DETERMINATION OF BEARING CAPACITY FOR BUILDING AND STRUCTURAL DESIGN IN OWO LOCAL GOVERNMENT AREA, ONDO STATE, NIGERIA

OTUAGA, Philips Moses
Department of Civil Engineering and Technology
Rufus Giwa Polytechnic, Ondo State, **NIGERIA**

ABSTRACT

Owo, one of the largest producer of timber and cocoa, a commercial city in Ondo State requires adequate planning in terms of building and structural design for both low rise and multi-storey structures, as regards the bearing capacity that is, the ability of a soil to support a load from a structural foundation without failing in shear .This implies that the stability of a foundation depends on bearing capacity of the soil beneat5h the foundation and the settlement of the foundation. This paper presents the shear strength parameters: Cohesion(C) and the angle of internal friction (ϕ) of some sampled coordinated points in the study area. It is found that the minimum bearing capacity is acceptable. This implies that high –rise building pose none or very little risks irrespective of the technology used in the study area.

Keywords: Planning; Building and Structural Design; Load; Cohesion; Internal Friction; and Minimum Bearing Capacity.

INTRODUCTION

Good description of soil and site involve close and careful observations of soil profile in-site and of many aspects of its environment. Laboratory studies are becoming increasingly important but the significance of field study is undiminished. The purpose of this study is to carry out soil exploration (collection of data), analysis of data to determine the shearing strength parameters and to determine the bearing capacity of the soil. The graphs and site grid plan are provided in the appendix.

Objectives

The purposes of the soil test are:

1. To classify the soil
2. To know the bearing capacity of the soil so as to determine the type of foundation for the structure.

Location of the Site

From figure 1, the site for the proposed Achievers University, is located in Idasen, Owo, on longitude 5°36' N, latitude 7° 06' E and elevation 300m above mean sea level, in Owo local government area of Ondo State, Nigeria with a total land area of 170.6 hectares. The average annual rainfall is 2100mm, minimum temperature of 18.5°C and maximum temperature of 32°C, humidity range between 65 and 97 and wind speed of 2.0 knot. The site is divided into grid lines of 50m x 50m square.

- The topography map of the site has been produced and the elevation of the site ranges between 293 meters to 327 meters. The site has gentle slopes.
- The site in Idasen, Owo, in Ondo State lies within the rain forest. Rain forest with their dense layered structure can intercept a significant proportion of the rainfall. This can have an important bearing on seasonal moisture regimes. All but the simplest plant communities are layered.
- From the reconnaissance survey carried out, de-afforestation is gradually taking place and about 40 percent of the site is used for arable farming. The site is dominated by light and dense vegetation, thus preventing soil erosion and deposition of soil. In the dense vegetation, there are some trees which are of economic value like Iroko, Omoh and Afra
- From geological finding, there is the absence of fractures, faults and landslip on the site in the past and at the present; hence, the trees are vertically upright. There is also the absence of igneous intrusion that may involve rock excavation, which can hider construction works.
- From careful examination of the soil, there is the absence of sloping clay formation, a condition prominent along beeches.
- Surface water flows away at such a rate that a moderate proportion of the water enters the soil profile and free water lies on the surface for only short periods. A large part of the precipitation is absorbed by the soil and used for plant growth, is lost by evaporation, or moves downward into underground channels. With medium run- off, the loss of water over the surface not reduced seriously the supply available for plant growth. The erosion hazard is slight for cultivating this class of soil.
- The soil is well drained, since the water is removed readily but not rapidly from the soils, which consequently are not wet for a significant part of the time although they commonly retain near optimum amounts of moisture for lengthy periods. Well-drained soils are commonly intermediate in texture although soils of other textural classes may also be well drained.

The site is divided into three zones A, B and C
Zone A

In zone A, there is a hut in grid line 15A whose roof is covered with bamboo and cellophane. The sides of the hut are not protected from rain. There are about one thousand two hundred cocoa trees and about twenty-five orange trees in grid lines 10A, 11A and 12A. There is a major earth road that cut across the site. Erosion is evident along the sides of the earth road since there is inadequate drainage. There is a swamp and a source in grid lines 13-1, 13-2, 14-1, 14-2 and 15-1.There is a swampy region in grid lines 29-2, 29-3, 28-2, 27-2, 27-3,26-3 and 26-4. It is bonded by the west by an earth road.

Zone B:

In zone B, there is a hut in grid lines 9B and 10B whose roof is covered with corrugated iron sheets and the sides are not protected. There is another hut in grid line 14B whose roof is covered with bamboo; the sides of the hut are not protected from rain. There is a stream that cut across the site. The stream cut across grid lines 1-2, 2-2, 3-2, 4-2, 5-2, 6-2, 7-2, 8-2, 9-2, 11-3, 12-4, 13-5, 14-6, 10-3 and 10-3.

Zone C:

In zone C, there is a hut (with three rooms) in grid line 8C that is gradually degenerating, whose roof is covered with corrugated iron sheets. The sides are protected from rain. There are about one hundred cocoa trees and about twenty orange trees. There is a stream that cut across the site. It is bounded in the east by an earth road. The stream cut across grid lines 4-4, 9-4, 10-4, 11-4, 12-4, 13-4, 5-5 and between [1-3 and 1-4, 2-3 and 2-4, 3-3 and 3-4, 6-4 and 6-5, 7-4 and 7-5, 8-4 and 8-5]

Test conducted under British Standard

The soil tests are conducted in accordance with British Standard [BS] 1377 of 1975.

Types of test conducted

In this soil analysis, the tests conducted are: -

1. Moisture content.
2. Triaxial / Shear box test

Test 1
The Traxial Compression Test

Aim/Objective: -To determine the sharing resistance of soil

Apparatus: - Rubber membrane, top and bottom porous stones, Perspex cell, water, vertical load proving ring, soil sample.

Procedure: -The soil sample is cylindrical with a height to diameter ratio of 2:1. The sample is enclosed in a rubber membrane with porous stones at each end and placed in Perspex cell. The cell is sealed up and water poured in to fill the cell at any required pressured. Thus initially the sample is subjected to a principal stress in all directions. A vertical load is applied through a proving ring at a constant rate of strain until the soil sample fails in shear. The total vertical stress on the sample is then $\sigma 1$ (the major principal stress) and since the sample was initially subjected to a stress $\sigma 3$ from the water in the cell, the additional vertical stress applied via the proving ring = $\sigma 1 - \sigma 3$ and this is referred to as the deviator stress. The test is performed a number of times on similar samples using different initial cell pressure.

Expression of Results

From the result obtained a series of Mohr's circles of stresses are drawn. A line tangential to the entire circle is drawn to represent the coulomb shear strength equation and the appropriate values of **C** and $\boldsymbol{\phi}$ are read off the resulting diagram.

Site Exploration
Selection of Samples for Classification

The first step in classifying the soils from the site is to set out the samples in a logical order .The samples from each boring are set out in one row with the top sample at the back and the next in front of it, and so on. The soil samples are then grouped into limited number of types, from each of which a few samples representing the extremes and means of particle-size

distribution and consistence are selected for classification tests. The grouping of this stage is carried out by means of visual comparison of one soil with another, note being taken of the field description of each soil and of any tentative grouping for classification purpose suggested at the site. Reference is also made to the relative positions of the soils on the site, since soils of one type tend to occur in continuous beds.The trial pit is the site exploration method used.

1. Trial Pits: - This is a 1.2m by 1.5m pit dug in the ground large enough for a ladder to be inserted, thus permitting a close examination of the sides of the soil profile. With this method, undisturbed soil [cohesive soils] samples are obtained relatively easily. The samples, which are 225mm by 225mm by 225mm cube, are wrapped airtight with black cellophane.

Proforma for recording and indexing the characteristic of a soil site.

Table 1: *The topsoil is dominated by compact sandy soil.*

Fig.	Profile no:	Grid reference:	Depth of top soil	Depth of strata:	Description of topsoil	Description of strata	Sample stoniness	Date
1	2A; 2C; 4A	1; 2; 12	0.30m; 0.275m; 0.275m.	0.85m; 0.800m; 0.900m.	Dark grayish brown; Brown; Dark brown.	Medium dense to dense reddish brown silty sand medium gravel.	It has a high percentage of gravel, little percentage of sand and reasonable amount of salt and less of clay.	June 2004
2	2; 1C; 4B	8; 7; 13	0.325m; 0.15m; 0.225m.	0.870m; .0750m; 0.950m.	Grayish brown; Brown, Brown.	Compact reddish brown and fine to medium gravel.	The soil has more than 505 of medium gravel, reasonable amount of sand and less of silt.	June, 2004
3	4; 3C	18; 6	0.350m; 0.32m.	0.850m; 1.00m.	Grayish brown; Brown.	Compact brown silty clay and gravel.	It has high medium gravel, little sand and appreciable amount of silt.	June 2004
4.	3B; 4C	3; 6	0.375m; 0.325m.	0.85m; 0.900m.	Dark brown. Brown.	Compact reddish brown sandy silt and clay plus gravel.	**The soil has a high percentage medium gravel and about equal proportion of sand and plus clay.**	June 2004

5.	8B; 1C	3; 9	0.325m; 0.350m.	0.875m; 0.875m.	Dark brown; Dark brown.	Reddish brown sandy clay.	It contains a high percentage of sand and Clay with little or no gravel.	June 2004
6.	3A; 2A	19; 16	0.300m; 0.275m.	0.875m; 0.900m.	Compact Brown soil; Brown.	Dense brown sandy clay.	Has a high percentage of sand and less of Gravel, Greasy to the touch.	June 2004
7.	7B; 3B	10; 2	0.350m; 0.225m.	0.925m; 0.850m.	Brown; Brown.	Compact brown sandy clay and layers of silt.	Has an almost equal proportion of sand and clay. - Do not –exhibit dilatancy.	June 2004
8.	7B; 2A; 2B	9; 15; 10	0.30m; 0.315m; 0.225m.	0.850m; 0.1.150 m; 0.850m.	Brown; Dark brown; Brown.	Compact brown silty sand with layers of silty clay.	Has little or no gravel, almost equal Proportions of silt and sand. - Show some shrinkage on drying.	June 2004
9.	2B; 4C	13; 1	0.30m.; 0.225	0.825m; 0.715m.	Dark Brown; Brown.	Medium dense brown silty sand with clayey layers, containing occasional gravel.	Has a high proportion of sand, medium of silt and clay and less of gravel.	June 2004
10.	5A; 2A; 4B	19; 25; 10	0.35m; o.275m; 0.225.	0.875m; 0.825m; 0.900m.	Brown; Brown; Brown.	Medium dense to dense red brown silty sand and gravel.	Have equal proportions of gravel and sand with a High proportion of silt and clay.	June 2004
11.	4A; 3A	27; 14	0.375m; 0.300m	0.850m; 0. 900m.	Brown; Dark brown.	Compact brown clayey sits and dense brown sand.	Has a little or no gravel, has a high proportion of silt and clay and adequate amount of sand. - exhibit dilatancy	June 2004

12	3A; 3C; 4A	28; 12; 26	0.350m; 0.375m; 0.325m	0.925m; 1.150m; 0.980m.	Dark Brown; Grayish brown; Dark brown.	Compact brown sandy clay.	Has a little or no gravel, has a high or proportion of clay and adequate amount of sand. - Do not exhibit dilatancy	June 2004
13.	3B; 7A	5; 14	0.475m; 0.375m.	1.O50m; 0.980m.	Dark brown; Dark brown.	Compact brown silty sand with layers of silty Clay.	Has a little or no gravel and equal proportion of Sand, silt plus clay.- Show some shrinkage on drying.	June 2004
14.	4B; 7A	6; 13	0.350m; 0.375m	0.900m; 0.850m.	Brown; Brown.	Compact brown sandy clay.	Has a little or no gravel, less proportion of Sand and compacted to that clay. - Do not exhibit dilatancy	June 2004
15	6B; 4C; 3B	7; 3; 12	0.275m; 0.300m; 0.250m	0.850m; 0.900m; 0.900m.	Dark Brown; Brown; Dark brown.	Compact brown silty sand.	Contains little or no gravel, a high proportion of Sand compared to that of silt. -Exhibit dilatancy	June 2004
16.	3C	2	0.365m	0.95m	Dark brown.	Hard brown silty clay.	Has little or no sand with high proportion of clay and little silt	June 2004
17.	3A	25	0.325m	0.90m.	Brown.	Compact brown sandy clay.	Has little or no gravel, high proportion of sand and adequate amount of clay. - Show some shrinkage on drying	June 2004

18.	3A	22	0.350m	0.875m.	Dark Brown.	Medium dense brown sandy silt.	Have a higher proportion of sand, adequate amount of silt and little or no gravel. - Exhibit dilatancy	June 2004
19.	5c	7	0.150m	0.90m	Brown.	Compact brown sandy clay.	Has a little proportion of gravel, adequate amount of clay and high proportion of sand. Do not exhibit dilatancy	June 2004

Analysis of Data

This involves laboratory experiment on the samples on each of the tests stated above. Test results are computed and graphs plotted. The analyses of the data after plotting the graphs are given below.

From the test result, the cohesion (c) between the soils particles, the angle of internal friction (ϕ), and the unit weight (γ) of the soil are determined. With the information given above, the Bearing capacity of the soil can be determine**.** Terzaghi`s equation for the ultimate bearing capacity (qu) for a strip footing of breadth B and depth Z, soil cohesion C and unit weight of soil (γ) is given by: -

$$qu = cNc + \gamma zNq + 0.5\gamma BN\gamma.$$

Where Nc, Nq and Nγ are dimensionless numbers known as bearing capacity factors. Their values depend only on the value of the angle of shearing resistance (ϕ) for the soil.

Safe bearing capacity of soil

Assume the following foundation parameters for all computations: -

- Width of strip footing = 1.5m
- Depth of footing = 1.5m
- Factor of safety = 3.0

❖ The ultimate bearing capacity (qu) can be determine

$$qu= cNc + \gamma zNq + 0.5\gamma BN\gamma.$$

And therefore, the

❖ Safe bearing capacity (q) of the soil is: -

$$q = \frac{\text{ultimate bearing capacity}}{\text{Factor of safety}}$$

Table 2

Fig	Grid No.	Profile No.	Cohesion C [KN/m²]	Angle of internal friction (ϕ) in degrees	Unit weight of the soil (γ) KN/m³.	Ultimate bearing capacity [qu] KN/m²	Safe bearing capacity [q] KN/m²
1	1; 2; 12	2A; 2C; 4A	48	13	18.25	740.25	246.75
2	8; 7; 13	2; 1C; 4B	38	10	18.84	417 .04	139.01
3	18; 6	4; 3C	60	10	20.11	600.67	200.22
4	3; 6	3B; 4C	39	10	18.34	422.04	140.68
5	3; 9	8B; 1C	20.01	10	20.01	520.07	173.36
6	19; 16	3A; 2A	60	18	21.00	1044.75	348.25
7	10; 2	7B; 3B	40	24	18.49	1499.23	499.74
8	9; 15; 10	7B; 2A; 2B	22	23	19.1	928.08	309.36
9	13; 1	2B; 4C	50	25	18.85	1787.23	595.74
10	19; 25; 10	5A; 2A; 4B	63	27	19.4	2462.4	820.8
11	27; 14	4A; 3A	58	30	17.85	2806.45	935.48
12	28; 12; 26	3A; 3C; 4A	25	23	18.43	978.5	326.1
13	5; 14	3B; 7A	20	19	23.1	706.5	235.5
14	6; 13	4B; 7A	38	20	17.88	990.2	330.07
15	7; 3; 12	6B; 4c; 3B	50	20	17.98	1219.54	406.51
16	2	3C	68	18	17.83	1125.85	375.28
17	25	3A	48	28	18.76	2282.28	760.76
18	22	3A	61	20	18.65	1438.75	479.58
19	7	5C	50	22.4	19.1	1358.13	452.71

Results and Discussion

The soil composition of the site is stable and firm, and can be used as a foundation and subgrade material. The soil range from clay to silt to medium gravel. Coarse and boulders does not dominate.

The optimum moisture content of the soil ranges between 8% and 18.5% and the maximum dry density ranges between 1.53g/cm³ and 2.09g/cm³. Using the AASHTO and Casagrande soil classification system, the soil ranges between good and poor, and GC and CI respectively. The safe bearing capacity of the soil ranges between 139.01 KN/m² and 935.43 KN/m².

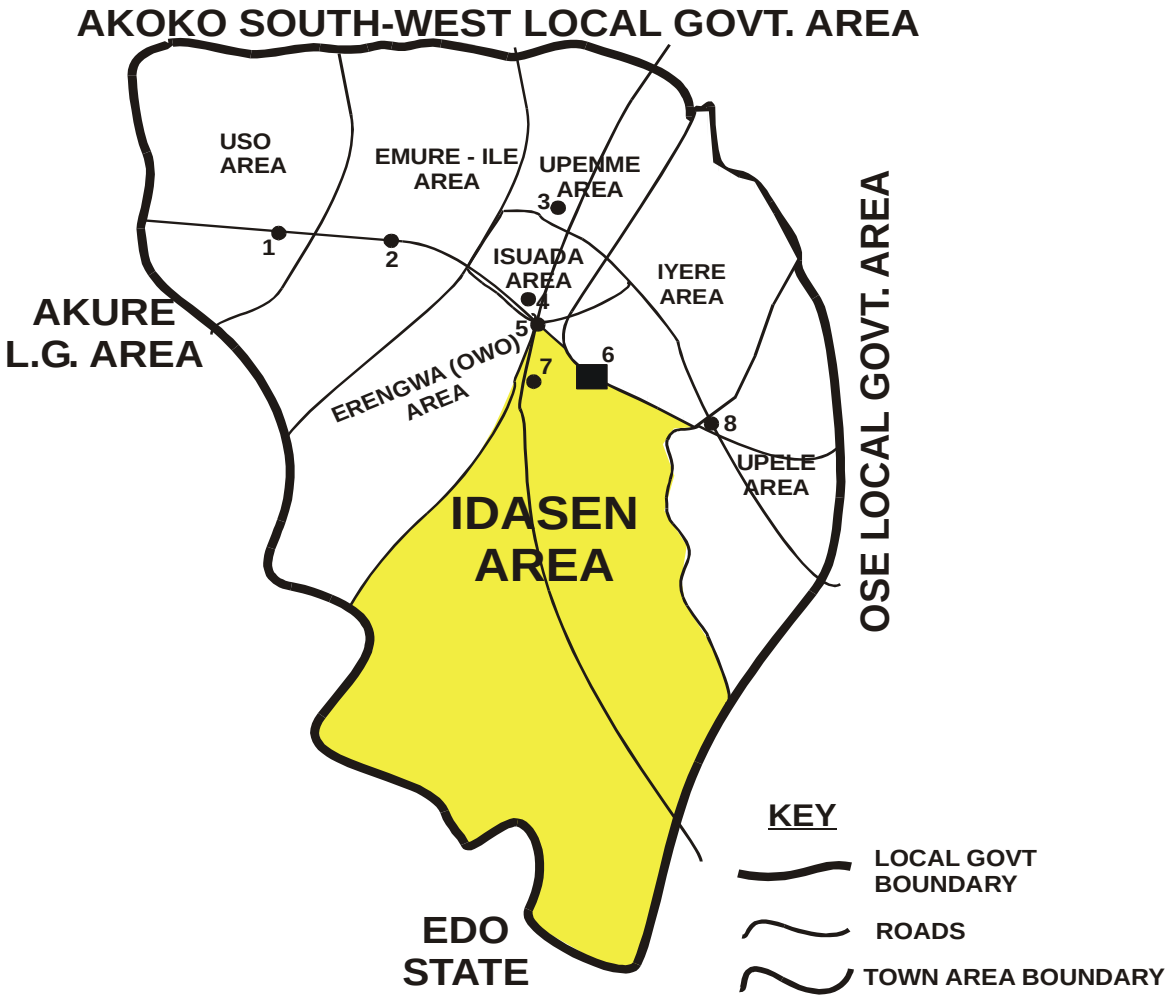
RECOMMENDATION

The following recommendations are made:

- A safe Bearing Capacity of 139.01 KN/m² is adopted for all foundation design.
- Strip footing is adopted
- Most soils can be used as subgrade material except CI soils.

CONCLUSION

From the investigations carried out, it is evident that the study area is situated on a firm soil; the bearing capacity of the soil exceeds 100kn/ m², thus eliminating the use of pile and raft foundations.



KEY TOWNS

1. USO
2. EMURE ILE
3. UPENUME
4. ISUADA
5. ERENGWA (OWO)
6. IYERE
7. IDASEN
8. UPELE

FIGURE 1: OWO LOCAL GOVERNMENT AREA (MAP)

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