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Geotechnical Evaluation of Foundation Soils for a Building (Case Study of a Site in Jimma City, Southwestern Ethiopia)

Lollo Chande Lollo
Department of Civil Engineering, Wolaita Sodo University, P.O.Box 138, Wolaita Sodo, Ethiopia

Abstract
This paper presents the findings of laboratory tests that were carried out on a soil sample collected from a site, in Jimma City, southwestern Ethiopia. The aim of the investigation is to determine the basic shear strength parametres of the soil, which is an important parametre to determine bearing capacity of the soil. Engineering tests such as direct shear, sieve size analyses, atterberg limits, and specific gravity were carrieid out on sample collected from 3m hund dug test pit. All analysis was carried out in line with the ASTM standards. Results obtained showed that the soil investigated contains 35.85% clay, 24.32% silt, 60.17% fine, and 28.70% sand and 11.13% gravel. The result of Atterberg limits analysis showed that the liquid limts is 81%, plastic limit is 55.57% and index of plasticity is 24.43. Clay activity of the soil is 0.68. Thus, the soil investigated is classified as inactive clay of high plasticity. The cohesion value of the soil is 40.2kPa and the angle of internal friction is 19.26°. With these c and ϕ values, the soil will have good bearing capacity and will be good foundation materials for structures.
Keywords: Bearing capacity, shear strength, sieve size analysis, specific gravity.

1. Introduction

A foundation is that part of a structure which transmits the loads directly to the underlying soil (Craig, 2004). Broadly speaking foundations are classified into shallow foundation and deep foundations. Those foundations that transmit structural loads to the soil strata at a relatively small depth are considered as shallow foundations. Foundations in turn are supported by soil below. Soil is also a foundation for the structure and affords the entire load coming from above. For that, soil should be defined before any design process, starting with site investigations to define the types and properties of the soil (Das, 2009 and Kameswara Rao, 2011). Different datas attained from the explorations will assist geotechnical engineers in design and choice of appropriate type of footing for a given structure. For satisfactory performance foundation soil must be capable of carrying the loads from any engineered structure placed upon it without a shear failure and with the resulting settlements being tolerable for that structure (Bowles, 1996).

The bearing capacity of soil under foundation depends on different factors such as soil shear strength parametres (cohession angle of internal friction), unit weight of the soil (γ), proximity to gound water etc. Shear strength is the main important principal engineering property of a soil which controls the stablity of soil mass under loads. It controls the bearing capacity of soils, stablity of slopes in soils, the pressure against retaining structure and many other problems (Arora, 2004). Thus, the need for investigations of shear strength properties of soils before their application as foundation soil is pertinent. Therefore this study aims at assessing shear strength parameters/angle of internal friction ϕ and cohesion **c**/ and other engineering parametres that can be used to estimate the bearing capacity of the soil.

2. Study Area

Jimma is the largest city in southwestern Ethiopia. It is located 346km southwest of Addis Ababa at latitude of about $7^0$40'N and longitude of about $36^0$50'E. The average altitude is 1760 m above sea level. According to the national census undertaken in 2005, the city has a total human population of 159,009 of which 80,897 were men and 78,112 were women (CSA, 2005).

3. Materials and Methods

Disturbed and undisturbed samples were collected from 3m hund dug test pit. Disturbed samples were collected using split spoon sampler and tasted for index properties (Atterberg limit and Sieve analyses, hydrometre analysis and specific gravity). Undisturbed samples were also collected and tasted for shear strength parametres. The procedures for these tests are explained as follows.

3.1 Sieve Analysis

The sieve analysis was carried out in accordance with the procedures outlined in **ASTM D422-63**. Suitable quantity of soil sample was taken from representative sample and soaked with water. Slurry of soaked water was transferred in to 75µm sieve and washed with jet water. Finally material left on the sieve was oven dried and analyzed for the coarse fraction of the sample using sieves (0.0075mm-4.75mm). The particle retained on each sieve was weighed and the percentage of weight of soil retained on each sieve determined for each sample.

Hydrometre analysis method was used to determine the size distribution of fine grained soil having particles sizes smaller than 75µm. For Hydrometer analysis 50gm of soil passing 0.075mm sieve and retained on the pan is used. Using 125ml Sodiumhexametaphosphate (40gm/ml) solution the sample was stirred and soaked for 16 hours. At the end of the 16hrs of soaking, the suspension is stirred for one minute and transferred to hydrometer jar or sedimentation cylinder and water is added to the mark of 1000ml.

The slurry was agitated for one minute and placed in convenient position. Using hydrometer (152H) readings were recorded for the time of 1min, 2, 5, 15, 30, 60, 120,…. 1440. A mixture of sodiumhexametaphosphate (40gm/ml) and water is kept alongside the soil slurry to observe the effect of the dispersing agent on the hydrometer reading at different times of record.

3.2 Atterberg Limits.

Liquid limit was determined using Casagrande method as outlinde in test method **ASTM D 4318**. 250gm soil passing sieve No 40(425µm sieve) was mixed with water thoroughly to form a uniform paste. The uniform paste formed was kept in a covered dish for 16hours. A portion of the paste was put on the Casagrande's cup and spread over the cup at an approximate depth of 10mm and divided to the center using grooving knife. The cup was given blows by manual operation of handle, the rotation of handle being at the rate of 2rev/sec. The number of blows required to close approximately 13mm of the separated parts of soil on the cup was noted down. A portion of the soil is saved for water content determination. The procedure was repeated two more times by adding a little more water to the soil water mixture after each trial.

The moisture content values were plotted against the corresponding number of blows and linear graph was obtained. The moisture content at the 25th blow was taken as liquid limit value (LL).

Plastic limit of the soil was determined using the procedure outlined in test method **ASTM D 4318.** 20gm of soil sample passing sieve No 40 (425µm Sieve) was mixed with water until it become plastic enough to be rolled into ball. The mixture is rolled by hand on a smooth glass plate to a thread of approximate 3mm diameter. When cracks open up on the surface of the threaded soil, the sample is saved for moisture content determination. The moisture content was recorded as plastic limit (PL) value. The plastiicity index (PI) of the soil was determined as PI = LL – PL.

3.3. Direct Shear Test

In this test a normal load of 1kg was applied using a lever arm which multiplies the load by 10 for 24 hours. Finally after 24 hours horizontal load was applied and shearing continued at the rate of 1.27mm/min until the shear force goes beyond its maximum value and becomes constant or decreases, representing failure condition.Two more samples were tasted with the same procedure but different normal forces (2kg and 3kg). The results of the direct shear tests for the soil is presented in the form of stress-strain curves and plots of shear stress versus normal stress. From these, the shear strength parameters (angle of cohesion (c) and angle of internal friction (ϕ)) were obtained.

3.4. Bearing Capacity Calculation

The calculations of ultimate bearing capacity (qult) of the soil was performed using equation proposed by Terzhaghi for bearing capacity calculation of square footing depending on the parameters obtained from the direct shear test:

$$q_u = 1.3c'N_c + \gamma DN_q + 0.4\gamma BN_\gamma \tag{1}$$

γB γD

Where: c: cohesion of soil, *kPa*.

D: Depth of the footing, *m*.

B: width of foundation*, m*.

γ: unit weight of soil, *KN/m³*.

Nc, Nq, Nγ: bearing capacity factors, (their values can taken from special tables).

The equation given in above section assumes that the water table is located below the failure surface in the soil supporting the foundation. However, if the water table is present near the foundation, the terms γD and γB in the given equation need to be modified (Das, 2009). The level of ground water was obseved to be 1.5m below ground surface during investigation period but for conservative estimation of bearing capacity the level of ground was assumed to be at gound surface level and γD and γB are replaced with $\gamma' D$ and $\gamma' B$ respectively in the given equation.

Finally allowable bearing capacity of the soil was estimated as

$$q_{all} = \frac{q_{ult}}{FS} \tag{2}$$

Where: FS is factor of safety.
For estimation of allowable bearing capacity factor of safety of 3 was used.

4. Results and Discussions

4.1. Grain size Analysis

The particle size distribution that defines the texture of the foundation was analysed and the results are summrized in Table-1. Results obtained showed that the soil investigated contains 35.85% clay, 24.32% silt, 60.17% fine, and 28.70% sand and 11.13% gravel. Hence the soil will be catogorized as fine grained soil.

4.2. Atterberg Limits.

Atterberg test results are summarized in Table 3. Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) are valuable limits for identifying and classifying soils. The LL is the higher limit establishing the state of consistency (degree of firmness) for fine-grained soils. Liquid limit divides the liquid state from the plastic state of the soil and dividing line between plastic states and semi solid states of soil is termed as plastic limit (Liu and Evett, 2000). The liquid limit of the tasted soil is 81%, its plastic limit is 55.57% and index of plasticity is 24.43%. The clay activity (plasticity index, PI/clay fraction) is 0.68. Thus the soil investigated is classified as A-7-5 according to the AASHTO classification system, while the Unified Soil Classification System (USCS) classifies the samples as CH, which is an indication of high plasticity clay (Coduto, 2003). On the basis of the Casagrande plasticity chart, these soils are inorganic clays of high plasticity (Murthy, 2009).

4.3. Shear strength parametres

The result from direct shear test showed that the cohesion value is 40.2Kpa and the angle of internal friction is 19.26^0 (Table 2). The studied soils possess good shear strengths as evident in the values of its angle of internal friction (ϕ) and cohesion (c). With these c and ϕ values, the soil will have good bearing capacity and will be good foundation materials for structures.

4.4. Bearing Capacity of the soil investigated

The interface between foundation and soil supports is defined by the most essential parameter which is the bearing pressure. It is the contact force per unit area along the bottom of the foundation (Coduto, 2003). The maximum pressure the soil can carry without shear failure is termed as ultimate bearing capacity of the soil. Values of ultimate bearing capacity and allowable bearing capacity of the soil for four trial footing width are presented in table 3. For 1m x 1m square footing the allowable bearing capacity of the soil is calculated to be 319kPa.

5. Conclusion

From the analysis of the results obtained from the laboratory test conducted on the sample from a site in Jimma city, southwestern Ethiopia. The following conclusion can be drawn:

i. The soil sample are classified as A-7-5 according to the AASHTO classification system, while according Unified Soil Classification System (USCS) classifies the samples as CH, which is an indication of high plasticity clay.
ii. The allowable bearing capacity of soil in the study area is found to be more than 300kPa and this showed the soil in the study area generally have good load carrying capacity.

References

Arora, K. R. (2004). Soil Mechanics and Foundation Engineering (6th ed.). Standard Publishers, Delhi.
Bowles, J. E. (1996). Foundation Analysis and Design (5th ed.). McGraw Hill, New York.
Coduto, D. P. (2001). "Foundation Design: principles and practices (2nd ed.). Prentice-Hall, Inc. New Jersey.
CSA (2005). National Statistics. Obtained through internet: http://www.csa.gov.et [Accessed on 19 February, 2016].
Das, B. M. (2009). Shallow Foundation: bearing capacity and settlement (2nd ed.). press Taylor & Francis group, New York.
Das, B. M. (2011). Principles of Foundation Engineers (7th ed.). Cengage learning. Stamford.
Kameswara, Rao N. S. V. (2011). "Foundation Design theory and practice", John Wiley & Sons (Asia) Pte Ltd, Singapore.
Liu, C. and Evett, J. B.(2000). Soil properties testing, measurement, and evaluation (4th ed.). Prentice Hall, Upper Saddle, New Jersey.
Murthy, V. N. S. (2009). Geotechnical Engineering: Principles and practices of soil mechanics and foundation engineering. Marcel Dekker Inc., New York.

ABOUT THE AUTHORS
Lollo Chande Lollo (M.Tech.) was born in Oromia Regional State, Borana zone, Hidi Lola town. He obtained His M.Tech, and B.Sc. degrees from Jimma University in 2005, and 2012 respectivelly. Currently Lollo is lecturer in Civil Engineering Department, Wolaita Sodo University. He teachs Soil Mechanics and Foundation Engineering courses. He is interested in geotechnical evaluation of lateritic soils. His current research field includes evaluation of naturally occuring clay materials as liner in Sanitary Landfill (E-mail: lollochande@yahoo.com)

Table 1: Grain size distribution characterstics of studied soil.

Sieve Size (mm)	Mass retained gram	Percentage retained (%)	Cumulative percentage retained (%)	Percentage finer (%)
9.5	0	0	0	100
4.75	25.5	11.13	11.13	88.87
2	38	16.58	27.71	72.29
1	11	4.8	32.5	67.5
0.85	0.6	0.26	32.77	67.23
0.425	5.8	2.53	35.3	64.7
0.25	3	1.31	36.61	63.39
0.18	2.1	0.92	37.52	62.48
0.15	2	0.87	38.39	61.61
0.075	3.3	1.44	39.83	60.17

Table 2: Atterberg limits, Particle size analysis, Shear strength Parametre of the studied soil.

Samples	
% Gravel	11.53
% Sand	28.30
% Fine	60.17
% Silt	24.32
% Clay	35.85
Specific gravity	2.8
Liquid Limit %	81
Plastic Limit %	55.57
Plasticity Index %	24.43
Activity	0.68
Cohesion	40.2
Angle of Internal friction	19.26
AASHTO Classification	A-7-5
USCS Classification	CH

Table 3: Bearing capacity calculation

N_c	N_q	N_γ	C'	γ_{sat} (kN/m3)	γ' (kN/m3)	D (m)	B (m)	q_{ult} (kPa)	q_{all} (kPa)
16.89	6.92	4.42	40.2	18.5	8.69	1	0.5	950	317
16.89	6.92	4.42	40.2	18.5	8.69	1	1	958	319
16.89	6.92	4.42	40.2	18.5	8.69	1	1.5	966	322
16.89	6.92	4.42	40.2	18.5	8.69	1	2	974	325