© AUG 2019 | IRE Journals | Volume 3 Issue 2 | ISSN: 2456-8880

Geotechnical Characterization and Foundation Condition of Soil in Southern Yangon Area

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Abstract— Yangon area, because of its social-economic political significance, has undergone very rapid development and expansion. In such study the combined use of geological information and soil study, natural hazards and urbanization study have beneficial effect on development of urban areas. The study areas are covered by Irrawaddian rocks, residual soils, and transported soils. Quaternary sediments of older and younger alluvium deposits are widely distributed thoroughly the Yangon area. These soils are classified into CL, CH, OH, ML and MH according to the Unified Soil Classification System. To evaluate the physical characteristics of the soil, moisture content, wet and dry density, atterberg limit test, grain size distribution, triaxial compression test, unconfined compression strength test and standard penetration compression test were performed and the result thoroughly elaborated. For the foundation analysis, the shallow foundation depth is considered at 8 ft foundation. Total numbers of the selected boreholes are 21 boreholes from 8 townships in Yangon City. Tezarghi, Meyerhof, Hansesn, and Vesic bearing capacity equation are used for shallow foundation.

Indexed Terms - Bearing Capacity, Shallow Foundation, Irrawaddian Rock, Standard Penetration Test

I. INTRODUCTION

The purpose of the study is to show how engineering geology is essential in the urban planning and development which is now accepted thoroughly the work as vital public service. Due to the rapid growth of population, the development of industrial zones and the extension of new satellites towns, and the most effective development of town planning are very important in urban development planning. Therefore, engineering characteristics and foundation properties of rocks and soils, and engineering geological are necessary to be investigated in details. The geological character of all sites used for civil development must be known with certainty if planning is to be well done and construction could be carried out safely and economically.

Yangon is situated in Yangon Division and at the eastern margin of Irrawaddy delta. The boundary of this study area is between north Latitude 16˚ 45′ to 17˚ 0′ and east Longitude 96˚ 0′ to 96˚ 15′ where refer to 94C/4 and 94D/1.In such study the combined use of geological information and soil study, natural hazards and urbanization study have beneficial effect on development of urban areas. The city can be reached from all parts of the country by car rail, plane and water-way. The city also has a sea port and international airport. The study area includes the following Hlaing Township, YankinTownship, Kyaukta Township, Pazundaung Township, Thingyun Township, Kamayut Township, Lanmadaw Township and South Okkalapa Township. The location map of study area is shown in Figure 1.

Figure 1. Location map of study area

II. GEOLOGY OF THE STUDY AREA

Yangon and its surrounding region include ridges and deltaic low lands and also extensional rolling region of Bago Yoma anticlinorium. The area is located in a N-S trending sedimentary basin containing a thick Tertiary and Quaternary deposits. Tertiary deposits belong to the Hlawga shale of lower Pegu Group, Thadugan sandstone (lower) and Besapet alternation (upper) of upper Pegu Group, and Arzadugan sandstone (lower) and Danyingon clay (upper) of Irrawaddy Formation. Quaternary sediments of older and younger alluvium deposits are widely distributed throughout the Yangon area. The synclinal valley west of the Yangon anticlinal ridge is filled with unconsolidated water laid deposit of Quaternary age. These form a wedge shaped alluvial accumulation ranging in thickness from a few feet near the ridge to about 200 to 300 feet in the valley [7]. The wedge shaped nature is evidenced by thickening of the sediments toward the south and west .These sediments include clays, silts, sands and predominantly fine to coarse gravels. Pegu group includes three lithostratigraphic units, such as Thadungan shales, Thadungan sandstone and Besapet Alternations.The well consolidated marine sandstones of the Pegu Group are considered to be non-water bearing beds. Irrawaddy formation includes two lithlstratigraphiv units. They are Arzarnigon sandrocks and Danyingonclays. The geology of study area is shown in Figure 2.

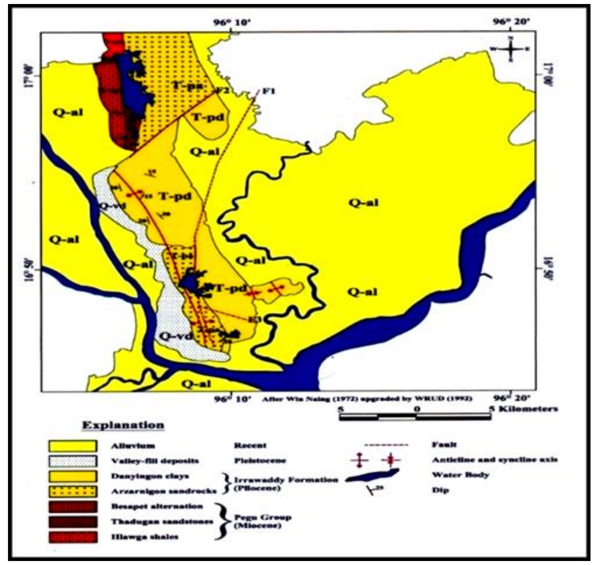

Figure 2. The geology of study area

III. METHOD OF THE STUDY

An attempt is made to study the lithologic units of the study area. Samples of rocks and soils in the study areas were collected and their engineering properties were conducted in the laboratory. Existing tube well data, historical and instrumental earthquake data were also investigated. Engineering Geological Map has been drawn by using the data of engineering properties of soils and rocks as well as groundwater data. The collected data are analyzed for famous authors such as Terzarghi's, Mayeyhorf's, Hansens's, and Vieses's equation.

IV. EVELATION OF BEARING CAPACITY AND FOUNDATION CONDATION OF SOIL

A. Method of Ultimate Bearing Capacity of Soil

The bearing capacity of a soil is defined as a unit load which can be placed safely, that is without detrimental deformation to the structure on the surface of soil. The bearing capacity is variable depending on the soil type. The bearing capacity problem can be considered in two ways, which are ultimate bearing capacity and allowable bearing capacity. Factor of safety is calculated 2.5 because most of the data analyzed are obtained from building construction project site. There are several methods for evaluation of ultimate bearing capacity of the soil. There are

. Terzarghi's Bearing Capacity Equation,

q_{ult} = cNc + qNq + 0.5γBNr
q_{ult} = Ultimate bearing capacity of soil
Ø = angle of internal friction of soil
B = foundation width
c = cohesion of soil
q =effective stress at the level of the bottom of the foundation = γD
γ = unit weight of soil
D = depth of foundation
N_c, N_q, N_r = bearing capacity factor
$S_c.S_q,S_r$ = shape factor
d_c,d_q,d_r =depth factor

Meyerhor's Bearing Capacity Equation,

$q_{ult} = cN_cS_cd_c + qN_qS_qd_q + 0.5\gamma BN_rS_rd_r$
q_{ult} = Ultimate bearing capacity of soil
Ø = angle of internal friction of soil
B = foundation width
c = cohesion of soil
q =effective stress at the level of the bottom of the foundation =γD
γ =unit weight of soil
D = depth of foundation
N_c, N_q, N_r = bearing capacity factor
$S_c.S_q,S_r$ = shape factor
d_c,d_q,d_r =depth factor

$N_q = e^{\pi \tan Ø} \tan^2(45+ Ø/2)$
N_c = (Nq-1) cotØ
N_r = (Nq-1) tan (1.4 Ø)
$S_c = 1+0.2K_p$ (B/L)
$S_q = S_r = 1+0.1K_p$ (B/L) for Ø>10 degrees
$S_q = S_r$ = 1 for Ø>0
$d_c = 1+0.2\sqrt{Kp}$ (D/B) Any Ø
$d_q=d_r = 1+0.1\sqrt{Kp}$ (D/B) Ø>10
$d_q=d_r$ =1 (for Ø=0)
$K_p = \tan^2 (45+ Ø/2)$
γ′ = γsat- γw
Where, γw = Unit weight of water
= 62.4 lb/ft^3 or 9.81 kN/m^3

Hansen's Bearing Capacity Equation,

$q_{ult} = cN_cS_cd_ci_cb_qg_q + {}^{-}qN_qS_qd_qi_qb_qg_q + 0.5\gamma BNrSd_ri_rb_r$ (3)

q_{ult} = Ultimate bearing capacity of soil
Ø = angle of internal friction of soil
B = foundation width
c = cohesion of soil
q =effective stress at the level of the bottom of the foundation =γD
γ =unit weight of soil
D = depth of foundation
N_c,N_q,N_r = bearing capacity factor
$S_c.S_q,S_r$ = shape factor
d_c,d_q,d_r =depth factor

$N_q = e^{\pi \tan Ø}\tan^2 (45+Ø/2)$
$N_c = (N_q-1)$ cotØ
S_c = 0.2 (B/L) for Ø=0
$S_c = 1+ (N_q/Nc)(B/L)$
S_q = 1+ (B/L) sinØ
$S_r = 1-0.4(B/L) \geq 0.6$
d_c =0.4k for Ø=0
d_c = 1+0.4k

$k = \frac{D}{B}$ for D/B ≤1

$k = \tan^{-1}\frac{D}{B}$ for D/B>1

k in radians.

$d_q = 1+2\tan Ø \left(1-\sin\phi\right)^2 k$
d_r =1 for all Ø
$i_c=i_q=i_r$ =1
$g_c=g_q=g_r$ =1
$b_c=b_q=b_r$ =1

Vesic's Bearing Capacity Equation

$q_{ult}=cN_cS_cd_ci_cb_qg_q+{}^{-}qN_qS_qd_qi_qb_qg_q+0.5\gamma BN_rS_rd_r$

q_{ult} = Ultimate bearing capacity of soil
Ø = angle of internal friction of soil
B = foundation width
c = cohesion of soil
q =effective stress at the level of the bottom of the foundation =γD
γ =unit weight of soil
D = depth of foundation
N_c,N_q,N_r = bearing capacity factor
$S_c.S_q,S_r$ = shape factor
d_c,d_q,d_r =depth factor

$N_q = e^{\pi \tan Ø}\tan^2 (45+Ø/2)$
$N_c = (N_q-1)$ cotØ

S_c = 0.2 (B/L) for Ø=0

S_c = 1+ (N_q/Nc) (B/L)

Sc = 1 for strip

S_q = 1+ (B/L) tanØ

S_r = 1-0.4(B/L) ≥ 0.6

d_c =0.4k for Ø=0

d_c = 1+0.4k

$k = \frac{D}{B}$ for D/B ≤1

$k = \tan^{-1}\frac{D}{B}$ for D/B>1

k in radians

d_q =1+2tanØ $(1-\sin\phi)^2$ k

d_r =1 (for all Ø)

Calculated allowable capacity for different equations at 8 feet as shown in Table 1 to 4.

Table 1. Calculated Allowable Bearing Capacity by Terzaghi's Equation

Sr. No	Township	BH-No	qall lb/ft²		qall kN/m²	
			strip	square	strip	square
1.	Hlaing	1	3306.44	3991.856	158.3123	191.1301
		2	1830.384	2277.472	87.63879	109.0454
		3	3495.835	4207.803	167.3806	201.4696
2.	Yankin	1	2072.96	2539.326	99.25331	121.5829
		2	3545.78	4186.608	169.7719	200.4548
3.	Kyauk data	1	8626.756	8714.608	413.0491	417.2554
		2	3795.76	4505.856	181.741	215.7404
		3	6620.34	6766.032	316.9819	323.9576
4.	Pazund aung	1	2036.781	2492.901	97.52108	119.3601
		2	2139.092	2626.208	102.4197	125.7428
		3	2135.12	2644.112	102.2295	126.6001
5.	Thinga nkyun	1	1368.672	1705.136	65.53202	81.64191
		2	3687.211	4443.859	176.5437	212.772
		3	2072.96	2539.326	99.25331	121.5829
6.	Kamay ut	1	3842.244	4610.944	183.9666	220.772
		2	5567.376	6619.824	266.566	316.9572
		3	3596.84	4369.376	172.2167	209.2057
7.	South Okkala pa	1	1403.28	1747.52	67.18905	83.67126
		2	1434.696	1786.768	68.69324	85.55045
8.	Lanma daw	1	3068.836	3645.856	146.9359	174.5636
		2	4273.724	4434.136	204.6259	212.3064

Table 2. Calculated Allowable Bearing Capacity by Meyerhof's Equation

Sr. No	Township	BH,-No	qall lb/ft²		qall kN/m²	
			strip	square	strip	square
1.	Hlaing	1	4072.262	4230.279	194.9799	202.5458
		2	2231.475	2300.393	106.843	110.1428
		3	4335.67	4507.019	207.5919	215.7961
2.	Yankin	1	2480.751	2563.134	118.7783	122.7229
		2	4379.35	4558.961	209.6833	218.2831
3.	Kyaukdata	1	10079.72	10579.1	482.6169	506.5271
		2	4702.956	4897.502	225.1775	234.4924
		3	8247.12	8632.445	394.8721	413.3214
4.	Pazundaung	1	2435.295	2516.071	116.6019	120.4695
		2	2565.611	2651.09	122.8414	126.9342
		3	2579.527	2663.859	123.5078	127.5456
5.	Thingankyun	1	1667.722	1716.078	79.85054	82.16581
		2	4569.433	4750.49	218.7845	227.4535
		3	2481.056	2563.446	118.793	122.7378
6.	Kamayut	1	4772.352	4966.568	228.5002	237.7993
		2	7106.683	7427.562	340.268	355.6317
		3	4450.644	4624.972	213.0969	221.4437
7.	South Okkalapa	1	1709.408	1758.937	81.84644	84.2179
		2	1747.363	1798.003	83.66374	86.08838
8.	Lanmadaw	1	3772.053	3923.368	180.6059	187.8509
		2	2780.349	2921.359	133.1231	139.8747

Table 3. Calculated Allowable Bearing Capacity by Hansen's Equation

Sr. No	Township	BH-,No	qa lb/ft^2		qall kN/m^2	
			strip	square	strip	square
1.	Hlaing	1	4502.672	4684.131	215.5879	224.2762
		2	2470.905	2546.967	118.3069	121.9488
		3	4795.896	4994.439	229.6275	239.1337
2.	Yankin	1	2749.972	2842.822	131.6687	136.1143
		2	6882.466	7304.605	329.5325	349.7445
3.	Kyaukdata	1	10496.49	10956.32	502.572	524.5888
		2	7347.617	7804.689	351.8039	373.6885
		3	8186.132	8541.245	391.952	408.9548
4.	Pazundaung	1	2699.374	2790.377	129.246	133.6033
		2	2844.954	2941.385	136.2164	140.8335
		3	2859.485	2953.831	136.9121	141.4294
5.	Thingankyun	1	1836.296	1888.07	87.92186	90.40081
		2	5063.903	5273.961	242.4597	252.5172
		3	2749.972	2842.822	131.6687	136.1143
6.	Kamayut	1	5256.125	5479.124	251.6632	262.3404
		2	7729.797	8091.226	370.1027	387.4079
		3	4925.969	5095.978	235.8554	243.9954
7.	South Okkalapa	1	1881.913	1934.913	90.10601	92.64365
		2	1924.184	1978.385	92.12995	94.72508
8.	Lanmadaw	1	4160.76	4334.562	199.2172	207.5388
		2	5328.07	5553.128	255.108	265.8838

Table 4. Calculated Allowable Bearing Capacity by Vesic's Equation

Sr. No	Township	BH-No	qall lb/ft^2		qall kN/m^2	
			strip	square	strip	square
1.	Hlaing	1	3811.508	4774.304	182.495	228.5937
		2	2135.483	2570.464	102.2469	123.0738
		3	4049.262	5094.701	193.8787	243.9343
2.	Yankin	1	2368.194	2882.76	113.3891	138.0266
		2	5540.258	7623.85	265.2675	365.0299
3.	Kyaukdata	1	10276.56	11837.46	492.0417	566.7774
		2	5841.152	8128.256	279.6744	389.1809
		3	7940.672	9164.952	380.1994	438.8179
4	Pazund	1	2326.	2830.	111.3	135.5
		2	2444.789	2981.09	117.0565	142.7346
		3	2456.597	2987.991	117.6219	143.065
5.	Thingankyun	1	1600.902	1900.989	76.65119	91.01936
		2	4268.997	5378.013	204.3996	257.4993
		3	2368.194	2882.76	113.3891	138.0266
6.	Kamayut	1	4425.668	5549.682	211.901	265.7188
		2	6408.979	8278.686	306.8619	396.3835
		3	4140.03	5216.557	198.2246	249.7687
7.	South Okkalapa	1	1946.574	2339.773	93.20196	112.0283
		2	991.1413	1165.702	47.45585	55.81383

8.	Lanmadaw	1	3546.391	4436.995	169.8012	212.4433
		2	5126.26	5914.573	245.4453	283.1898

V. CONCLUSION AND RECOMMENDATION

In this study, comparative study on prediction of the bearing capacity by using Standard Penetration Test is focused on allowable bearing capacity of square footing and strip footing for selected areas in Yangon City. Total numbers of the selected boreholes are 21 boreholes from 8 townships in Yangon City. Physical properties tests are grained size analysis and Atterberg limit test. The bearing capacity for strip footing and square footing are nearly equal but the bearing capacity of the square footing is slightly greater than the strip footing for the shallow foundation The highest value of allowable bearing capacity for Terzarghi's equation is 6620.34 lb/ft^2 which is 8 ft depth for Kyaukdata Township. The lowest value of allowable bearing capacity for Terzarghi's equation is 1434.696 lb/ft^2 which is 8 ft depthe for South Okkalapa Township. Thus, the above finding and presentations will have solved some of the urbanization problems with reference to geology such as engineering characteristics, environment and natural hazards.

ACKNOWLEDGEMENTS

The authors wish as to their express sincere thank U Kyaw Htun, (Retired Associate Professor), Department of Engineering Geology, Yangon Technological University for giving support in the preparation of this paper.

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