Soil Profile Type Reference for Second Congressional District in the Province of Sorsogon, Philippines

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***Abstract*—** This study compiled the soil profile type in the nine municipalities of the second congressional district in the province of Sorsogon, Philippines. The soil profile types are parameters for seismic response coefficient used in determination of design base shear in seismic analysis of buildings. Standard Penetration Test (SPT) result obtain from Department of Public Works and Highways (DPWH) Sorsogon Second District Engineering Office (DEO) subsoil exploration file were used to estimates these parameters. A total of 564 boreholes were analyze and computed the average field standard penetration resistance N prior to assigning soil profile type based on categorization procedure set forth in National Structural Code of Philippines (NSCP). Based on the result of the study, it was found out that in several locations in the Sorsogon second district, soil profile type varies. Different soil profile type are scattered all throughout in each municipality. Areas that have stiff soil profile have tuff, coralline or boulders underlying materials. Thus the use of coring on this area in advancing borehole for geotechnical investigation is recommended. Also, soil showing soft profile type must have established comprehensive geotechnical analysis in order to attain proper geotechnical characteristics. Furthermore, for proper evaluation of the soil profile type and other geotechnical parameters, SPT should be done for at least 30 m depth as suggested in the National Structural Code of the Philippines. This study can provide engineers a reference guide in estimating the soil profile type within the second congressional district in the province of Sorsogon. Also, this study may provide preliminary data in conducting specific sub-surface exploration in any place in the municipality of Sorsogon second district.

***Keywords*—** Borehole Logs, NSCP, Soil Profile Type, Standard Penetration Test.

INTRODUCTION

The seismic analysis provision of NSCP requires determination of seismic zoning, site characteristic, occupancy, configuration, structural system and the height to primarily design structure safeguard against major structural damaged. The evaluation of seismic site condition is commonly made following seismic site classification system based on average shear wave velocity (SWV) of the materials[1,2]. Because of economic constraints, not all structure projects choose to perform such test. In the Philippines, the most common soil survey conducted is the Standard Penetration Test (SPT). From this SPT data, a correlation regarding geotechnical characteristic of the underlying materials is adapted.

Boreholes with SPT N values are one of the oldest, popular and common in situ test used worldwide. Methods and procedures of test are enumerated in the standard methods of test of the American Society for Testing and Materials ASTM D1586. Since SPT are common widely used in estimating soil properties including seismic site characterization, the authors decided to compiled the data of SPT available in the DPWH Sorsogon second district engineering office to able to use by the engineers and geologist in their preliminary study. Using the geotechnical report available at DPWH Sorsogon 2nd DEO, the study analyzed the SPT borehole logs, calculate the average Standard Penetration Resistance N, assigning soil profile type and compiled to be used as reference showing the soil profile type of the study areas in a map. This study aims to create a reference that will provide geotechnical engineers and geologist the estimated soil profile type in the municipality of second district of Sorsogon. It also aims to provide data on the preliminary assessment of geotechnical properties at any point in Sorsogon second district.

METHODOLOGY

The province of Sorsogon lies at the southern tip of Luzon. Its total land area is 2,141.44 sq.km. divided into 14 municipalities and one component city, the Sorsogon City. It has 641 barangays, two congressional districts and is considered as a second class province[3]. The second district comprise of the municipality of Juban, Irosin, Bulan, Matnog Sta. Magdalena, Bulusan, Barcelona, Gubat and Pto. Diaz.

The borehole collected were the available data for these municipality obtain from the DPWH files. The amount of borehole log and location is not distributed evenly

hence the checking on properly distribution was not done. Borehole logs collected are ranges from 1 to a maximum of 8 per location but 3 boreholes per location is common. Borehole logs that are similar and repetitions of result and seemed erroneous were discarded.

In properly designing the structure to withstand the lateral forces induced by seismic load, the soil profile type and other seismic site hazard characteristic must be known. This is because the seismic analysis and design depends on the factors like soil condition, occupancy type, and other seismic factors.

The soil profile type is assigned utilizing the average SPT N values found in the borehole logs directly measured in the field without corrections using site categorization procedure discussed in NSCP[4] NEHRP[5], and ASCE 7-02[6] also shown in Table 1.

Table 1: Soil Profile Type

Soil Profile Type	Soil Profile Name/ Generic Description	Average Standard Penetration Test, N
SA	Hard Rock	NA
SB	Rock	NA
SC	Very Dense Soil and Soft Rock	> 50
SD	Stiff Soil Profile	15 to 50
SE	Soft Soil Profile	< 15
	Any Soil Profile with more than 3m of soil having the following characteristics: • Plasticity Index PI > 20 • Moisture content w ≥ 40% • Undrained Shear strength Su < 24 Kpa	
SF	Soil Require Site Specific Evaluation	

The raw SPT N values from the field were then used to compute the average field standard penetration resistance N. The N values shall be determining in accordance with the following equation: [4, 5, 6]

$$N = \frac{\sum_{i=1}^{n} di}{\sum_{i=1}^{n} di/Ni} \quad \text{(Eq.1)}$$

where
N = average field standard penetration resistance
di = thickness of layer *i* in m
Ni = the standard penetration resistance of soil layer in accordance with approved national recognized standards.

Aside from the computed average standard penetration resistance N, water table, depth of borehole and other parameters are also observed.

The computed average N values is compared with the data in the Table 1 and assigned the designated soil profile corresponding to the N values calculated. The soil profile type assigned are plotted to the map at designated locations of the borehole logs.

STUDY AREA

Sorsogon Second District is composed of 9 municipalities that lies at the southern part of Luzon island, Philippines. It is bounded by the municipalities in the first district of Sorsogon at the north, Philippines sea at the east, Ticao Pass of Masbate at the west and San Bernardino Strait in the South. The total land area of second congressional district of Sorsogon is 1,015.28 sq. km.

Regional Geology

The stratigraphy of the Bicol Region in southern Luzon has investigated by the Mines and Geoscience Bureau is composed of the Quaternary Alluvium, Ligao Formation, Malamba Siltstone, Paulaba Sandstone, Aliang Sandstone, Talisay limestone, Bicol Formation, Panganiran Diorite, Ragay Volcanics, Panatao limestone and Basement.[7] The soil is generally the recent deposition of clastic sediments, volcanics mixed with coralline sands, tuff, gravel and silts.

Volcano

The active volcano is mount Bulusan. Mt. Bulusan is categorically an active volcano in the province of Sorsogon. The hazard associated with this volcano are volcanic eruption with pyroclastic materials composed of dust and other volcanic materials.

Seismicity

Based on the NSCP[4], the nearest active faults for Sorsogon province would be the Legazpi Lineament. The Philippine archipelago is divided into two seismic zone and the province of Sorsogon is belong to seismic zone 4.

Other seismic parameters used in the analysis of structures are established based on soil profile type which under study.

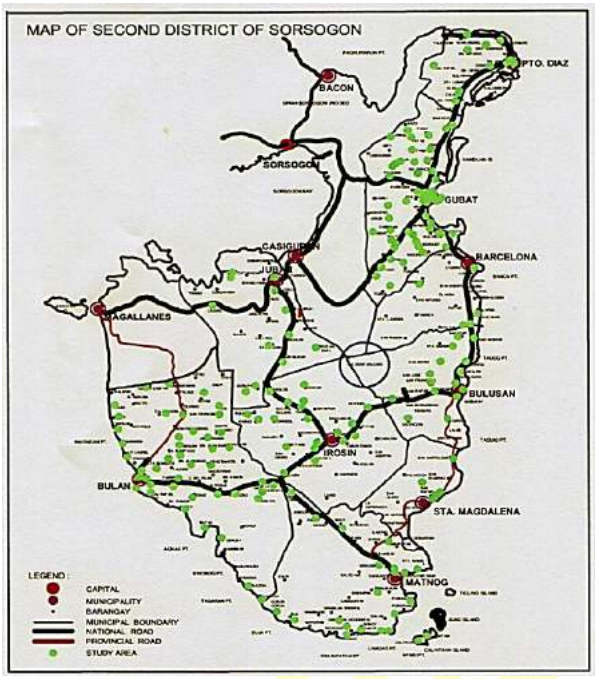

Figure 1: Study Area

***Table 2**: Number of Borehole and Its Depth*

Municipality	Borehole Location	Borehole Done Length in Meters										Total
		10.5	15	16.5	18	19.5	21	22.5	24	30	34.5	
Barcelona	5		2				8			2		12
Bulan	46	29	94		1	3	22	3				152
Bulusan	15		25				15					40
Gubat	56	4	102	10	15	12	28	1	3		2	177
Irosin	18	18	13				24			2		57
Juban	12	3	10				13					26
Prieto Diaz	12	2	4				18					24
Matnog	23		16				36		4			56
Sta. Magdalena	5	8	10				2					20
Total	**192**											**564**

RESULTS AND DISCUSSIONS

Borehole Location

Figure 1 shows the location of the data points that were used in the study while Table 2 summarizes the gathered data in each of the comprising municipality in the second congressional district in the province of Sorsogon. It shows in the figure the approximate location of borehole done in selected barangay and each municipality are highlighted.

It is gleaned from the table that a total of 192 borehole location distributed in 9 municipalities was observed. There were 564 holes in 192 location analyzed and computed the N values before assigning soil profile type. The highest number of borehole observed were in the municipality of Gubat and Bulan with borehole of 177 and 152 respectively while the least observed borehole was in the municipality of Barcelona. This best explain that the two municipalities with highest number of borehole has big land area compare with the land area of the municipality of Barcelona.

Based on DPWH data, these borehole locations are the proposed structures composed of 6 flood control, 168 school building, 11 multi-purpose building and 7 bridges. The depth of borehole varies from 10.5 m to 34.5 m in which 15 m depth were the most number of borehole done.

Soil Profile Type

Figure 2 shows the soil profile type of the municipalities in the Sorsogon second district. It can be seen that the most number of borehole done were in the municipality of Gubat. Almost all the barangay are represented by atleast two boreholes. This is because most of the barangay had proposed school building in which sub soil exploration is conducted. Also, the soil profile type shown were mostly SD described as stiff soil with scattered soft soil profile designated as SE.

It is also gleaned from Figure 2 that in the municipality of Prieto Diaz most of the soil profile type were SD described as stiff soil. Based on the analyzed borehole log, except for Lupi elementary school borehole log with assigned SE as soil profile type, coring was applied to all borehole done. At a depth of atleast 4.5 m, core was done to advance drilling and the underlying materials found were sandstone, cobbles, boulders, limestone and tuff. Also, it is observed from borehole log that all locations had encountered the water table except in San Rafael. It is because San Rafael is the barangay in Prieto Diaz located in higher elevation aside from being the far from the town proper.

It also gleaned from the figure that the soil profile type for the municipality of Matnog varies from SE to SC described as soft soil to very dense soil. It is observed that most of the very dense soil located away from the town proper while soft soil or SE type identified at the urban area. This is maybe the urban area is located near

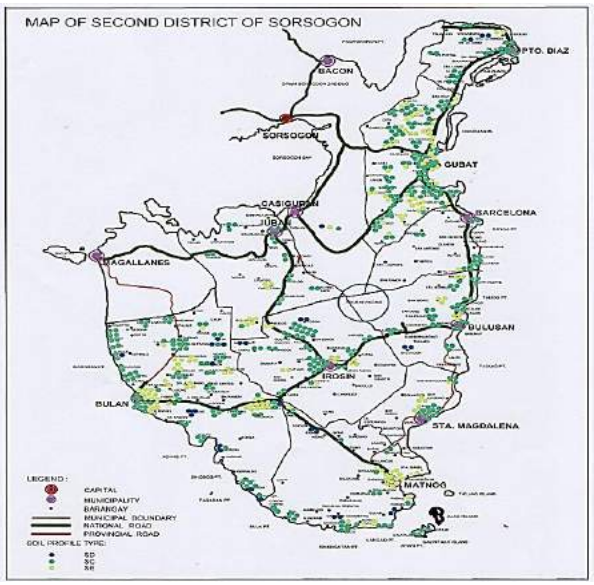

Figure 2: Soil Profile Type

in the bodies of water. Those observed dense soil profile is at mountainous area and coastal barangay of the municipality. It implies that soft soil may be encounter in the urban area in the municipality of Matnog were business establishment often build. Hence, caution must be taken when building structures in these area.

It shown from Figure 2 that most of the soil profile type for the municipality of Bulan were SD type described as stiff soil. This could mean that the town soil is good foundation material. However, it good practice to always check the actual soil condition and determine its geotechnical properties prior to analysis and design of any structure. Care should be taken because there is some location particularly in the urban areas that SE type soil is observed.

Due to limited data obtained from the municipality of Barcelona and Sta. Magdalena, properly assessment of the soil profile type cannot be done. However, the available data can be used in the preliminary soil investigation in the area.

Looking at Figure 2, it can be generalized that the soil profile type of Juban, Irosin, and Bulusan varies from SE to SC. It implies that the underlying materials have different geotechnical properties. With this information, the different point location in each municipality had its specific soil description and properties.

Generally, the soil profile type in the second district of Sorsogon varies from SE to SC. This reflect that scattered soil profile type will have observed in the area of Sorsogon second district.

Borehole logs data were collected and compiled for a total of 564 borehole locations all over Sorsogon second district. Maps were created in order to show the locations of the collected boreholes throughout the nine municipality in the second district in the province of Sorsogon.

Using a spreadsheet program, an average penetration resistance N of the borehole log collected were computed. Using the computed average value of N, a soil profile type is assigned based on the procedure described in NSCP, NEHRP, ASCE 7-02. Maps of soil profile type of each borehole were made and analyzed. Based on the result of the study, it was found out that in several locations in the Sorsogon second district, soil profile type varies. Different soil profile type are scattered all throughout in each municipality.

CONCLUSION AND RECOMMENDATIONS

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Areas that have stiff soil profile have tuff, coralline or boulders underlying materials. Thus the use of coring on this area in advancing borehole for geotechnical investigation is recommended. Also, soil showing soft profile type must have established comprehensive geotechnical analysis in order to attain proper geotechnical characteristics. Furthermore, for proper evaluation of the soil profile type and other geotechnical parameters, SPT should be done for at least 30 m depth as suggested in the National Structural Code of the Philippines. Also, the data presented in this study is importance in the preliminary data gathering for future geotechnical investigation in the Sorsogon second district. It is recommending to future researcher to conduct study on the area for allowable soil bearing capacity.

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