Journal of Science and Technology Research 2(1) 2020 pp. 85-93 ISSN-2682-5821

NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

The Influence of Moisture Content on Settlement of Compacted Soils

***Kayode-Ojo, N*[a] *and Ighavongbe G. E.*[b]**

[a,b]*Department of Civil Engineering, Faculty of Engineering, University of Benin, Benin City, Edo State, Nigeria.*
Email: engrngozi@yahoo.com , Phone: +234 802 352 2239
Email: oghosaokhuaihesuyi@gmail.com, Phone: +234 802 399 2815

Article Info

***Keywords*:**
Consolidation settlement, Compaction, Moisture content, Elastic settlement, Silty clay

Received 23 January 2020
Revised 30 January 2020
Accepted 01 February 2020
Available online 02 March 2020

Abstract

Compaction of soils is an important pre-requisite for the construction of man-made structures like roads, dams, embankments etc. Likewise, the consolidation test is of great importance as the consolidation properties determined from the test are used to estimate the magnitude and the rate of both elastic and primary consolidation settlement of a structure. This paper focuses on the effect of moisture content on settlement in compacted soils. Soil samples were obtained from Useh, Upper Siluko road in Egor Local Government Area of Edo State. Geotechnical properties of the soil samples were carried out in accordance with the British Standard codes. The results revealed that the soils in the area are silty clay, the consolidation settlement were negligible but will increase when inundated with water, indicating that the soils from the location can actually withstand settlement problems.

1. Introduction

The ability of soil to bear the loads of structures or moving loads while remaining stable is of a serious concern in construction activities. Ensuring long-term stability requires proper compaction and consolidation of soil before a permanent load is placed upon it. Excavation processes disturb soil, loosen them and cause void spaces between soil particles to become much larger [1]. For this reason, engineering specifications often require that foundations be placed on undisturbed soils [2]. In areas where structures are built partially or completely on fill, such as structures built on hillsides, the fill must be made as solid as possible before a permanent load is placed on it. This is done by mechanical compaction of the soil. Soil is placed in layers (called “lifts”). Each layer is mechanically compacted by impact and sometimes by vibration. The compaction process forces out air from the spaces between soil particles. Compaction, which increases the density of the soil and improves its ability to bear a load, is greatly affected by the soil type (clay, sand, silt, level of organic matter, etc.), soil characteristics (uniformity, gradient, plasticity, etc.), soil thickness, method of compaction, and the moisture content at the time of compaction [3].

Soil undergoes both elastic and primary consolidation. Elastic consolidation is short-term and takes place during the mechanical compacting process. Secondary consolidation is long-term and takes place after the compaction process is complete and the permanent loads are in place [2]. During primary consolidation, the weight placed on soil slowly forces water out of the pore spaces between soil particles. As this happens, soil particles will move close together and settlement will occur. The source of the weight would be both the structure and the overlying soil. The amount of primary consolidation which can be expected increases with the depth of the affected area. A common scenario is when a structure is built partly on undisturbed soil and partly on compacted fill. Soil in these two areas will consolidate at different rates as the weight of the newly-built structure forces water out of the soil particles; this is called “differential settlement”. In adequately-compacted soil, settling will be so minor that evidence would not be visible. Extreme differential settlement will create stresses which are relieved by cracking [4]. Compaction and consolidation are affected by the composition of the soil as fine-grained soils have more interior surface area and can hold more air and water than coarse-grained soils. When a saturated stratum of sandy soil is subjected to a stress increase, such as that caused by the erection of a building on the ground surface, the pore water pressure is increased. This increase in pore pressure leads to drainage of some water from the voids of the soil [5]. Due to the relatively high permeability of the sandy soil this drainage process will occur quite quickly. In other words, the pore pressure increase will dissipate rapidly. As a consequence of the drainage of some water from the soil, volume change will occur and settlement will take place. When a saturated stratum of clayey soil is subjected to a stress increase, the dissipation of the excess pore pressure generated will take place much more slowly because of the relatively low permeability of the clayey soil [6]. This means that the settlement, caused by the drainage of some water from the voids of the soil, will take place gradually over a long period of time. The process of gradual transfer of stress from the pore pressure to effective stress with the associated volume change is referred to as consolidation. The rate at which the settlement occurs depends upon the rate at which water is expelled from the soil and this depends upon the total head gradient and the permeability of the soil [7].

The most difficult problem a Geotechnical Engineer is asked to solve is the accurate prediction of the settlement of a loaded foundation. The problem is in two distinct parts: the value of the total settlement that will occur and the rate at which this value will be achieved. The settlement of structures founded on soil is a subject of considerable interest to practicing engineers since excessive settlements often lead to serviceability problems. Various failed and abandoned structures in the study area, Useh, Upper Siluko area of Benin City located in Egor Local Government Area, where occupants have evacuated their homes due to settlement problems is a pressing example of this (Figure 1). Thus, the necessity of this study which aim is to discover the influence of varying moisture on the settlement of compacted soils. The objectives are to determine the basic geotechnical and strength properties of the soil, ascertain the settlement parameters of compacted soil, assess the settlement behaviour of compacted soil when inundated with water and use a mathematical and statistical model that will help to establish the relationship between moisture content and consolidation settlement.

2. Methodology

2.1 Site Description

Useh is located in Upper Siluko road, Egor Local Government Area of Benin City, Edo state and lies between latitude 05^{o} 45’ E and longitude 09^{o} 31’ N. This area is known for its susceptibility to settlement problems which has caused some residents deserting their homes for fear of their safety.

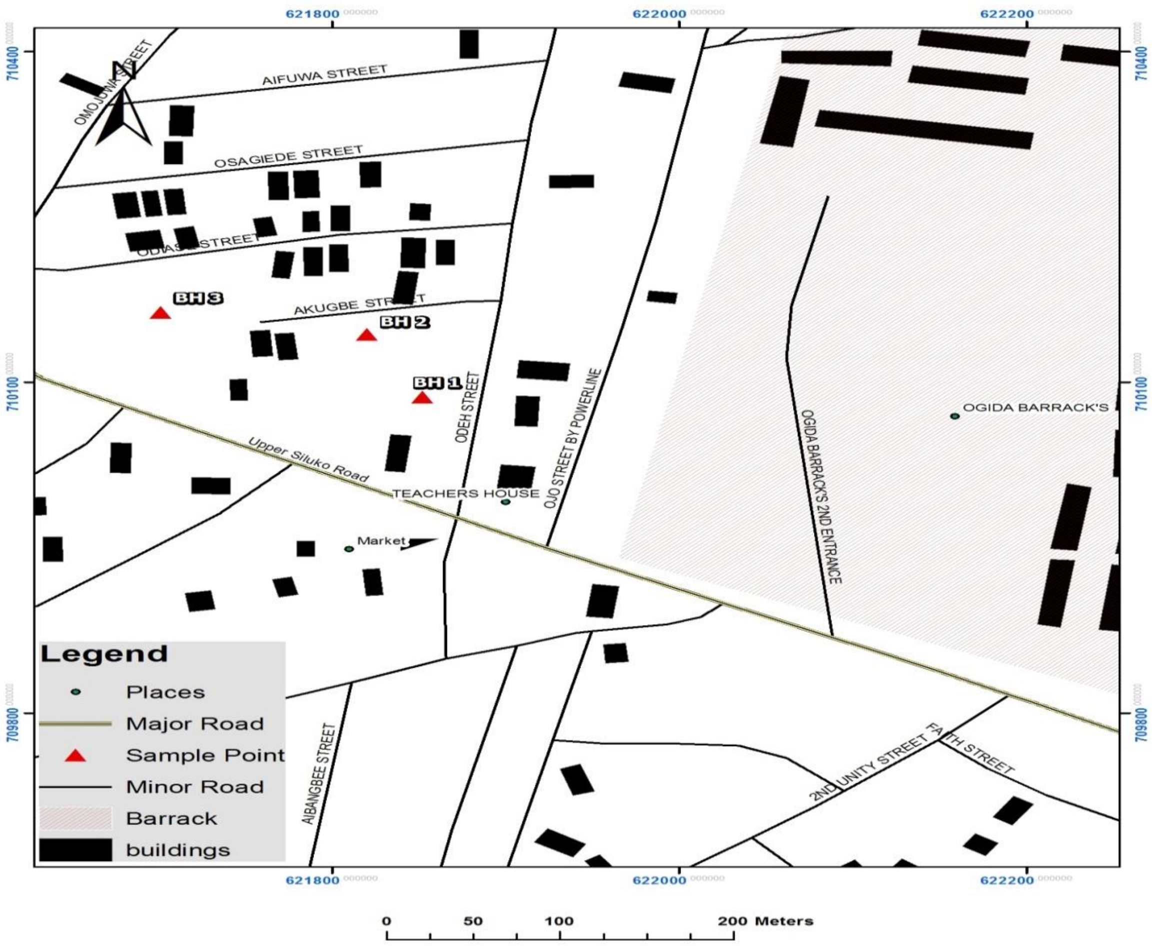

Figure 1: Map of Study Area

2.2 Research Procedure

This study provides an overview for an in-depth study of foundation settlement, to accurately discern the effect of wetting of the soil on the settlement of compacted soils. Various steps were carried out in this research work as follows: Reconnaissance survey, Field geotechnical sampling, and Laboratory testing.

2.2.1 Reconnaisance Survey

A reconnaissance survey was carried out in Useh, Upper Siluko road, Egor Local Government Area which showed that for a long time, there has been settlement problems associated with the area which has resulted in a lot of indigenes being rendered homeless and even subsequent loss of lives.

Table 1: Sampling Point Location

S/N	LOCATION	DEPTH (m)	CO-ORDINATES	
			N	E
1	BH 1	1.15	06.36603^{O}	005.58596^{O}
2	BH 2	1.0 – 2.0	06.36608^{O}	005.58582^{O}
3	BH 3	1.0 – 2.0	06.36643^{O}	005.58515^{O}

2.2.2 Field Geotechnical Sampling & Laboratory Testing

A total of five undisturbed samples were collected from the three sampling points at depths 1.5m in borehole one (BH1), depths 1m and 2m in boreholes two (BH2) and three (BH3) as shown in Table 1. The tests carried out include, particle size distribution (sieve analysis and hydrometer), natural moisture content, specific gravity, atterberg limit test, compaction, oedometer (consolidation). All laboratory tests carried out were done according to the general specification given in the British specification BS 1377, 1990, 'Methods of Testing Soil for Civil Engineering Purposes' and American (ASTM) standards [8].

3. Results and Discussion

Results acquired from the various test carried out are presented in Table 2.

Table 2: Geotechnical Investigation Results

	Sample depth (m)	NMC (%)	Gs	Sieve analysis (mm) Sieve Percentage passing (%)			Atterberg limit (%)			BS Compaction Standard Proctor 2.5Kg MDD (g/cm3)	**OMC (%)**	Soil Classification
				1.18	0.425	0.075	LL	PL	PI			
1	BH1 1.5	56.28	2.23	99.63	90.18	74.50	61.04	29.95	31.09	1.26	29.8	A-7-6
2	BH2 1.0	13.19	2.56	98.22	86.39	66.15	28.59	11.87	16.72	1.83	12.1	A-7-6
3	BH2 2.0	43.49	2.31	99.92	99.23	91.89	45.65	24.21	21.43	1.28	30.6	A-7-6
4	BH3 1.0	29.87	2.53	99.59	91.31	85.67	39.26	18.08	21.18	1.58	18.4	A-2-6
5	BH3 2.0	26.50	2.56	99.39	90.89	86.76	45.04	20.10	24.94	1.52	20.6	A-7-6

NMC Natural Moisture Content
G_s Specific Gravity
OMC Optimum Moisture Content

The result of the natural moisture content test shows that the natural moisture content of the soil ranges from 13.19% to 56.28%. The specific gravity result shows that the specific gravity ranges from 2.23 – 2.56. BH 1, 1.5m and BH 2, 2.0m shows that the materials have clay contents while BH2,1.0m, BH3 1.0m and BH3,2.0m shows that the soil contains silt, clay, sand.

It can be seen from the soil particle passing through the 1.18mm sieve ranges from 98.22% - 99.63%, the percentage passing through the sieve 0.425mm sieve ranges from 86.39% - 99.23% while the percentage passing through the 0.075mm sieve ranges from 66.15% – 91.89% . On the average the soil materials are silty clayey soils as the percentage passing the 0.075mm sieves is above 35%. (i.e. 66.15% to 91.89%)

The atterberg limit test result shows that the soils from the three boreholes are Silty clays the liquid limit of the soil ranges from 28.59% to 61.04%, the plastic limit ranging from 11.87% to 29.95% and the plasticity index ranges from 16.72% to 31.09%. This implies the soils plasticity varies from low to high plasticity clay in accordance with AASHTO classification [9]

Results from the compaction test shows that the designated samples BH1.1.5m, BH2, 2.0m and BH3, 2.0m have high optimum moisture contents (OMC) which indicates the presence of clay contents this suggest the soil is subject to extremely high volume change in agreement with Tatsuoka and Correia in 2016 [10]. Also the maximum dry density (MDD) ranges from 1.26g/cm3 to 1.83g/cm^3. Again BH2, 1.0m and BH3, 1.0m show the soil is clayey Silty.

3.1 Consolidation Test

The consolidation settlement (Sc) and the final moisture content (MC$_f$) for the boreholes experimented in this research are shown in Tables 3 – 5.

Table 3: Consolidation Test Result for BH1

S/N	Pressure (kN/m^2)	MC$_F$	BHI Sc (mm)
1	39.96	29.9%	0.003103298
2	79.93		0.00639696
3	159.86		0.008042936
4	319.71		0.008139527
5	639.43		0.00678895
6	39.96	33.47%	0.008203055
7	79.93		0.00199898
8	159.86		0.005595576
9	319.71		0.006592608
10	639.43		0.007189344
11	39.96	31.37%	0.006602988
12	79.93		0.003298367
13	159.86		0.005196074
14	319.71		0.005194722
15	639.43		0.006391456
16	39.96	27.62%	0.015200339
17	79.93		0.007491488
18	159.86		0.007189236
19	319.71		0.007386199
20	639.43		0.006535639
21	39.96	52.94	0.010152791
22	79.93		0.015679708
23	159.86		0.018409133
24	319.71		0.014258101
25	639.43		0.018528204

Table 4: Consolidation Test Result for BH2 at depth of 1.0m

S/N	BH	Pressure	MC$_F$	Sc (mm)
1	BH2, 1.0m	39.96	12.65%	0.002202
2		79.93		0.0009998
3		159.86		0.0019995
4		319.71		0.002499
5		639.43		0.0026986
6		39.96	13.76%	0.0029532
7		79.93		0.0026493
8		159.86		0.0035983
9		319.71		0.004397
10		639.43		0.0039965
11		39.96	13.28%	0.0072546
12		79.93		0.0031484

13		159.86		0.0038972
14		319.71		0.0046955
15		639.43		0.0099855
16		39.96	11.25%	0.0026529
17		79.93		0.0122209
18		159.86		0.0025678
19		319.71		0.002947
20		639.43		0.0029965
21		39.96	13.29	0.0015318
22		79.93		0.0023995
23		159.86		0.0026991
24		319.71		0.0027987
25		639.43		0.0027983
26	BH2, 2.0m	39.96	29.90%	0.0063043
27		79.93		0.007295
28		159.86		0.0080912
29		319.71		0.0082876
30		639.43		0.0070868
31		39.96	30.25%	0.002202
32		79.93		0.0017996
33		159.86		0.0038985
34		319.71		0.0050967
35		639.43		0.0059943
36		39.96	22.70%	0.0013012
37		79.93		0.0020996
38		159.86		0.0049479
39		319.71		0.0048468
40		639.43		0.0082911
41		39.96	35.64%	0.009407
42		79.93		0.0049465
43		159.86		0.005944
44		319.71		0.0061918
45		639.43		0.0062897
46		39.96	62.00%	0.0136044
47		79.93		0.0136813
48		159.86		0.0156663
49		319.71		0.0212813
50		639.43		0.013547

Table 5a: Consolidation Test Result for BH3 at depth of 1.0m

S/N	BH	Pressure	MC_F	Sc (mm)
1	BH3, 1.0m	39.96	19.21%	0.00495373
2		79.93		0.00304878
3		159.86		0.0039976
4		319.71		0.00499575
5		639.43		0.00549381
6		39.96	18.90%	0.00495373
7		79.93		0.00304878
8		159.86		0.0039976
9		319.71		0.00499575
10		639.43		0.00549381
11		39.96	18.01%	0.00485368
12		79.93		0.0028489
13		159.86		0.0044473
14		319.71		0.00564497
15		639.43		0.00434518
16		39.96	176.19%	0.01300455
17		79.93		0.00479573
18		159.86		0.00629241
19		319.71		0.00619061
20		639.43		0.00578953
21		39.96	59.18	0.01205479
22		79.93		0.01353266
23		159.86		0.01467038
24		319.71		0.01480905
25		639.43		0.01330428

Table 5b: Consolidation Test Result for BH3 at depth of 2.0m

S/N	BH	Pressure	MC_F	Sc (mm)
26	BH3, 2.0m	39.96	19.80%	0.0063043
27		79.93		0.0035982
28		159.86		0.0060851
29		319.71		0.0079505
30		639.43		0.0050926
31		39.96	23.52%	0.009025
32		79.93		0.0027284
33		159.86		0.0045463
34		319.71		0.0051944
35		639.43		0.0055924
36		39.96	18.01%	0.0048537
37		79.93		0.0028489
38		159.86		0.0044473

39		319.71		0.005645
40		639.43		0.0043452
41		39.96	19.40%	0.0039031
42		79.93		0.0042982
43		159.86		0.0050966
44		319.71		0.0051952
45		639.43		0.0096863
46		39.96	43.14%	0.0287374
47		79.93		0.0118259
48		159.86		0.0097753
49		319.71		0.0149012
50		639.43		0.0089665

The overall results of the consolidation tests carried out showed that the consolidation settlement is very negligible, implying that the soil in the location do not actually have settlement problems [11]. It also indicated that when the soil is subjected to load it tends to compress at a minimal level and will settle more when inundated with water.

4. Conclusion

From the results obtained from the laboratory tests, the following conclusions can be made: the soil in the area according to AASHTO are classified as A-2-6 and A-7-6 this indicates the soil has a low to moderate shrink-swell potential. The consolidation test carried out shows that the consolidation settlement is very negligible, implying that the soil in the location do not actually have settlement problems. It also indicated that when the soil is subjected to load it tends to compress at a minimal level and tends to settle more when inundated with water

References

[1] Ehiorobo, J. O., Izinyon, O. C. and Ogirigbo, R. O. (2015). “Measurement and Documentation for structural Integrity Assessment of In-Service Building at Risk”. http://fig.net/pub/fig2013/T307E_Ehiorobo_Izinyon_et_al 6638pdf.

[2] Gomes, C A. (2008). Innovations in design and construction of granular pavements and railways Advances in Transportation Geotechnics: Proc. of the 1st International Conference on Transportation Geotechnics (Eds: Ellis, E., Yu, Hai-Sui, McDowell, G., Dawson, A.R. & Thom, N.), 1-13. CRC Press, London, UK.

[3] Gordon, A. Fenton, and Griffiths, D. V. (2002). “Probabilistic Foundation Settlement on a Spatially Random Soil”, ASCE J. Geotech. and Geoenv. Engr., 128(5), 381–390.

[4] Acaron, J. M. (2015). Soils and Settlement (Waterford Lakes, Orlando, Florida). Home Inspectoz with Home Inspector USA HI-80 & MRSA 1895. http://activerain.com/blogsview/4786904/soils-and-settlement--waterford-lakes--orlando--florida. Accessed on February 17, 2016.

[5] Das, B. M. (2010). “Principle of Geotechnical Engineering” 7th Edition, Cengage Learning Publishers. USA.

[6] Taylor, D. W. (1948). “Fundamentals of Soil Mechanics”, John Wiley & Sons, New York.

[7] Hadewych, V., Leen D. V., Evy, B. and Jan G. (2014). “Using Field Data to Improve the Settlement Prediction Model of a Breakwater on Soft Soil”, Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 140, No. 2, pp. 173-187.

[8] British Standard 1377, (1990). “Methods of Test for Soils for Civil Engineering Purposes”, British Standards Institution, London.

[9] AASHTO (1986) “Standard for Transportation Materials and Methods of Sampling and Testing” Fourteenth Edition, AASHTO: Washington, DC.

[10] Tatsuoka, F. and Correia, A. G. (2016). ‘’Importance of controlling the degree of saturation in soil compaction. Journal of Procedia Engineering, Volume 143, 2016, pp. 556 – 565.
[11] Craig, R. F. (2004). Craig’s Soil Mechanics Text 7th Edition. Published by Spon Press 29 West 35th Street, New York, NY 10001.ISBN 0-203-57441-9