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Investigating the Causes of Downward Displacement of Soil Using Compaction Test Analysis

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Abstract
Soil compaction is one of the ground improvement techniques. It is a method in which by expending compactivity energy on soil, the soil grains are more closely repositioned. Compaction rises the shear strength of soil and decreases its compressibility and permeability. The proper compaction of the soil is proposed to make certain that the compacted soil will unfailingly and in one-piece resist loads of numerous types. Soil was extracted at a depth of 600mm from two different locations and placed in an aluminium bowl. Laboratory compaction (Standard proctor compaction test), in-situ density and permeability test were conducted on the samples. The result of coefficient of permeability is 6.649×10^{-5} *and was compared to the standard and was observed to be a very fine sand soil which has a poor drainage condition and not suitable as fillings for under-laying material for interlocking pavement concrete stone. The soil was seen to have a poor drainage condition when compared with the standard and this indicated that passage of water through it will be difficult and could lead to erosion. After the in-situ density test and laboratory test were conducted, the results were compared to know the level of compaction required for the soil. The result shows that the level of compaction done before the laying of the interlocking concrete stone is very poor when compared to the acceptable limit.*
Keywords
Soil compaction, in-situ density, permeability, standard proctor, settlement,

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I. Introduction

Soil displacement are usually as a result of either settlement or subsidence. While settlement occur due to reposition of soil from the over-bearing load, subsidence is cause by repositioning of ground elements due to presence of void. A mere physical observation is not enough to distinguish between these occurrences. The performance of every single foundation, road and airfields rest largely on the engineering features of the deposits of soil or rock lying beneath it [1]. Soil compaction is one of ground enhancement systems and it is a procedure in which by expending compactivity dynamism on soil, the soil grains are further thoroughly repositioned. Soil compressibility and permeability diminishes when compacted while shear strength rises [2-3]. Correct compaction of the soil is planned to confirm that the compacted soil resolves dependably and in one-piece bear loads of different types. Soil compaction on construction sites happens either consciously when foundations and sub-grades are ready or as an unplanned result of vehicular traffic flow [5]. It is good to note that soil compaction reduce porosity [4]. The intensity of compaction must be enumerated to distinguish the compaction grade of a soil and the level of remedy for the improvement of the soil compaction if necessary. Through compaction the bulk of air in a pavement blend is reduced by using outward forces to rearrange the component aggregate particles into a further closely space-out arrangement. This reduction of air quantity in a mixture gives an equivalent rise in unit weight or density [6]. Soil compaction is done in civil construction works to enhance the quality of soil utilized, for intensification of load-bearing capacity, avert soil clearance, frost destruction and ground instability and lessen sinking of soil, liquid seepage, swelling and contraction. When a soil is not appropriately compacted previous to construction, it could lead to settlement due to several events held on the area. In geotechnical engineering, research laboratory compaction ethics have been adhered, to compact cohesive soils such as Standard Proctor, which is used to evaluate the utmost soil density. In all compaction procedure, there is an optimum water content, which corresponds to the highest dry density. At any further water content, the subsequent dry density is less than the maximum density [7].

Plate 1a: Depressed Area

Plate 1b: Spaces between Interlocks

II. Material and Method

Soil was extracted at 600mm depth from different locations and placed in an aluminium bowl. Laboratory compaction (Standard Proctor compaction), in-situ density and permeability tests were carried out on the samples. The materials used for the laboratory compaction test includes compaction mould in which the sample was poured, No. 4 U.S. sieve (4.75 mm) in order to have even distribution of sample, standard proctor hammer to compact the sample, balance to determine mould weight with and without samples, moisture cans to put samples for drying, drying-oven to dry samples, squeeze bottle filled with water for the mixing of the sample to make it moist, steel straight edge to trim the excess samples that are above mould.

2.1 Laboratory compaction (Standard Proctor) Test

4.5 kg of dried soil was obtained in which compaction test was conducted. The samples were broken to reduce the lumps and then sieved using No.4 U.S. sieve. The samples were collected on the sieve and this should not be less than 2.7 kg. Water was added and mixed to produce moisture substance up to 5%. The Proctor mould base plate weight was determined without the extension on crest of the mould. The attachment was inserted and the moist soil poured into the three equal layers. Each layer was properly compacted by the proctor hammer for 25 times before pouring the next layer of loose soil. This was done such that the soil extends slightly above the

top of the rim of the compaction. The top attachment was removed such that it does not break off any of the compacted soil inside the mould. A straight edge was used to trim the excess soil above.
In determining the mould weight + compacted moist soil + seat plate in the mould, the base was removed from the mould and a jack was used to extrude the compacted soil cylinder from the mould. The mass of a moisture can was determined from the extruded moist soil. Moisture sample was amassed in the moisture can and it mass + moist soil was calculated. The container with the moist soil were placed in oven to dry to a uniform weight. The mass of the moisture cans + soil samples were determined the following day.

2.2 In-situ Density Test

This is a compaction test that is done on the field to establish the soil's dry density. The materials used are in-situ mould, spatula, balance, digger, shovel, in-situ hammer. The in-situ compaction mould is weighed on the balance. The interlocks are remove so as to retrieve the soil on the field. The top layer of the soil was removed to about 600 mm. The in-situ mould was positioned on top of the sol and the in-situ hammer was used to push the mould down the soil. The in-situ mould together with the soil sample was removed from the soil. The combined mould and soil were trimmed by using a spatula then weighed on a balance. The area where the test was carried out were refilled and the interlocks replaced. The moisture content of in-situ was immediately calculated in the laboratory.

2.3 Permeability Test (Constant Head Test)

The equipment used includes constant head permeameter, graduated cylinder, Balance, Rubber tubing, Stop watch. The mass of the plastic specimen tube, porous stones, spring and rubber stopper were determined. the bottom porous stone was slipped into the specimen tube, then the bottom rubber stopper was fixed to the specimen tube. Oven-dry sand was collected in a container. A spoon was used to pour the sand into the specimen tube in small layers and compacted by vibration. When the length of the specimen tube was about two-third the length of the tube, the top porous stone was slipped into the tube to rest firmly on the specimen. A rubber stopper was fixed to the top of the specimen tube so as not to allow any expansion of the specimen volume, and thus the void ratio, during the test. The mass of the assembly was determined and the length of the compacted specimen in the tube was measured. The permeameter was assembled near a sink. Water was running into the top of the large funnel fixed to the stand through a plastic tube from the water inlet. The water flowed through the specimen to the constant head chamber.

After some time, the water flowed into the sink through the outlet in the constant head chamber. The supply of water to the funnel was adjusted so that the water level in the funnel remains constant. At the same time the flow was allowed to continue for about 10 minutes in order to saturate. After a steady flow is established (that is, once the head difference h is constant), water flowing out of the constant head chamber *(Q)* was collected in a graduated cylinder. Collection time *(t)* was recorded with a stop watch. The step was repeated to keep the collection time *(t)* the same and determine Q. The average value of Q was calculated. The head difference h, was changed and steps repeated three times and the temperature of the water was recorded to the nearest degree.

Table 1: Coefficient of Permeability of some Soil (Casagrande and Fadum 1940)

K (cm/sec)	Soil Type	Drainage Condition
10^{1} to 10^{2}	Clean gravels	Good
10^{1}	Clean sand	Good
10^{-1} to 10^{-4}	Clean sand & gravels mixture	Good
10^{-5}	Very fine sand	Poor
10^{-6}	Silt	Poor
10^{-7} to 10^{-9}	Clay soil	Practically impervious

III. Results

Table 2: Permeability Test

AREA OF STANDING PIPE (a) (cm^2)	**0.882**	**COEFFICIENT OF PERMEABILITY (k) (cm/sec)**
CROSS SECTIONAL AREA OF SOIL SAMPLE (A) (cm^2)	81.713	$K = 2.303\left(\left(\frac{a.L}{A.t}\right) log\left(\frac{h1}{h2}\right)\right)$
LENGTH OF THE SAMPLE (L) (cm)	11.2	
INITIAL HEAD (h_1) (cm)	80	
FINAL HEAD (h_2) (cm)	78	
TIME INTERVAL (sec): TEST 1	43.49	7.042×10^{-5}
TEST 2	44.89	6.822×10^{-5}
TEST 3	45.76	6.692×10^{-5}
TEST 4	46.62	6.569×10^{-5}
TEST 5	49.18	6.227×10^{-5}
TEST 6	46.81	6.542×10^{-5}
AVERAGE	46.13	6.649×10^{-5}

Table 3: Laboratory Compaction Test for Sample A

COMPACTION

Location - Academy Building Car Park, FUTA

Sample - A

WT. CYL AND WET SAMPLE (g)	3500.00		3800.00		3900.00		4000.00		3800.00	
WT. OF CYLINDER (g)	1700.00		1700.00		1700.00		1700.00		1700.00	
WT. OF WET SAMPLE (g)	1800.00		2100.00		2200.00		2300.00		2100.00	
WET DENSITY (g/cc)	2.27		2.65		2.77		2.90		2.65	
CONTAINER NO.	1.00		2.00		3.00		4.00		5.00	
	T	**B**	**T**	**B**	**T**	**B**	**T**	**B**	**T**	**B**
WT. OF CONT. AND WET SAMPLE (g)	18.90	29.70	29.40	25.80	17.10	19.70	27.30	19.10	30.40	35.80
WT. OF CONT AND DRY SAMPLE (g)	18.00	29.00	28.50	24.90	16.00	18.30	25.90	17.70	28.10	33.60
WT. OF MOISTURE (g)	0.90	0.70	0.90	0.90	1.10	1.40	1.40	1.40	2.30	2.20
WT OF CONTAINER (g)	5.80	14.00	18.60	14.60	5.80	4.10	14.10	5.70	11.40	17.70
WT. OF DRY SAMPLE (g)	12.20	15.00	9.90	10.30	10.20	14.20	11.80	12.00	16.70	15.90
MOISTURE CONTENT %	7.38	4.67	9.09	8.74	10.78	9.86	11.86	11.67	13.77	13.84
AVG. MOISTURE CONTENT %	6.02		8.91		10.32		11.77		13.80	
DRY DENSITY (g/cc)	2.14		2.43		2.51		2.60		2.33	
C.B.R.										

OMC - 11.50%
MDD -2.62g/cc

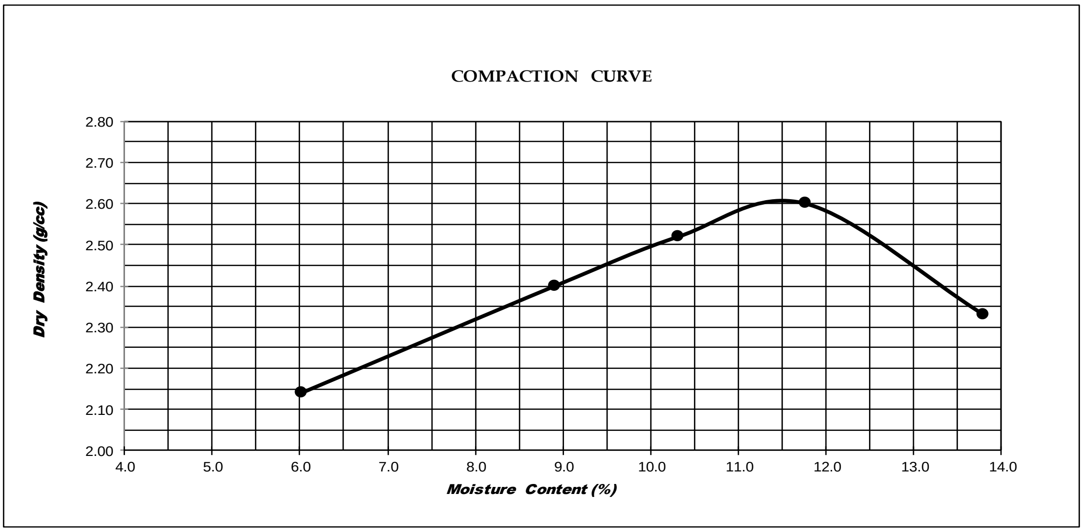

Table 4: Laboratory Compaction Test for Sample B

COMPACTION

Location - Academy Building Car Park, FUTA

Sample - B

WT. CYL AND WET SAMPLE (g)	3600.00		3800.00		4000.00		4000.00		3800.00	
WT. OF CYLINDER (g)	1700.00		1700.00		1700.00		1700.00		1700.00	
WT. OF WET SAMPLE (g)	1900.00		2100.00		2300.00		2300.00		2100.00	
WET DENSITY (g/cc)	2.40		2.65		2.90		2.90		2.65	
CONTAINER NO.	1.00		2.00		3.00		4.00		5.00	
	T	B	T	B	T	B	T	B	T	B
WT. OF CONT. AND WET SAMPLE (g)	60.70	62.50	61.50	60.70	61.40	57.40	58.90	58.30	52.10	42.70
WT. OF CONT AND DRY SAMPLE (g)	59.70	61.70	60.60	59.80	59.80	56.00	57.50	55.80	49.20	41.00
WT. OF MOISTURE (g)	1.00	0.80	0.90	0.90	1.60	1.40	1.40	2.50	2.90	1.70
WT OF CONTAINER (g)	35.10	43.90	45.40	44.70	41.50	41.00	43.80	33.90	27.40	29.00
WT. OF DRY SAMPLE (g)	24.60	17.80	15.20	15.10	18.30	15.00	13.70	21.90	21.80	12.00
MOISTURE CONTENT %	4.07	4.49	5.92	5.96	8.74	9.33	10.22	11.42	13.30	14.17
AVG. MOISTURE CONTENT %	4.28		5.94		9.04		10.82		13.73	
DRY DENSITY (g/cc)	2.30		2.50		2.66		2.62		2.33	
C.B.R.										

OMC - 9.75%
MDD -2.67g/cc

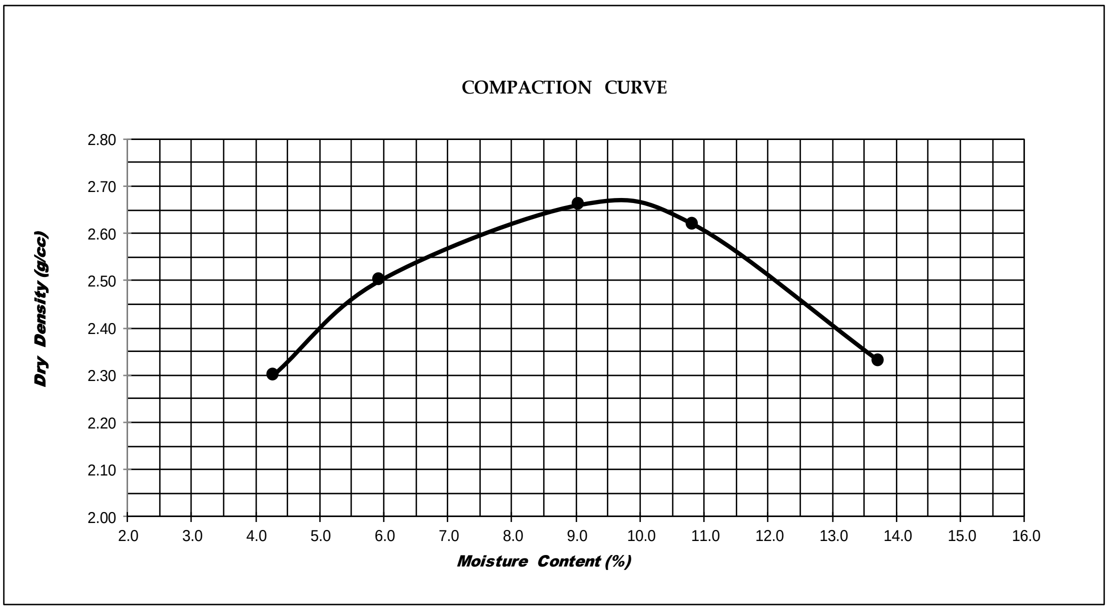

Table 5: In-situ Density Test

Sample	A	B
Weight of mould, g	1000	1000
Volume of Mould, cm^3	1062	1062
Weight of mould + soil, g	3400	3300
Weight of soil, *g*	2400	2300
Moisture content, *%*	9.14	9.4
Bulk Density, Kg/cm^3	2.26	2.17
Dry Density, Kg/cm^3	2.07	1.98

Table 6: Comparison between Compaction and In-situ Density Test

Sample	IN-SITU DENSITY		COMPACTION	
	Moisture Content (%)	Dry Density (g/cc)	Optimum Moisture Content (%)	Dry Density (G/Cc)
A	10.3	2.07	10.77	2.62
B	14.8	1.98	10.93	2.67

IV. Discussion

The result of coefficient of permeability of 6.649×10^{-5} from Table 2 was compared to the standard in Table 1 and was observed to be a very fine sand soil which has a poor drainage condition and not suitable as fillings for under-laying material for interlocking pavement concrete stone. This indicated that passage of water through it will be difficult and could lead to erosion. After the in-situ density test and laboratory tests were conducted, the results were compared to know the level of compaction required for the soil. The result shows that the level of compaction done before the laying of the interlocking concrete stone is very poor when compared to the acceptable limit. The in-situ density was found to be lesser than the acceptable limit of 0.2 g/cc for sample A and it has a dry density of 2.07 g/cc and that of laboratory compaction is 2.60 g/cc. The difference is seen to be 0.53 g/cc which is far above the limit. For sample B the in-situ density has a dry density of 1.98 g/cc and the laboratory compaction has a dry density of 2.67 g/cc, it is still seen to be higher than the acceptable limit for compaction.

V. Conclusion

After the tests was conducted on the soil sample, the soil is seen to be a sandy soil which has large pore spaces. Compaction in the field can fail if not properly done in layers (subgrade, sub base and base). When load exacted on the soil is more than that of the original designed, failure could occur. The presence of plant also could lead to sinking because water will be penetrating into the soil. As plants begin to grow, an increment in the diameter of the root will bringing about hole which in turn sinks when vehicle ply on them. The in-situ density has a dry density of 2.07 g/cc for sample A and 1.98 g/cc for sample B and when compared to the laboratory test dry density of 2.62 g/cc for sample A and 2.67 g/cc for sample B, it has a difference of 0.55 g/cc for sample A and 0.69 g/cc for sample B. This shows that the difference is more than the acceptable limit of 0.2 g/cc and indicates that the soil was poorly compacted on the field.
Therefore, the failure around the said building is as a result of settlement and not subsidence.

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