Site Investigation by Bore-Hole Drilling in Sagaing City, Sagaing Region

Razar Hlaing[1], Myo Thant[2] & Than Than Nu[3]

Abstract

Sagaing City is one of the seismic prone regions since active Sagaing Fault passes through the urban center. The damage properties are commonly influenced by the seismic source properties and the site properties. Site condition associated with surface geological conditions is an important role of seismic hazard assessment. As the effects of earthquakes are commonly influenced by the seismic source properties and the site properties, geotechnical site investigation was carried out for an adequate evaluation of seismic hazard in Sagaing City. Totally (4) boreholes, two of them located in the east and west, and the other two in the north and south across the urban area of the city were carried out in Sagaing City. The collected soil samples from SPT test were sent for laboratory testing. The subsoil site classification will be made for seismic local size effect evaluation based on average shear wave velocity of 30m depth (V_S^{30}) of sites by using Uniform Building Code (UBC) classification. Results were obtained from the geotechnical boreholes and it was shown that the results can be used for a rough estimation of sediment thickness. According to the values of shear wave velocity, the soil types found to be the very dense soil including soft rock and soil classes are S_C and S_D.

Keywords: Sagaing Fault, seismic prone regions, site classification, soil type

Introduction

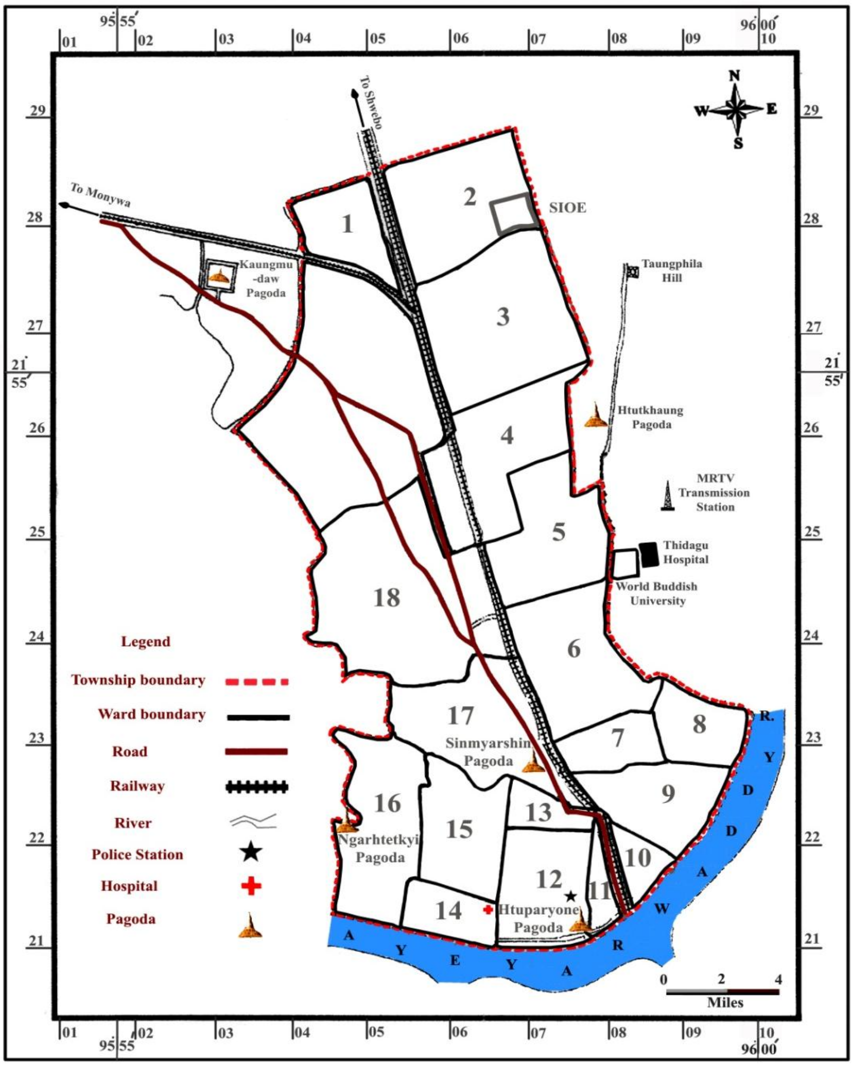
The hazards associated with earthquakes are referred to as seismic hazards and the most devastating like other natural hazards. Earthquake is one of the most destructive geological hazards which can cause damage due to the primary effects of ground motion and ground failure. Secondary hazard effects include tsunamis, landslide, soil liquefaction and fire, all of which can add more damage to property and causalities. Among them the main earthquake hazard is the effect of ground shaking. Ground Shaking can be considered to be the most important of all seismic hazards because all the other hazards are caused by ground shaking. When an earthquake occurs, seismic waves radiate away from the source and travel rapidly through the earth's crust. When these waves reach the ground surface, they produce shaking that may last from seconds to minutes. The strength and duration of shaking at a particular site depends on the size and location of the earthquake and on the characteristics of the site condition. At sites near the source of a large earthquake, ground shaking can cause tremendous damage. Besides, the characteristics of the surface and surface materials, surface and surface geology and soil types influence the damage. Some soil characteristics can filter the seismic waves and some can amplify the seismic waves. The seismic wave's amplification is one of the most important phenomena that can cause severe damage in a particular site condition. The strength of ground shaking is influenced by several factors such as the magnitude of the earthquake, the distance from the seismic source to the site and the surface and surface geological conditions [1].

[1] Lecture, Dr, Department of Geology, University of Mandalay
[2] Professor, Dr., Department of Geology, University of Yangon
[3] Professor & Head, Dr., Department of Geology, University of Mandalay

Location of the study area

Sagaing city of Myanmar lies on the geographical coordinates of 21° 52" 00' N, 95 °59" 00'. It occupies an area of 15.75 square mile (40.32 km^2). The city includes 18 wards. The location of the study area is represented in Figure (1.1).

Earthquake of the Sagaing area is believed to be related to the Sagaing Fault [2]. The Sagaing fault is a major tectonic structure in the area. The Sagaing fault is a continental transform fault that runs a length of over 1000km from the East Himalayan Syntaxis to the Andaman Sea. The fault's motion is right lateral strike slip fault. The rate of motion is 20mm yr-1 [3]. Lateral displacement of 203 km in the Sagaing Fault was suggested [4] since Middle Miocene.



Explanation : 1.Nilar Ward, 2.Padanmyar Ward, 3.Shweminwon ward, 4. Meeyahtar Ward, 5.Zayar Ward, 6.Parami Ward, 7.Myothit Ward, 8.Htonebo Ward, 9.Htankone Ward, 10.Takaung Ward, 11.Khinlan Ward, 12.Poelan Ward, 13.Moewai Ward, 14.Ayemyawaddy Ward, 15.Nadawin Ward, 16.Darwaizay Ward, 17.Papaedan Ward, 18.Ywahtaung Ward.

Figure 1.1 Location map of Sagaing City.

Objectives

The main objectives of this research are to characterize the influences of the site conditions on the ground for Sagaing city. Specific objectives are:

1. To identify the soil classes for Sagaing city based on bore-hole drilling results.
2. To characterize the general inflence of the site conditions for the Sagaing City.
3. To determine the relationship between shear wave velocity (Vs30) and corrected N-values.
4. To determine the overburden thickness and the blow counts of the site.

Methodology

Site investigation consisted of exploring the subsurface condition and sampling the soils. It was carried out to evaluate the seismic hazard assessment of Sagaing City. Rotary drilling method and standard penetration tests (SPT) were carried out as the surface investigation. From these investigations, the nature of soil at the site and its stratification may be determined. Collected soil samples were used for laboratory testing.

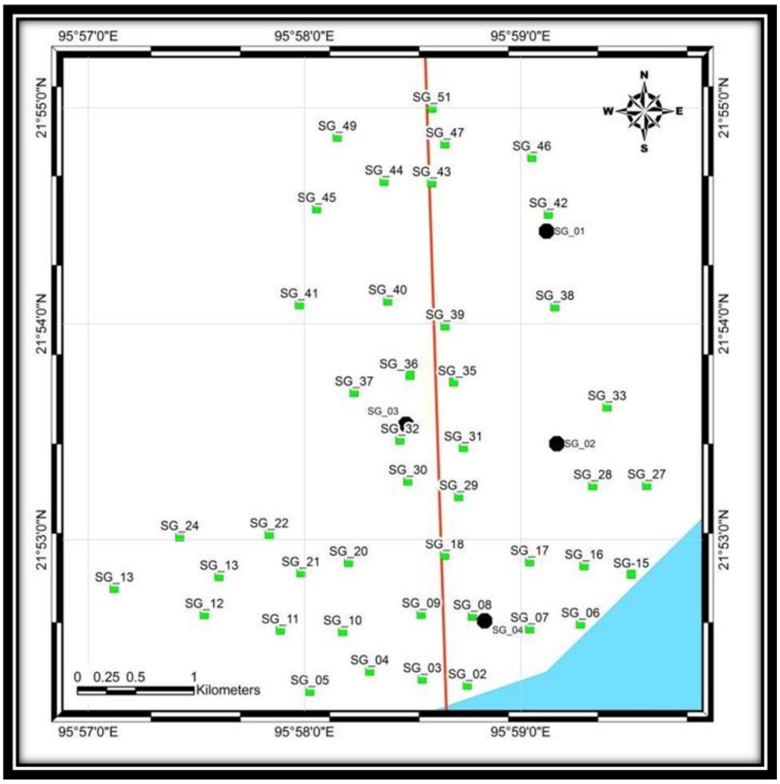


Figure 1.2 Map showing the locations where the microtremor survey and boreholes were carried out in Sagaing City. (Black circle mentioned for bore-hole drilling site)

Standard Penetration Test (SPT)

The Standard Penetration Test (SPT) was carried out as the subsurface investigation to determine the nature of soil at the site and its stratification, the depth of the water table etc. The location of the boreholes was determined based on the topographic maps, geological maps, satellite images and ground checking. Finally, four boreholes were carried out for geotechnical site investigation for seismic hazard assessment of Sagaing City. Four boreholes, located two of them located in the east and west, and the other two in the north and south across the urban area of the city were carried out in Sagaing City (Figure 1.2). SG-1 was carried out near

Sagaing Taungyo Road (N 21° 54' 25.7" and E 95° 59' 07.2"), SG-2 was performed near Sagaing Kaungmudaw Road (N 21° 53' 26.7" and E 96° 59' 10.6"), SG-3 was located in front of the B.E.H.S (1) (N 21° 53' 32.1" and E 96° 58' 28.2") and SG-4 was carried out north of the Thidagu monastery (N 21° 52' 37.5" and E 95° 58' 28.2"). The SPT was carried by Geo-friends Co. Ltd. The procedure of SPT test is as follows:

Step (1) Drilling boring to the depth of the first is 2.5 to 8 in (60-200mm) diameter.

Step (2) Insert the SPT sampler (split-spoon sampler) into the boring.

Step (3) Using either a rope and cathead arrangement or an automatic tripping mechanism,raise the hammer a distance of 30in (760mm) and allow it to fall.

Step (4) This energy drives until the sampler has penetrated a distance of 18in (450mm) and then recording the number of hammer blows required for each 6in (150mm) interval.

Step (5) Stop the test if more than 50 blows for each interval or if more than 100 total blows are required.

Step (6) Compute the N value by summing the blow counts for the last 12inch (300mm) of penetration. The first 6 in (150mm) is not used because the boring is loose soil.

Step (7) Remove the SPT sampler, remove and save the soil sample.

Step (8) Drill the boring to the depth of the next test and repeat step (2) through (8) arequired.

Step (9) Compute the SPT N - value, which is defined as the sum of the blows required drive the sample for the second and third increments, correction is made to estimate the soil parameters, particularly the shear strength and density of cohesionless soil

Laboratory Methods

Collected soil samples from the SPT were brought to a soil laboratory to identify their index properties. The following laboratory tests were carried out.

- Density Test (used for computation of bearing capacity)
- Moisture Content Test (It is an indicator of strength of soil)
- Specific Gravity Test (to know the specific gravity of the soil. Grain size analysis (Pipette method) is to determine the percent of sand and gravel and Grain size analysis (hydrometer method) is used to determine percent of silt and clay)
- Atterberg’s Limit Test (used as a basic for the classification of soil types according to the plasticity chart of unified soil classification system)
- Grain size Analysis (generally used to define the particle size distribution of soil)
  - Sieving Method (mainly used for particle size larger than 0.075 mm in diameter)
  - Hydrometer Method (mainly used for the particle size smaller than 0.075 mm in diameter)
- Direct shear Test (used to obtain the strength parameter cohesion (c) and angle of internal friction of the soil (Φ))

Figure 1.3 The SPT test in the site investigation at SG-1 near Sagaing Taungyo Road (N 21° 54' 25.7" and E 95° 59' 07.2")

Relationship between the corrected N value and shear wave velocity of upper 30 m (Vs^{30})

To determine the relationship between the average shear wave velocity and average N (SPT) blow count are obtained by using the classification of subsurface soil of UBC and EC8 code and it is described in Table (1.1).

Table 1.1 Ground profile (soil) types or classification of subsoil classes according to UBC (Uniform Building Code) and EC8 (Eurocode 8) standards based on the $V_{s^{30}}$ values (modified by [6] from Sêco e Pinto, 2002; Dobry *et al.* 2000; Sabetta & Bommer 2002).

Ground profile (Soil) type (UBC) or Subsoil Class (EC8)	Ground description (UBC)	Description of stratigraphic profile (EC8)	Shear wave velocity $V_{s^{30}}$(m s^{-1})
S_A(UBC)	Hard rock	—	>1500 (UBC)
S_B(UBC) or A (EC8)	Rock	Rock or other rock-like geological formation, including at most 5m of weaker material at the surface	760–1500 (UBC) or >800 (EC8)
S_C(UBC) or B (EC8)	Very dense soil and soft rock	Deposits of very dense sand, gravel or very stiff clay, at least several tens of m in thickness, characterized by a gradual increase of mechanical properties with depth	360–760 (UBC) or 360–800 (EC8)
S_D(UBC) or C (EC8)	Stiff soil	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of m.	180–360 (UBC and EC8)
S_E(UBC) or D (EC8)	Soft soil	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil	<180 (UBC and EC8)
S_F(UBC) or E (EC8)	Special soils	A soil profile consisting of a surface alluvium layer with V_s^{30} values of class C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with $V_{s^{30}}$> 800 m s^{-1}	—
S_1 (EC8)	—	Deposits consisting—or containing a layer at least 10 m thick—of soft clays/silts with high plasticity index (PI > 40) and high water content	<100 (EC8)
S_2 (EC8)	—	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in classes A–E or S_1	— (EC8)

Results

Totally four standard penetration test (SPT) were carried out in Sagaing City. The major soil type in the study area is alluvial deposits i.e, sand, silt, gravel and clay. The evaluated subsurface profiles for SG-1, SG-2, SG-3 and SG-4 are shown in the figures (1.4), (1.5), (1.6) and (1.7). The results will be applied for the interpretation of soil profiles, to conduct the initial model for the average shear wave velocity. The results will be estimated from the overburden thickness and standard penetration test (SPT) blow counts of the site. The relationship between shear wave velocity (Vs) and corrected N values can be determined from the overburden thickness and the blow counts of the site.

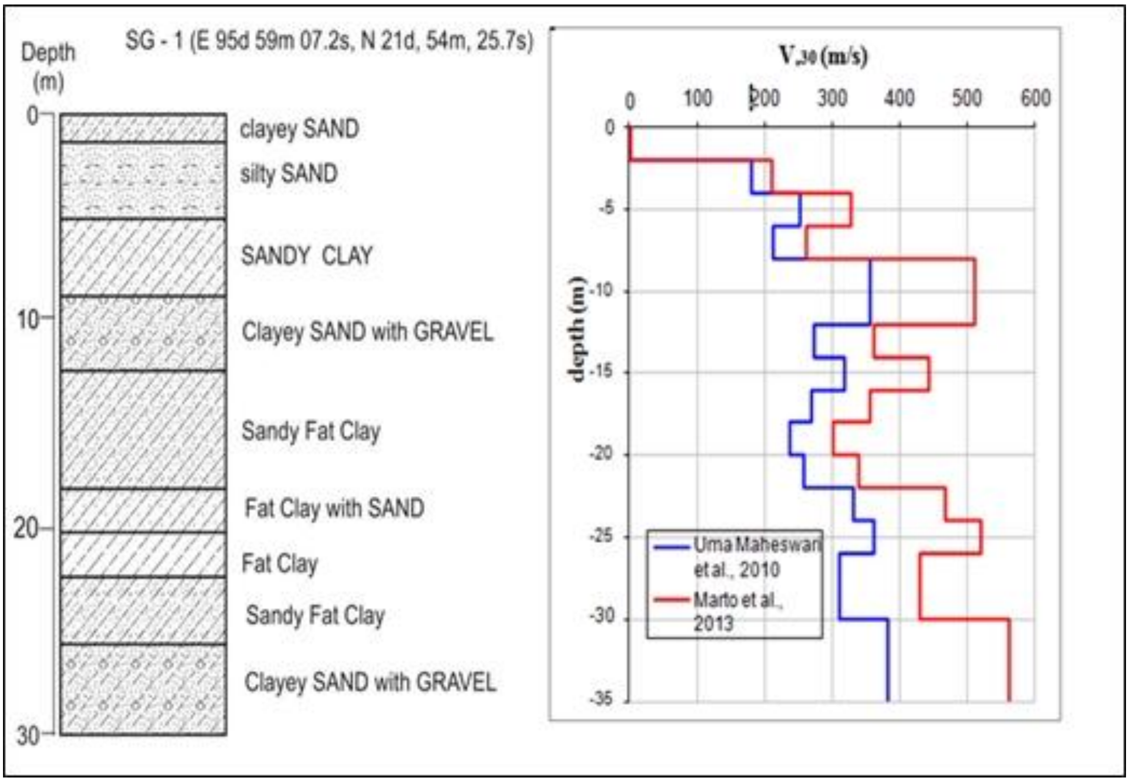


Figure (1.5) Soil profile and shear wave velocity profile (Vs 30) by using corrected N value for SG-1

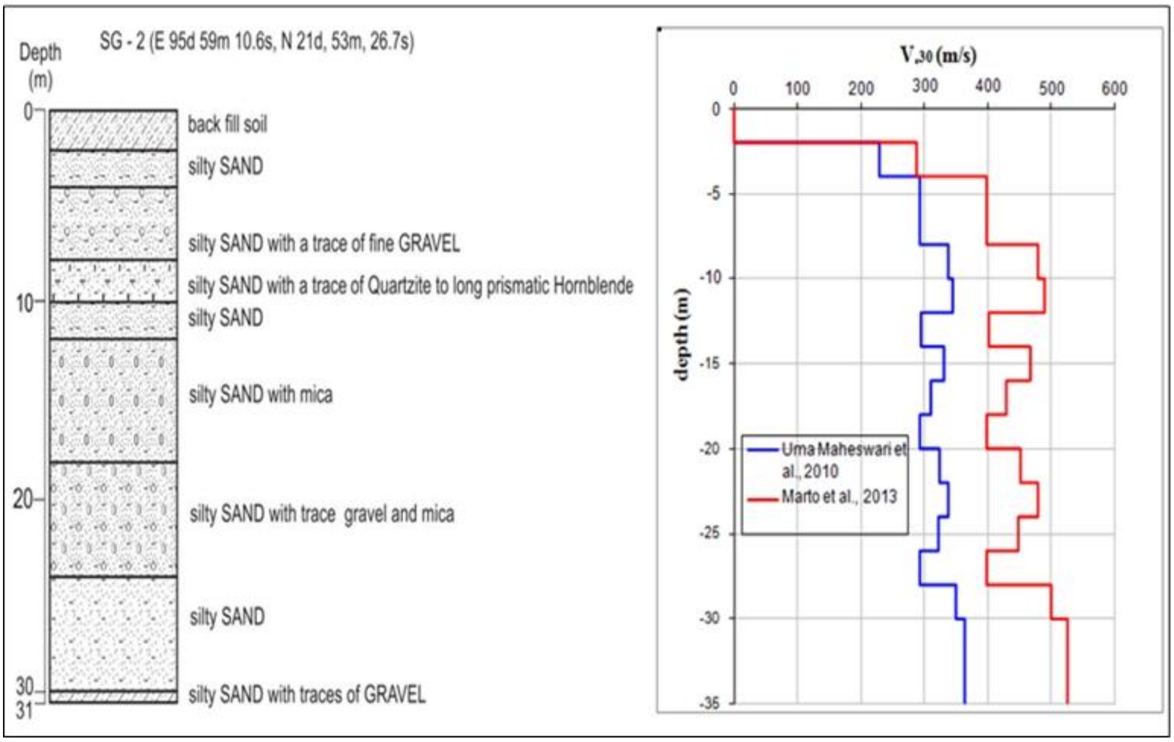


Figure (1.6) Soil profile and shear wave velocity profile (Vs 30) by using corrected N value for SG-2

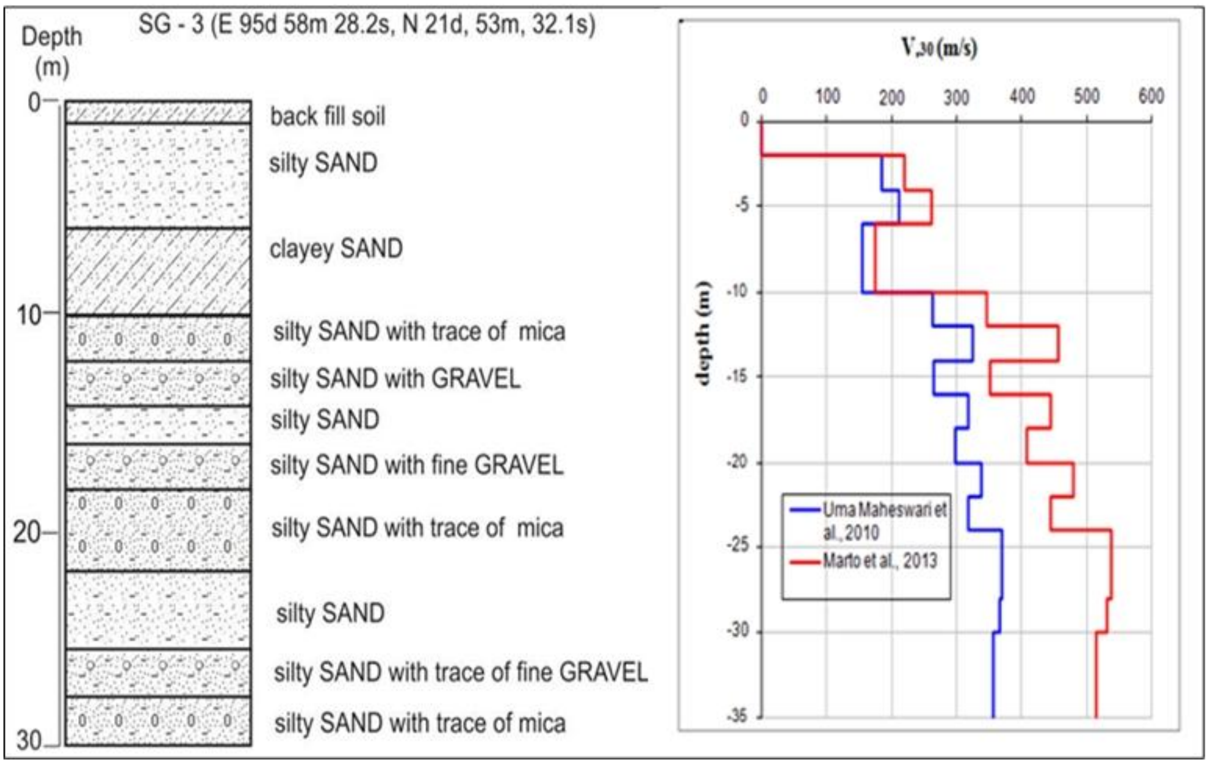


Figure (1.7) Soil profile and shear wave velocity profile (Vs 30) by using corrected N value for SG-3

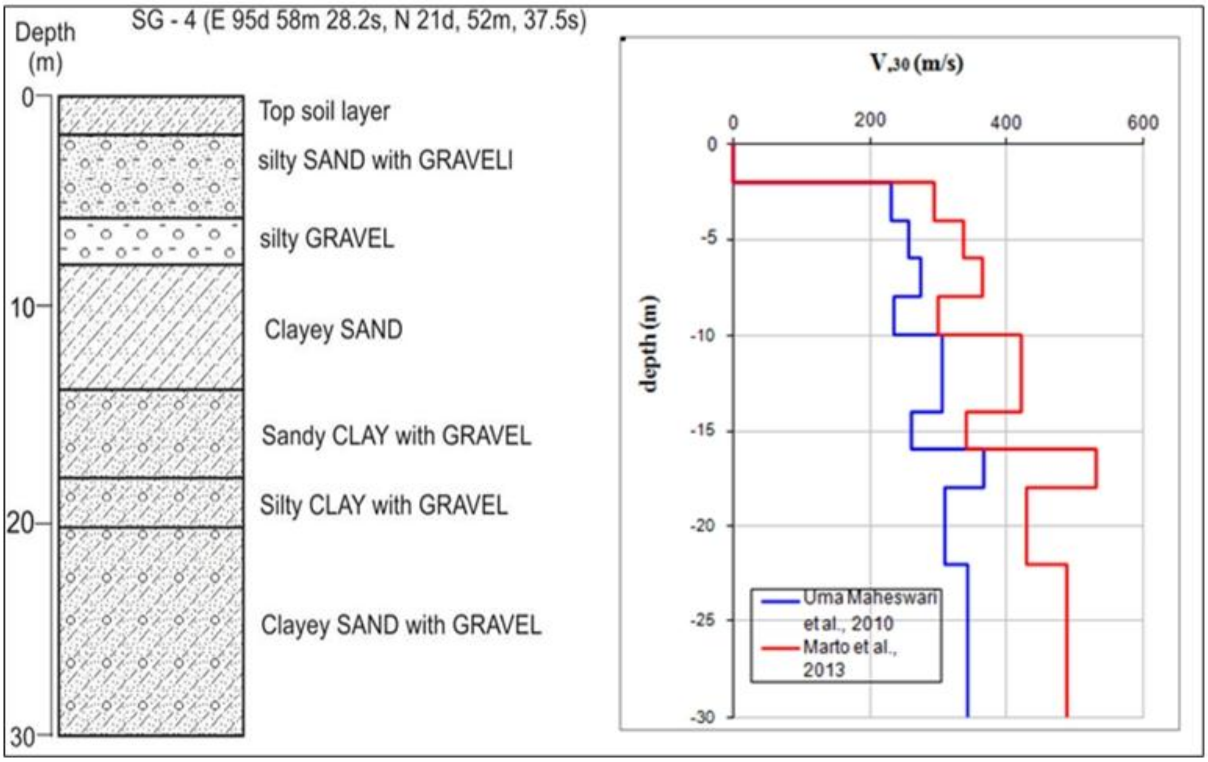


Figure (1.8) Soil profile and shear wave velocity profile (Vs 30) by using corrected N value for SG-4

Soil classifications and Soil types

Soil classification and soil types were determined by bore hole drilling in Sagaing City. The value of shear wave velocity was determined by using the Uniform Building Code (UBC). (Table 1.2).

Table 1.2 Values of shear wave velocity from Bore hole locations, respectively (According to UBC,Uniform Building Code)

	SG-1	**SG-2**	**SG-3**	**SG-4**
Uma Maheswan et.al 2010	382.507 m/s	362.930 m/s	357.660 m/s	343.560 m/s
Soil types	Very dense soil and soft rock	Very dense soil and soft rock,	Stiff soil	Stiff soil
Classification of sub soil classes	S_C	S_C	S_D	S_D
Marto et.al 2013	561.824 m/s	524.982 m/s	515.113 m/s	489.039 m/s
Soil types	Very dense soil and soft rock	Very dense soil and soft rock	Very dense soil and soft rock	Very dense soil and soft rock
Classification of sub soil classes	S_C	S_C	S_C	S_C

Conclusions

Site characterization is an important part in seismic hazard assessment. The effects of earthquakes are mainly influenced by the seismic source properties and the site properties. Geotechnically, site investigation was carried out for the evaluation of seismic hazard in Sagaing City.

Totally 4 bore hole drillings were carried out in Sagaing City. For an interpretation of these measurements, the initial model for average shear wave velocity estimated from the overburden thickness and standard penetration test (SPT) blow counts. The overburden thickness and the blow counts applied to generate the relationship between shear wave velocity (V_s) and corrected N values. Shear wave velocity (VS) is an essential parameter for calculating the dynamic properties of soil in shallow surface. The shear wave velocity profiles of each site has been determined currently and the examples of 4 sites are shown in Figure (1.5) to (1.8). For the final step for the determination of the shear wave velocity of each soil layer, it is needed to construct the input model and this model commonly bases on the borehole data. Therefore, as soon as the borehole data got, the determination of V_s^{30} carried out for Sagaing City.

According to the *Uma Maheswan et.al 2010* [7], the average shear wave velocity to the upper 30m, V_s30 is 382,507 m/s and according to UBC, the soil type is the very dense soil and soft rock and soil class is S_C. In the site of SG-2, the average shear wave velocity to the upper 30m, V_s30 is 362.930 m/s and according to UBC, the soil type is the very dense soil and soft rock and soil class is S_C. In the site of SG-3, the average shear wave velocity to the upper 30m, V_s30 is 457.660 m/s and according to UBC, the soil type is the stiff soil and soil class is S_D. In the site of SG-4, the average shear wave velocity to the upper 30m, V_s30 is 343.560 m/s and according to UBC, the soil type is the stiff soil and soil class is S_C.

According to Marto et.al 2013 [8], the average shear wave velocity to the upper 30m, V_s30 is 561.834 m/s and according to UBC, the soil type is the very dense soil and soft rock and soil class is S_C. In the site of SG-2, the average shear wave velocity to the upper 30m, V_s30 is 524.982 m/s and according to UBC, the soil type is the very dense soil and soft rock and soil class is S_C. In the site of SG-3, the average shear wave velocity to the upper 30m, V_s30 is 515.113 m/s and according to UBC, the soil type is the very dense soil and soft rock and soil class is S_C. In the site of SG-4, the average shear wave velocity to the upper 30m, V_s30 is 489.039 m/s and according to UBC, the soil type is the very dense soil and soft rock and soil class is $S_{C.}$

Acknowledgement

I would like to express my gratitude to Prof Dr. Than Than Nu (Professor & Head, Department of geology, University of Mandalay) and Prof Dr. Myo Thant (Professor, Department of geology, University of Yangon) for their guidance on this paper. I would like to thank the Geo friends Co. Ltd for their supported the SPT data.

References

[1] Kramer, S. L. 1996. Geotechnical Earthquake Engineering, Prentice-Hall International Series in Civil Engineering and Engineering Mechanics, 653 pp.

[2] Win Swe, 1970. Rift-features at the Sagaing-Tagaung Ridge. Abstract, Burma Research Congr., Rangoon, 101.

[3] Vigny, C., A. Socquet, C. Rangin, N, Chamot-Rooke, M. Pubellier, M.N. Bouin, G. Bertrand, M.Becker ., 2003. Present day crustal deformation around Sagaing fault, Myanmar. Journal of Geophysical Research 108, ETG 6-1-10.

[4] Myint Thein, Kyaw Tint and Aye, Ko Aung, 1991. On the lateral displacement of the Sagaing fault. Georeports 1, 23–34.

[5] Skempton, A. W. 1986. “Standard Penetration Test Procedures and the Effects in Sands of Overburden Pressure, Relative Density, Particle Size, Ageing and Over Consolidation”, Geotechnique 36: 3, September.

[6] Ali Ismet Kanl, P´eter Tildy, Zsolt Pr´onay, Ali Pınar and L´aszl´o Hermann, 2006. V_S^{30} mapping and soil classification for seismic site effect evaluation in Dinar region, SW Turkey, Geophys. J. Int. 165**,** 223–235

[7] Uma Maheswari R., A. Boominathan and G.R. Dodagoudar., 2010. Use of surface waves in statistical correlations of shear wave velocity and penetration resistance of Chennai soils. Geotech. Geol. Eng., 28(2): 119 - 137. DOI: 10.1007/s10706-009-9285-9

[8] Marto A., Soon T. C., Suhatril. M and Kasim F., 2013. A Correlation of Shear Wave velocity and Standard Penetration Resistance. Electronic Journal of Geotechnical Engineering, 2013;18: 463-471p.