International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 4 Issue 11|| November 2015 || PP.18-22

Geotechnical Investigation into the Causes of Cracks in Building: A Case Study of Dr. Egbogha Building, University of Ibadan, Nigeria

Prof. Agbede, O.A., Jatau, N. D., Oluokun, G. O. and Akinniyi, B.D.
Department of Civil Engineering, University of Ibadan, Ibadan, Nigeria.

Abstract: *The study examined the geotechnical properties of soil supporting Egbogha building that has been revealing deep cracks around its wall. Soil samples were collected around the building for laboratory study. The properties determined were natural moisture content, particle size, Atterberg limits, compaction, and consolidation. The results of the tests show that the site is dominated with poorly graded soil with specific gravity (2.48- 2.63), liquid limit (26%-53%), optimum moisture content (13.50%-26.20%) and maximum dry density (1.50kN/m^3-1.94kN/m^3). According to the soil settlement estimated, the result indicated insignificant settlement at 1.5m depth. According to the classification of potential swell of the soil, the soil has medium potential for shrinkage or swelling. This could be attributed to high clay content in the soil. Hence, the soil has tendency for expansion. This therefore suggested that the cause of the noticed cracks on the structure under study could be as a result of the expansive soil supporting the structure's foundation. Massive infiltration of water into the foundation occurs during raining season, and on dying up results into differential heave and the effect is pronounced on the wall through cracks.*

Keywords: *Building collapse, cracks, geotechnical test, settlement, soil.*

I. INTRODUCTION

Building collapse around the world has claimed a lot of lives and properties [1]. Researchers have established that some of the collapses can be attributed to several factors among which are wrong construction methodology or foundation problems [1]. The incessant failures of building nowadays are so enormous that it's now a serious concern to all the building construction stakeholders including the general public. Building construction comprises of many stakeholders and individual has different role to play. The Architect is not expected to do the assignment of civil engineer and even civil engineer should not stand in for geotechnical expert. This seems to contribute greatly to foundation problems. It is unfortunate that severally members of public held the architect and building (civil) engineer who most time directly involved in the construction responsible for building failures while the geotechnical engineer who has or expected to confirm the capability of the soil supporting the structure is exempted. Studies have shown that the frequent collapse of some buildings in major cities in Nigeria can be attributed to the absence of a geotechnical report on the project site before, during and after the construction exercise [1]. A case study of a collapsed four storey residential building covering 420 m^2 at No. 56 Bola Street, Ebute-Metta, Lagos, Nigeria that collapsed on 26th July, 2006 was as a result of the existence of reddish brown silty clayey material and compressible waste material like wood, plastic and nylon occurring from ground surface to about 11 m on which a shallow strip foundation was used [2]. Losses made from this building collapse would have not occurred if necessary geotechnical investigation of the site has been carried out before, during or after construction. Similar case study was the issue of 3-storey building collapse which occurs along Bank road, Port-Harcourt, Nigeria. The result of the liquid limit, plasticity index, shrinkage potential, moisture content, tri-axial stress range and coefficient of consolidation carried out on the building locations indicates that the soil have low bearing capacity to support the structure. Although the collapsed was also attributed to under design, improper supervision, poor quality construction, use of sub-standard construction materials and engagement of non-professionals (quacks) [2, 3]. It is therefore necessary to carry out geotechnical investigation of soil supporting building structure before, during and after construction. It is necessary before construction to establish the type of soil, its bearing capacity and the settlement characteristics. This helps to confirm the ability of the soil to safely support the proposed structure. During construction, it is necessary to confirm the properties of the materials filling into the structure during backfilling of foundation and after construction, whenever any defect like cracks is noticed on the structure. This paper therefore investigates into geotechnical properties of soil supporting Egbogha building, University of Ibadan, southwestern Nigeria after several years of construction. This is to confirm whether foundation soil properties contribute to the observed cracks on the wall of the structure. This is necessary in order to mitigate or ameliorate future collapse of the building.

II. METHODOLOGY

2.1 The Study Area

The study was conducted at University of Ibadan (UI), Nigeria. The building under study is two storey with basement complex and housed offices, classrooms, a laboratory, library and a computer room (Plate 1). This building is located in a flat, low terrain with an upper layer of loose lateritic clayey soils while the underlying soil is a sandy soil mixed with silty clay material. It lies between latitude $7^{0}30^{'}$ north of the Equator, and Longitude of $3^{0}30^{'}$ and 4^{0} east of the Greenwich meridian. Figure 1 shows the location of the study area on UI map. The structure has been in existence for about seven (7) years (commissioned on 20th December; 2008).

Plate 1: Photographic front elevation of Building under study

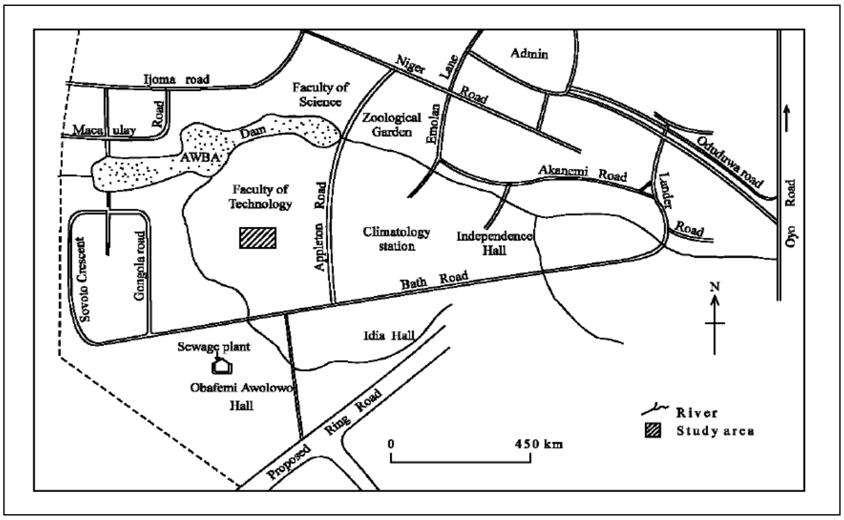

Figure1: Location map showing the study area, Faculty of Technology, University of Ibadan
Source: Badmus, B.S. 2010

2.2 Preliminary survey, Sample Collection and Preparation

An inception survey was carried out at the beginning of the study. This includes moving round the building structure under study and making findings about design and construction process of the building. Also established was the maintenance culture practice to keep the building stand.

A total of thirty six (36) samples were from six (6) sampling points established around the building with each point about 2meters away from the building (Figure 2). This made up of eighteen (18) disturbed and eighteen (18) undisturbed samples collected at 0.5, 1.0 and 1.5m depth.

The samples were secured in a black polythene bags to prevent loss of natural moisture content of the soil. Samples were prepared in accordance with [4].

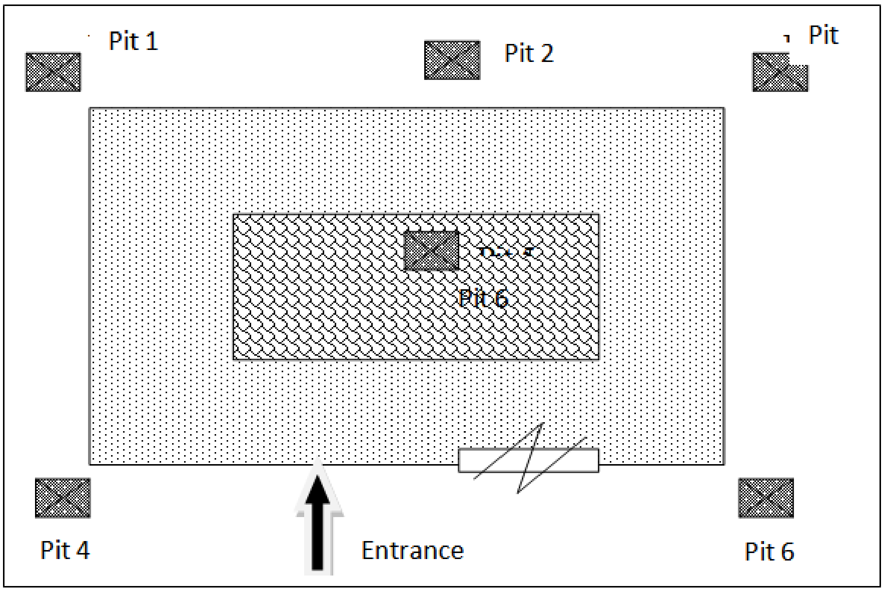

Figure 2: Cross section of sampling points around the structure

2.3 Test Procedures:

The following geotechnical tests were conducted on the prepared soil samples: particle size analysis, Atterberg limit, linear shrinkage limit, specific gravity, compaction and consolidation in accordance with [4, 5].

.

III RESULTS AND DISCUSSION

3.1 Geotechnical Properties and Soil classification

The results of the geotechnical tests carried out were presented in Table 1 and 2. Table 1 consists of the results of other tests except consolidation while Table 2 contains the consolidation result and the settlement estimated. Physical index property of the soils such as Atterberg limits, specific gravity and particle size distribution were used in the classification of the soil. Table 1indicated that foundation soil supporting the building under study contains soil with sandy clayey material with percentage of sand ranges from 66.2% to 88.05% and clay content from 5.5% to31.98%. The result further indicated that the soil can be classified as poorly graded and well graded sandy clay soil. The plasticity index result which is the difference between liquid limit and plastic limit ranges from 0.5% to 34.33%. This indicated that the soil can be further classified as sandy clay soil of low to high plasticity. The plastic limit value of the soil indicates high clay content present in the soil and a higher plasticity index implies that the soil has inherent swelling potential shrinkage tendency [5,6]. This is evidenced in the shrinkage limit values in Table 1 [7].

The table further indicated that the specific gravity of the soil ranges from 2.48 to 2.63. This suggested that the soil is highly influenced by fined grained [4,5, 7] The result obtained from natural moisture content and shrinkage tests indicated that the natural moisture content of the foundation soil supporting the building ranges from 2.55% to 34.92% with linear shrinkage coefficient ranges from 12.5% to14.65%. These results suggested that the soil has high ability to hold water during wet season which when loss during dry season could cause serious shrinkage as obvious by the high coefficient of linear shrinkage of the soil. The result of the compaction test on the soil indicated an optimum moisture content ranges 12.3% to26.2% and the dry density ranges from1.5kN/m^3 to 1.94kN/m^3. High density of soil implies hard soil while low density means soft soil. According to [8], the result of this study suggested that the soil contain some inorganic silt or clay (soil with optimum moisture content of 18.51% can be described having inorganic silt or clay silt or organic silt).

According to Table 2, the coefficient of consolidation, Cv ranges from 24.02 mm^2/min to 49.625 mm^2/min and that volume compressibility, mv ranges from $2.67x10^{-6}$ to $6.43x\ 10^{-4}$ mm^2/MN. The compression index, Cc ranges from 0.002017 to 0.064031. The result suggested a soil with relatively low coefficient of consolidation. This may be attributed to the poor hydraulic conductivity of the soil; hence the soil will continue to reduce in volume over a long period of time after the immediate settlement and may be several times greater than the immediate settlement [1]. The consolidation settlement experienced by the soil ranges from 0.91mm to 9.36mm. The consolidation settlement is the final results of a structure built over saturated clay and is the gradual reduction in volume of a fully saturated soil of low permeability due to drainage of some of the pore water. This settlement is considerably low and may not be the result of the cracks noticed on the wall of the structure. The coefficient of volume compressibility is used to estimate consolidation settlement. The result further indicates that the foundation soil possessed high coefficient of volume compressibility, mostly found in organic alluvial clays (with mv.$1.5x10^{-6}$mm²/MN) – [1].

Table 1.0: Laboratory Soil test results

Test	Depth	Natural Moisture content %	Gravel	Sand	Clay/silt	Cu	Cc	Soil classification	Specific gravity	Liquid limit %	Plastic limit %	Plasticity index %	Linear Shrinkage coefficient %	Opt Moisture Content %	Max. dry density g/cm3
A1S1	0.5	25.76	3.45	84.33	11.6	1.6	9.2	SP	2.48	51	31.67	19.33	13.22	22.5	1.67
A1S2	1	25.93	0.2	76.03	23.3	1.3	6.5	SP	2.56	46	17.86	28.14	13.93	18.5	1.88
A1S3	1.5	26.93	0.05	67.7	31.8	0.8	7.5	SW	2.59	47	36.67	10.33	15	23	1.68
A2S1	0.5	8.84	1.03	78.1	20.58	1.4	6.5	SP	2.6	48	72.91	24.91	13.93	17.2	1.5
A2S2	1	2.55	10.13	73.95	15.73	0.9	7.8	SW	2.62	26	36.76	10.76	13.57	13.5	1.89
A2S3	1.5	6.53	16.8	69.38	8.72	1.2	5.2	SW	2.54	52	52.5	0.5	11.79	12.3	1.8
A3S1	0.5	14.27	2.75	82.18	14.68	1.1	6.4	SP	2.6	37	35.67	1.33	13.22	16.2	1.59
A3S2	1	21.13	0.8	84.85	14.3	2.8	9.1	SP	2.54	51	36.1	14.9	13.57	26.2	1.56
A3S3	1.5	22.64	4.93	88.05	6.5	1.2	5.2	SW	2.63	43	27.58	15.42	12.5	15.1	1.68
A4S1	0.5	19.47	7.38	80.85	10.5	1.8	8.8	SP	2.51	44	56.58	12.58	13.22	17.1	1.71
A4S2	1	29.45	16.92	77.37	5.5	1.2	6.8	SP	2.5	42	25.08	16.92	12.86	17.2	1.88
A4S3	1.5	23.01	2.13	80.9	16.95	2	12.5	SP	2.59	53	21.4	31.6	13.57	22	1.67
A5S1	0.5	18.19	9	78.95	11.23	1.3	7.6	SP	2.6	43	22.5	20.5	13.57	18	1.62
A5S2	1	23.38	6.83	83.62	9.05	1.1	6.2	SP	2.56	52	34.91	17.09	13.57	22.5	1.68
A5S3	1.5	31.69	4.85	83.33	10.95	0.9	5.3	SW	2.59	33	19.75	13.25	13.22	14	1.94
A6S1	0.5	21.28	8.78	77.05	13.5	1	6.7	SW	2.51	49	38.46	10.54	13.93	16.5	1.82
A6S2	1	34.92	7.45	65.18	27.2	1.2	6.7	SP	2.54	46	11.67	34.33	14.65	16.4	1.77
A6S3	1.5	23.54	1.8	66.2	31.98	1.1	7.5	SP	2.63	48	40	8	14.65	25	1.58

Table 2: Consolidation characteristics and Settlement of the soil

Test	Coefficient of Consolidation, Cv (mm^2/min)	Coefficient of Vol compressibility mv(mm2/MN)	Compression Index, Cc	Settlement (mm)	Settlement at a poin (mm)
A1S1	36.11	3.24E-05	0.064031	1.95	
A1S2	36.435	1.04E-05	0.016613	0.39	7.14
A1S3	49.214	4.80E-04	0.370482	4.8	
A2S1	20.45	1.57E-04	0.022781	0.31	
A2S2	26.694	7.19E-06	0.010816	0.14	0.91
A2S3	40.47	7.60E-06	0.010885	0.46	
A3S1	37.05	8.22E-06	0.011218	0.58	
A3S2	32.412	8.05E-06	0.009057	0.52	1.31
A3S3	41.051	2.67E-06	0.002793	0.21	
A4S1	45.843	1.74E-06	0.002017	0.25	
A4S2	28.694	2.73 E-04	0.118784	4.37	7.3
A4S3	21.428	2.71 E-04	0.113663	2.71	
A5S1	37.712	6.25E-05	0.022817	0.99	
A5S2	24.02	6.43 E-04	0.289632	6.43	9.36
A5S3	47.667	5.69E-05	0.030502	1.94	
A6S1	49.625	2.64E-05	0.018419	1.45	
A6S2	42.391	2.22 E-04	0.076799	4.21	6.26
A6S3	31.133	3.24E-05	0.014407	0.59	

V. CONCLUSION AND RECOMMENDATIONS

Based on the geotechnical results obtained from the soil test conducted on the soil sample from the study area it was concluded that;

1. The foundation soil contains soil with sandy-clay soil possibly contaminated with inorganic silty soil.
2. The cracks are very growing from mild to severe, affecting the structural formation of the building (Plate 2a and b).
3. Settlement is not the major cause of the observed cracks on the building.
4. The cracks could be attributed to expansive soil supporting the foundation of the building. The soil foundation contains a considerably high amount of clay with high plasticity index
5. Water massively absorbed during raining season when dried up or withdrawn from the foundation during dry season could result in differential heave and the effect of this could be the observed cracks on the wall.

Based on findings obtained from this study the following recommendations are made towards securing the structure:

1. A proper and adequate drainage system should be constructed around the buildings to prevent continuous washing away of the building's foundation foot.
2. Sinking of boreholes or use of the equipment with dynamic load like blasting should be avoided around the structure because this could shake the building and increase the width of noticed cracks.
3. Timely repairs of cracks should be ensured. This will cut continuous effect of any further shaking of the building.
4. The usage of the building should be put under monitoring to avoid any overloading of the structure.
5. The foundation supporting the structure should be under further soil settlement investigation.

Plate 2a: Mild crack noticed on the structure

Plate 2b: Severe cracks noticed on the structure

V. ACKNOWLEDGEMENTS

Sincere appreciation goes to the Management and staff of Civil and Petroleum Engineering Departments, University of Ibadan, Nigeria, for their cooperation to have access to the facility for the purpose of sample collection for this study and for impleting some of the recommendations provided by this study. Thanks to Mr. Olasupo of the Geotechnical Engineering laboratory, Department of Civil Engineering, OAU, Ile-Ife and Mr. Akinyele and Co. of Soil Mechanics laboratory of University of Ibadan, for their availability and assistance during the laboratory work.

REFERENCES

[1] Amadi A. N., Eze C. J., Igwe C. O., Okunlola I. A. & Okoye N. O. Architect's and Geologist's View on the Causes of Building Failures in Nigeria. *Modern Applied Science*; *Vol. 6, No. 6*; 2012, ISSN 1913-1844 E-ISSN 1913-1852

[2] Oke, S. A., & Amadi, A. N. An assessment of the geotechnical properties of the subsoil of parts of Federal University of Technology, Minna, Gidan -Kwano Campus, for foundation design and construction. *Journal of Science, Education and Technology, 1(2)*, 2008, 87-102.

[3] Oke, S. A., Amadi, A. N., Abalaka, A. E., & Akerele, R. T. Result of subsoil investigation on a collapsed building site in Lagos.*Nigerian Journal of Construction Technology and Management, 10*(1&2), 2009a, 36-45.

[4] British Standard 1377. Methods of test for soils for civil engineering properties (London, UK: British Standard Institution), 1990, 143.

[5] Adunoye, G.O. and Agbede, O.A. Geotechnical Evaluation of Opa Dam, Obafemi Awolowo University, Ile-Ife, Nigeria. *The International Journal of Engineering and Science (IJES*), *Volume 2*, 2013, 160-165.

[6] Arora K. R.. Soil mechanics and foundation engineering standard. *Publishers Distributors, Delhi*, 2008, 118.

[7] Afolagboye O. L. and Talabi A. O.Consolidation properties of compacted lateritic soil stabilized with tyre ash JEMT, 2013, 205-353.

[8] Krebs, R. D., and Zipper, C. E. Foundations for Housing on Reclaimed Mine Lands. Retrieved February 13, 2008, from http://www.ext.vt.edu/pubs/mines/460.