATION OF SHEAR WAVE VELOCITY PROFILE:

For a rapid evaluation of shear wave velocities and associated SPT-N value, a power equation model $V_S= AN^B$ is proposed widely. Wherein A is a constant controlling the amplitude and B has the impact upon relationship curvature. This paper also examines the correlation based upon the corrected SPT-N value and the shear wave velocity of depth. Due to the different local site conditions in Yangon area, the suitable empirical correlation for shear wave velocity of Yangon subsoil should be developed. According to the borehole results, it is found that the SPT-N values varies in the same depth. Therefore, the relation of SPT-N value with depth (z) for Yangon subsoil are determined by using linear regression analysis and developed the correlation Eqn. (2) as;

$$N = 1.3257z + 4.1593 \quad (2)$$

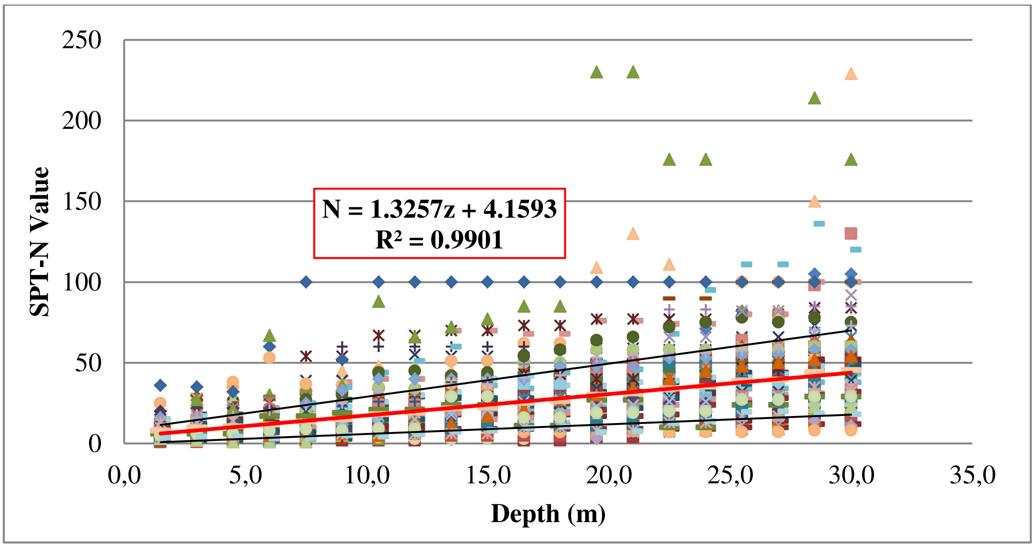

Figure 2. The relation of SPT-N value with depth for Yangon subsoil

By using nine different correlation equations presented in Table(1) and the SPT-N value from equation (2), evaluate the shear wave velocity profiles for Yangon subsoil. Figure (3) shows the correlation between shear wave velocity and SPT-N value for Yangon subsoil for nine different equations.After that, the suitable correlation equation for SPT-N value and V_s for Yangon subsoil are proposed as the following Eqn. (3), and the shear wave velocity profile for Yangon subsoil are shown in Fig (4).

$$V_s = 63.229N^{0.4298} \quad (3)$$

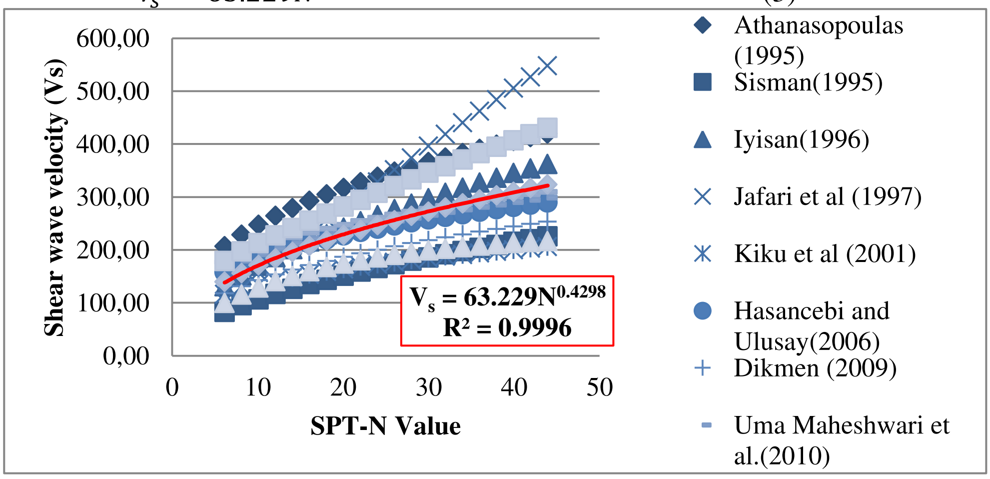

Figure 3. The correlation of shear wave velocity, V_s and SPT-N value for Yangon subsoil

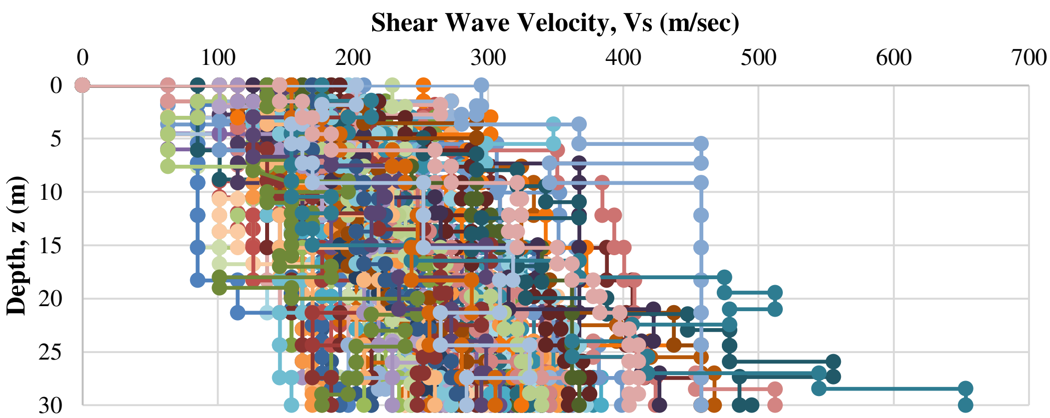

Figure 4. Shear wave velocity ($V_{s,30}$) profile for 159 borehole data

4. DEVELOPMENT OF AVERAGE SHEAR-WAVE VELOCITY $V_{s,30}$ Map:

The average shear wave velocity of soil up to 30m referred to as $V_{s,30}$is calculated according to soil borehole data by the following equation.

$$V_{s,30} = \frac{\sum d_i}{\sum \frac{d_i}{V_{si}}} \quad (4)$$

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 calculation procedure of average shear wave velocity is shown in table (2). The results of average shear wave velocity profiles for 159 boreholes data are shown in Fig (5).

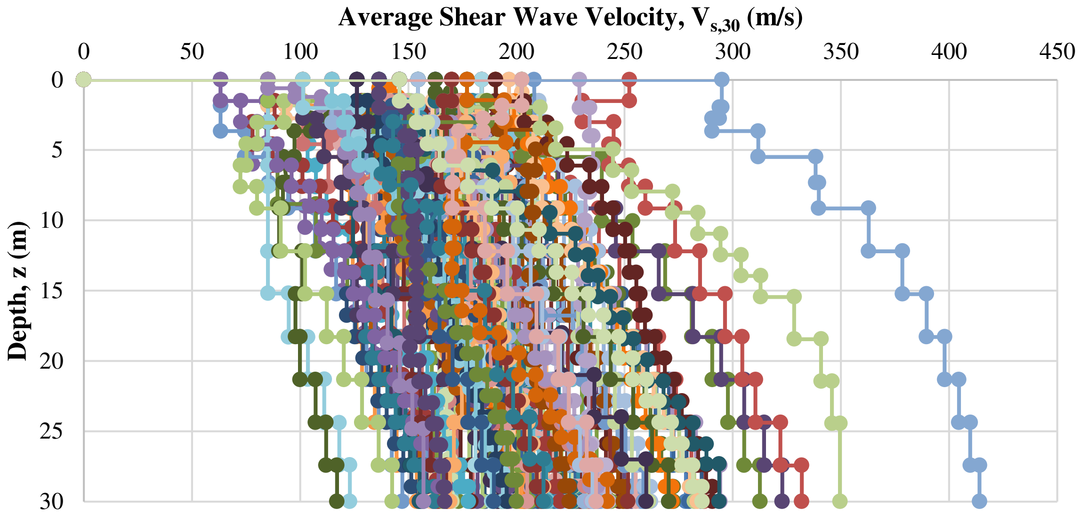

Figure 5. Average shear wave velocity, $V_{s,30}$profiles for 159 borehole data

Table 2. The calculation of average shear wave velocity, $V_{s,30}$ for sample borehole

Depth (m)	Depth (m)	SPT-N value (No. of blow per feet)	Moisture Content (%)	Densities (kg/cu-m)		$V_s = 63.229 N^{0.4298}$	Thickness	$\overline{V_s}$ (m/sec)
From	To			Wet	Dry			
0.0	1.5	1	25.12	19.98	15.97	63.23	1.5	63.23
1.5	4.5	3	25.12	19.98	15.97	101.39	3.0	84.41
4.5	6.0	1	18.40	19.98	15.97	63.23	1.5	77.89
6.0	7.5	7	32.78	21.20	17.91	145.93	1.5	85.90
7.5	9.0	15	20.81	18.78	14.19	202.49	1.5	95.01
9.0	10.5	13	18.45	20.57	17.03	190.41	1.5	102.34
10.5	12.0	15	18.45	20.57	17.03	202.49	1.5	109.08
12.0	13.5	13	18.45	20.57	17.03	190.41	1.5	114.52
13.5	15.0	15	18.45	20.57	17.03	202.49	1.5	119.72
15.0	16.5	22	18.45	20.57	17.03	238.72	1.5	125.40
16.5	18.0	17	18.45	20.57	17.03	213.68	1.5	129.87
18.0	19.5	20	28.95	19.78	15.64	229.14	1.5	134.35
19.5	21.0	30	28.95	19.78	15.64	272.76	1.5	139.40
21.0	22.5	23	28.95	19.78	15.64	243.33	1.5	143.49
22.5	24.0	22	28.95	19.78	15.64	238.72	1.5	147.16
24.0	25.5	22	28.95	19.78	15.64	238.72	1.5	150.55
25.5	27.0	28	28.95	19.78	15.64	264.79	1.5	154.25
27.0	28.5	28	28.95	19.78	15.64	264.79	1.5	157.72
28.5	30.0	26	36.45	20.54	16.81	256.49	1.5	160.81

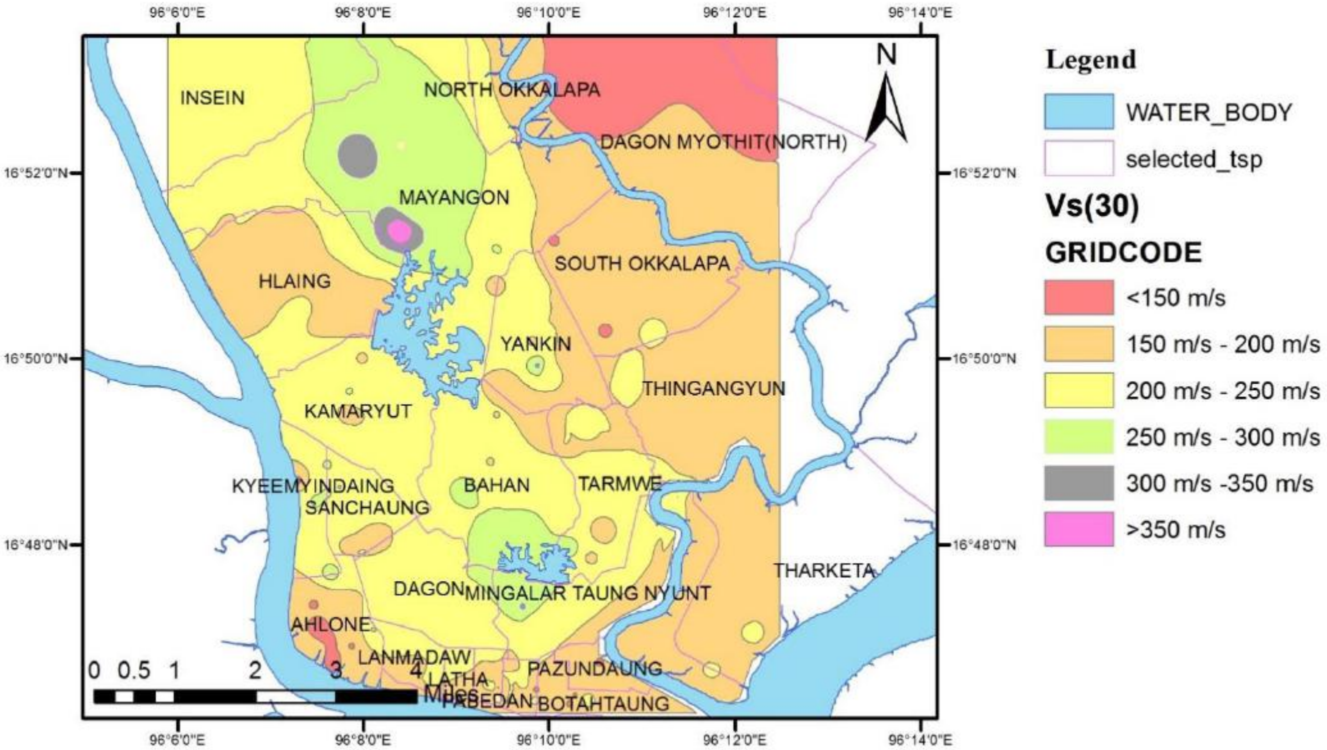

Figure 6. Average shear wave velocity, $V_{s,30}$ Map for Yangon Subsoil

Evaluation of average shear wave velocity 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 contour map of average shear wave velocity for Yangon subsoil is shown in Fig (6).

Table 3.Site classification according to Myanmar National Building Code (MNBC), 2016

SITE CLASS	Soil Profile Name	AVERAGE PROPERTIES IN TOP 30 METER	
		Soil shear wavevelocity,V_s,(m/s)	Standardpenetration resistance,N
A	Hard rock	$V_s > 1500$	N/A
B	Rock	$760 < V_s \le 1500$	N/A
C	Very dense soil and soft rock	$360 < V_s \le 760$	N > 50
D	Stiff soil profile	$180 < V_s \le 360$	$15 \le N \le 50$
E	Soft soil profile	$V_s < 180$	N <50

According to the Myanmar National Building Code (MNBC), it is found that most of the Yangon subsoil are site class 'D' as shown in Fig (6). It can be found that standard penetration 'N' value in Fig (2) is between the limitations of site class 'D' in Table (2). So that the proposed eqn. (2) is reliable for Yangon subsoil.

5. DISCUSSION AND CONCLUSION:

The shear wave velocity (V_s) used to correlate with the parameters of the soil depth (z), SPT-*N* value and un-drained shear strength of soil (s_u) respectively. The soil profiles as a depth (z) generally vary depends on the geological condition of the locations, and the SPT blow-count (*N*) is also the empirical parameter for the subsoil studies. The aim of this study is intended to investigate the reliable and applicable shear wave velocities and average shear wave velocity V_s30 map for Yangon subsoil. This paper therefore presents evaluation of shear wave velocity profiles and Vs30 map for Yangon subsoil based on nine different previous studies. As shown in Fig. (3), the proposed correlation equations (3) $\mathbf{V_s = 63.229N^{0.4298}}$are mention by combining the shear wave velocity values from 23 township in Yangon city area. The shear wave velocity profiles for Yangon subsoil are presented in Fig (4) and it can be seen that shear wave velocity of one borehole for Mayangone Township is greater than 400m/sec. The average shear wave velocity up to 30m is calculated by eqn. (6) according to Myanmar National Building Code (MNBC). The average shear wave velocity profile ($V_{s,30}$) of for Yangon subsoil are presented in Fig (5). Also the calculated average shear wave velocity ($V_{s,30}$) are drawn by spatially distributed contour map of six categories ranges <150, 150-200,200-250, 250-300, 300-350 and <350 m/s using Arc GIS-10 software. This paper presents subsurface geotechnical information of Yangon city in the form of GIS based maps in order to provide the database for preliminary assessment of subsoil of Yangon city. For this purpose, GIS based map of average shear wave velocity $V_{S,30}$. According to the average shear wave velocity contour map for Yangon subsoil presented in (Fig. 6), it is found that Dagon Myothit (North), North Okkalapa and South Okkalapa townships are lowest value of $V_{s,30}$<150 m/sec. Botahtaung, Pazundaung, KyeeMyintDaing, Ahlone, Tharkata and Thingangyun townships are lower value ($150 \leq V_{s,30} \leq 200$ m/sec). Mayangone, Insein and Bahan townships are high from 250 to 350m/sec. Most of the townships in Yangon City are between 200 and 250 m/sec. Therefore, the proposed correlation equation (3) $V_s = 63.229N^{0.4298}$shows the greatest predictive capability with a R^2 value of 0.9996. Since this equation show sufficient fitness to the dataset, therefore its use is reliable and V_{s30} map will be of use to the foundation designers at the initial stage for site selection and preliminary foundation design under static and seismic condition. Further, it can be used for low cost housing construction where generally subsurface investigations are not done.

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