

A REFERENCE FOR THE ALLOWABLE SOIL BEARING CAPACITIES IN QUEZON CITY, PHILIPPINES

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ABSTRACT: Quezon City is the largest city in the National Capital Region of the Philippines. This city has several other cities and provinces that bound it. North Caloocan and the province of Bulacan bound the northern portions of the city. The eastern side of the city is bounded by Marikina city, the city of Manila and the province of Rizal. Mandaluyong, Pasig and San Juan bound the southern portions of the city. And finally, the western portions of the city are bounded by the cities of Valenzuela and South Caloocan. This paper provides the estimated allowable soil bearing capacity at different locations within the city. The allowable soil bearing capacity is being used by structural engineers when determining the required sizes of the shallow foundation for the structures that they are going to build. Several borehole data were collected to estimate the geotechnical parameters. The geotechnical parameters such as the angle of internal friction, cohesion, and unit weight were estimated using the SPT values derived from the collected borehole data. These geotechnical parameters were then used to estimate the allowable soil bearing capacity using Terzaghi equation for bearing capacity. The final output is a map of the city showing the contours of different colors which correspond to the different values of the allowable soil bearing capacities. Due to the presence of Guadalupe tuff formation at shallow depths, the estimated allowable soil bearing capacity ranges from a low of 100 kPa near the ground surface to as high as 1000kPa at a depth of five meters.

Keywords: Soil Bearing Capacity, Foundation Design, Standard Penetration Test, Geotechnical Properties

1. INTRODUCTION

Quezon City is located near the center of Metro Manila, towards the northeastern portion of the metropolis. It is bordered by Manila City in the southwest, Caloocan City and Valenzuela city in the west and northwest, San Juan City and Mandaluyong City in the south, while Pasig City and Marikina City in the southeast. It has a total land area of 161.126 km², which is one-fourth of the area of the National Capital Region of the Philippines.

Quezon city is underlain by a thick sequence of predominantly water laid tuff and tuffaceous clastics collectively known as the Guadalupe Tuff Formation. The formation consists of lithified volcanic ash, lapili and crystal sands. Beds rich in sand and not directly derived from volcanic activity are common, especially in the upper section. They are generally compacted and slightly lithified or cemented by precipitated silica and/or clay. The underlying Tuff bedrock is generally well consolidated and cemented, however, varying degrees of chemical decomposition and disintegration are indicated at different intervals in the section with beds alternating with hard and unaltered layers [1].

There are 130 borehole locations that were used in this study. Borehole data from standard penetration tests (SPT) were collected within the city. The distribution of these data points is shown

in Fig. 1.

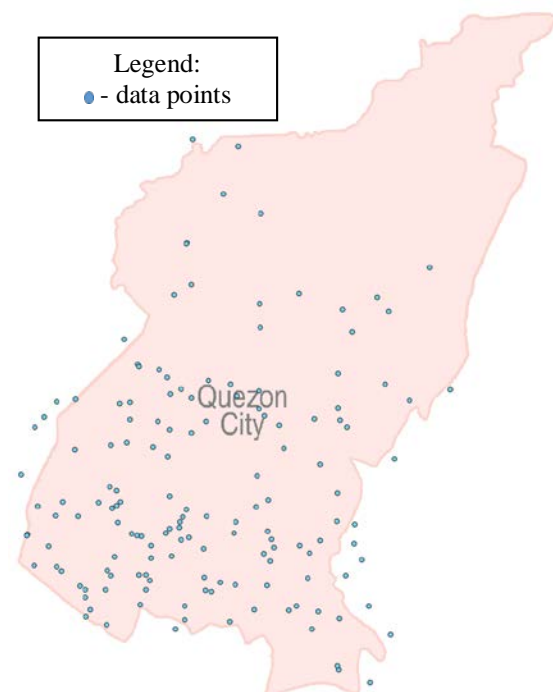


Fig.1 Distribution of soil data in Quezon City

2. GEOTECHNICAL CHARACTERISTICS

The northern section of Quezon City is predominantly composed of silty sand, and high

plasticity silts and clay up to the second meter; well-graded sand, low plasticity silts, and high plasticity silts and clays are the dominant soil type in the succeeding depths. Minor presences of poorly-graded sand and clayey sand are also observed. The central section is predominantly underlain by well-graded sand, silty sand, and high plasticity silts and clay with minor presences of clayey sand and low plasticity silt. Traces of well-graded gravel and poorly-graded sand are also observed. The southwestern section is predominantly underlain by silty sand, high plasticity silts and clays for depths reaching two meters; well-graded sand, low plasticity silts and high plasticity clays dominate the succeeding depths. Minor presence of clayey sand is observed as well as traces of poorly-graded sand and organic materials. The southeastern section is predominantly underlain by silty sand, high plasticity silts and clays up to a depth of two meters; well-graded sand, low plasticity silts and high plasticity clays dominate the lower depths. Minor presence of clayey sand is observed as well as traces of poorly-graded sand [2]. Table 1 further shows the distribution of the different soil types of both sections in varying depths up to a depth of five (5) meters. Table 2 shows the relevant design parameters that can be used for the designs of foundation in this area.

In soil sampling procedure, all sections are generally done by SPT up to the 2nd meter with mixed preference of SPT and RQD in the 3rd meter, and then the use of RQD in the succeeding depths.

Table 1 Soil type distribution for the (a) northern, (b) central, (c) southwestern and (d) southeastern sections of Quezon City.

(a)					
USCS Symbol	Depth				
	1m	2m	3m	4m	5m
SP	5.88	5.88	0.00	0.00	0.00
SW	0.00	5.88	17.65	23.53	17.65
SM	35.3	17.65	0.00	0.00	0.00
SC	5.88	11.76	0.00	0.00	0.00
ML	5.88	5.88	5.88	17.65	23.53
MH	29.4	23.53	29.4	11.76	11.76
CL	0.00	0.00	0.00	0.00	0.00
CH	17.6	29.4	29.4	47.06	47.06

(b)					
USCS Symbol	Depth				
	1m	2m	3m	4m	5m
SP	2.94	0.00	0.00	0.00	0.00

Table 1b Continued to next column

Table 1b continued

SW	2.94	14.71	14.71	35.3	35.3
SM	29.4	23.5	29.4	11.76	11.76
SC	5.88	2.94	2.94	2.94	0.00
ML	0.00	11.76	11.76	14.71	8.82
MH	20.6	17.65	11.76	8.82	2.94
CL	0.00	0.00	0.00	0.00	0.00
CH	38.2	29.4	29.4	26.47	38.24

(c)					
USCS Symbol	Depth				
	1m	2m	3m	4m	5m
SP	2.50	0.00	0.00	0.00	0.00
SW	2.50	12.50	17.50	30.00	35.00
SM	32.5	32.5	27.5	7.50	7.50
SC	5.00	10.00	5.00	0.00	0.00
ML	0.00	10.00	17.50	20.00	22.50
MH	30.0	12.50	7.50	10.00	7.50
CL	0.00	0.00	0.00	0.00	0.00
CH	25.0	22.50	25.0	32.5	27.50
OR	2.50	0.00	0.00	0.00	0.00

(d)					
USCS Symbol	Depth				
	1m	2m	3m	4m	5m
SP	2.70	0.00	0.00	0.00	0.00
SW	8.11	16.22	24.32	29.73	29.73
SM	18.9	24.32	10.81	8.11	10.81
SC	2.70	2.70	2.70	5.41	2.70
ML	16.2	10.81	16.2	13.51	16.22
MH	32.4	24.3	10.81	2.70	0.00
CL	0.00	0.00	0.00	0.00	0.00
CH	18.9	21.62	35.14	40.54	40.54

Table 2 Design parameters for foundation design.

USCS Symbol	Typical Unit Weight (kN/m ³)			
	Above GWT	Below GWT	e _{max}	e _{min}
	SP	15.0-19.5	19.0-21.0	0.60
SW	17.5-22.0	19.5-23.5	0.71	0.40
SM	12.5-21.0	17.5-22.0	0.75	0.40
SC	13.5-20.5	17.5-21.0	0.70	0.40
ML	11.5-17.5	12.5-20.5	0.98	0.58
MH	11.5-17.5	11.5-20.5	0.85	0.46
CL	12.5-17.5	11.5-20.5	0.90	0.46
CH	12.5-17.5	11.0-19.5	1.19	0.68
OR	11.5-12.5	11.5-16.5	0.76	0.44

3. METHODOLOGY

Quezon City has an approximate land surface

area of 160 square kilometers. a density of 0.80 borehole locations per square kilometer was used to describe the geotechnical characteristics and possible foundation design parameters of the said area. Borehole logs were collected for a total of 130 locations all over Quezon City.

The amount of borehole logs alone is not the only criterion in gathering data for the study. It is just as important as, that the locations of the borehole logs be properly distributed. To check their distribution, each of the locations of the borehole logs was plotted in a map of Quezon City. After this, the distribution was visually inspected and the areas that needed more data were determined. Aside from these, borehole logs that seemed erroneous were removed and disregarded.

In properly designing shallow foundations, the geotechnical characteristics and allowable bearing capacity of the soil must be known. This is because the design would largely depend on the strength and the behavior of the soil. The bearing capacities are computed using the SPT-N values found in the borehole logs which were corrected using the procedures discussed in [1], [3]-[5], also shown in Eq. (1).

$$N_{60} = \frac{E_m C_B C_S C_R C_N N}{0.6} \quad (1)$$

Where: N_{60} is the corrected SPT-N value (blows/ft), E_m is the hammer efficiency, C_B is the borehole diameter correction, C_S is the sampler correction, C_R is the rod length correction, C_N is the overburden pressure correction and N is the SPT-N recorded in the field.

The corrected SPT, N_{60} , values were then used to compute for various geotechnical parameters such as relative density, undrained shear strength and angle of internal friction using different correlation factors [6]-[10]. As such, the group computed the ultimate bearing capacity. The Terzaghi's and Vesic's bearing capacity formulas, shown on Eq. (2) and (3) respectively, were used to achieve this [11]- [13].

$$q_{ult} = 1.2cN_c + \gamma D_f N_q + 0.4\gamma B N_\gamma \quad (2)$$

where: q_{ult} is the ultimate bearing capacity, γ is the effective unit weight, B is the width of foundation, D_f is the depth of foundation below ground surface, N_c , N_γ and N_q are the Terzaghi's factors.

$$q_{ult} = c' N_c s_c d_c i_c b_c g_c + \sigma'_{zD} N_q s_q d_q i_q b_q g_q + 0.5\gamma' N_\gamma s_\gamma d_\gamma i_\gamma b_\gamma g_\gamma \quad (3)$$

Where: s_c, s_q, s_γ are shape factors; d_c, d_q, d_γ are depth factors; i_c, i_q, i_γ are load inclination factors; b_c, b_q, b_γ are base inclination factors; and g_c, g_q, g_γ are ground inclination factors.

A factor of safety of 3.0 was divided to ultimate bearing capacity to determine the allowable soil bearing capacity of the soil. The allowable soil bearing capacities at different locations were then plotted on to the maps at 1-meter, 2-meter, 3-meter, 4-meter and 5-meter depths. Contour maps were created to visually classify and analyze the allowable bearing capacities at different locations in Metro Manila.

4. SOIL BEARING CAPACITY ESTIMATES

The allowable soil bearing capacity of Quezon City at one-meter depth from the ground surface is in the range of 200 to 300 kPa, as represented by the color red in Fig. 2. The north, southwest, and some scattered portion of the center part of the city has bearing capacity values of 100 to 200kPa. Compared to other cities in Metro Manila, this is quite high for the first meter depth.

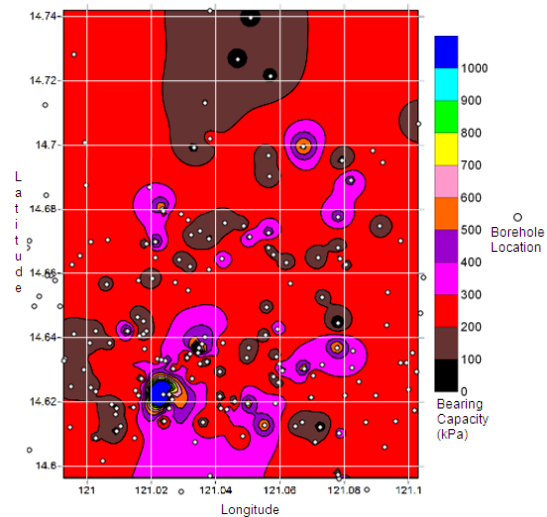


Fig. 2 Soil bearing capacity at 1-meter depth

At a depth of two meters from the ground surface, as shown in Fig. 3, a significant increase in allowable soil bearing capacity is observed. The allowable soil bearing capacity is in the range of 400 kPa to 500 kPa. This is dominant on the central to the eastern side of the city. The northern and some parts of the south-eastern part of the city have a bearing capacity of 300 kPa. The north- western part of the city has reached 600 kPa. It is also seen that there are certain portions that already reached

more than 1000 kPa, specifically the south-western part of the city. Those with high bearing capacities are those in the higher elevation areas.

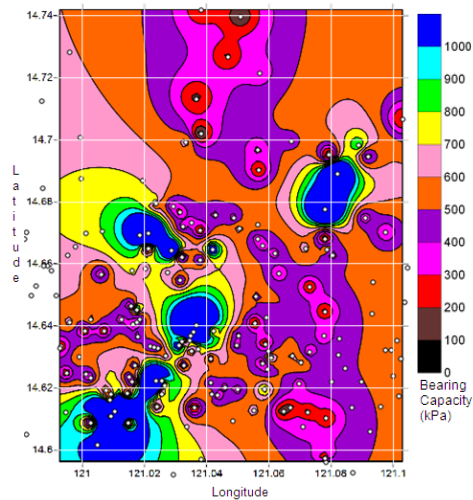


Fig. 3 Soil bearing capacity at 2-meter depth

At three-meter depth, there is a further increase in the allowable soil bearing capacity, as shown in Fig. 4. Majority of the bearing capacity that was computed is now split into three ranges: 700 to 800 kPa, 800 to 900 kPa, and more than 1000 kPa. The north and southeast part of the city has the least bearing capacity of around 600 kPa, while the central, southwest, and east part of the city now has the strongest, with more than 1000 kPa. One can observe that it still follows the trend that as the elevation increases, the bearing capacity also increases.

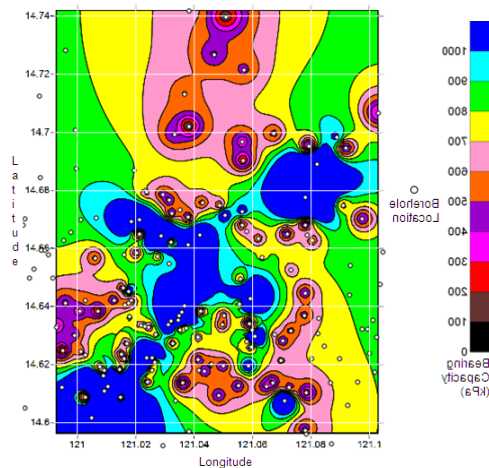


Fig. 4 Soil bearing capacity at 3-meter depth

An even larger increase in the allowable soil bearing capacity in the whole vicinity of Quezon City is seen at four-meter depth from the ground surface, as shown in Fig. 5. Take note of the south portion though, as the bearing capacity decreased from 1000 kPa to an average value of 500 to 600

kPa. Since the rock formation at this area has lower RQD index as seen from the borehole logs, the equivalent bearing capacity is much smaller compared to the layer above it.

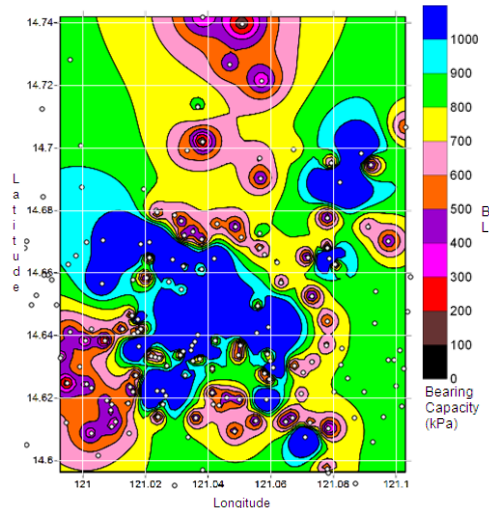


Fig. 5 Soil bearing capacity at 4-meter depth

At 5 meters depth from the ground surface, as shown in Fig. 6, there is a further increase in the allowable soil bearing capacity, wherein the 800 kPa to over 1000 kPa range is the dominant allowable soil bearing capacity. The lowest capacity easily seen here is the 400 kPa (violet) in the southwest and south parts of the city, while the highest still remains at those positions that are high in elevation, which are in the central and western parts of the city.

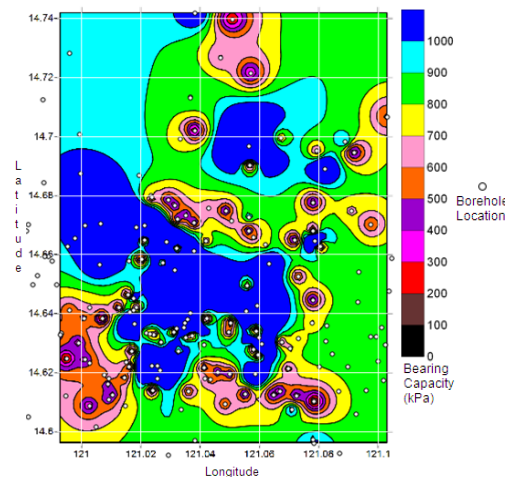


Fig. 6 Soil bearing capacity at five-meter

Fig. 7 shows the geological map of Metro Manila [14]. Quezon City is in the central part of Metro Manila. Quezon City has a different surface geology compared to its neighboring cities. Tuff was primarily observed in this area, and rock formations are common below the surface. SPT

blows depend on the amount of deposits that are present and increase as the soil goes deeper. SPT refusal was achieved at shallow depths of 2 to 3 meters in the outer regions and as shallow as the ground surface in the inner regions.

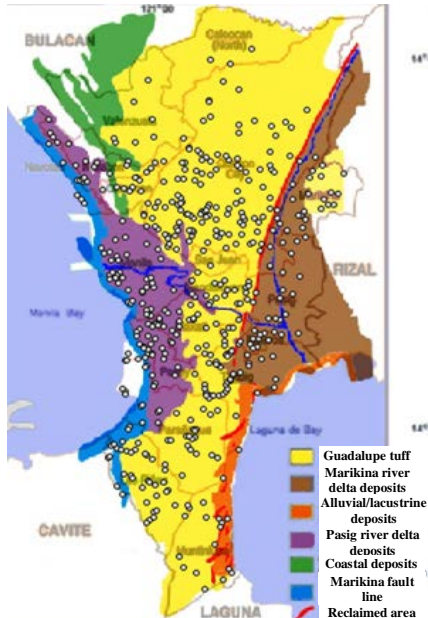


Fig. 7 Geologic Map of Metro Manila [13]

Since the surface geology of this area is reported as tuff, it can be generalized that the city is mostly made up of rocks. In accordance to this, the allowable soil bearing capacities of the rocks should have high values compared to soils and it is in this premise that the estimated soil bearing capacities in the different areas in Quezon city are relatively high.

5. CONCLUSION

Borehole logs were collected for a total of 130 locations all over Quezon City, Philippines. Maps were also created in order to show the locations of the collected boreholes throughout the city.

Using a spreadsheets, different geotechnical properties of the collected boreholes were computed. Some examples of this are the unit weight and the angle of internal friction. Also using the same spreadsheet, the allowable soil bearing capacity of the entire Quezon City was estimated and evaluated per meter depth until a depth of 5 meters. Contour maps of the allowable bearing capacities at each of the depths were also made and analyzed.

Because of the shallow rock formations beneath the surface of the city, high allowable soil bearing capacities were observed at shallow depths. It is recommended to place the foundations on these refusal levels since it is more than capable of carrying loads that are suited for shallow foundations. Nevertheless, caution must be taken

when placing structures in these areas, as the Valley Fault System is nearby, making the area prone to earthquakes.

The soil in the Quezon City area shows an increasing trend in the bearing capacity at every meter deeper. High-rise buildings can be easily built in the area without many struggles in the foundation design. Because of this, settlement in the said area can be considered minimal, thus, structures can be built confidently to resist such phenomena. This reference can be used by structural engineers and city engineers in properly designing the foundation of structures and can also be used for disaster mitigating activities of the city.

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