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ORIGINAL RESEARCH ARTICLE

EVALUATION OF SOIL SAMPLES IN ABEOKUTA-SOUTH LOCAL GOVERNMENT AREA OF OGUN STATE, SOUTHWESTERN NIGERIA

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ABSTRACT

This paper presents result of a laboratory investigation on soil samples from Abeokuta South Local Government, Southwestern Nigeria. Three comparative efforts namely standard Proctor (SP), West African Standard (WAS) and modified Proctor (MP), were employed. The results obtained showed that the compaction characteristics and unconfined compressive strength of the soil samples were found to increase with comparative effort. The unconfined compressive strength (UCS) values increased with compactive effort and decreased with increase in degree of saturation of the soil samples. All the samples did not meet the minimum specified requirements except for A1, A6 and A8. Upon stabilized with cement, samples A2 and A7 did not also meet the minimum CBR value of 180% as specified by the Nigerian General Specification for roads and bridgeworks (1997) or stabilized soil using standard Proctor compactive effort at 4% cement content. However, all the soil samples met the requirement using WAS compactive effort at 4% cement content. The samples met the conventional UCS values of (1500-3000 kN/m^2) for base course of lightly trafficked roads while only sample A4 compacted at 10% cement content using WAS compactive effort met the minimum (3000- 6000 kN/m^2) for base course of highly trafficked road. It is thus recommended that 4% cement should be used as an optimal content to stabilize the soils, if they are to be used as road construction materials.

1.0 Introduction

The development of infrastructure cannot be made in an intelligent and satisfactory manner unless the designer has at least a reasonable and accurate conception of the physical properties and general behaviours of the soil involved. Ogun State Government is actively involved in the construction of new roads within the state and in Abeokuta South Local government area, majority of soil materials are not yet explored. Rapid infrastructural development in terms of road construction, buildings and recreational centers are anticipated in the future within the studied area. This expectation calls for the knowledge of basic index and strength properties of the soils in question. Ogunsanwo (1989) reported that these parameters influence in a great deal the performance of the highway pavement during service when in use.

The highway pavement consists basically of four elements, namely: subgrade, subbase, base and wearing or surface courses. The subgrade course is the most important of the structural elements because the ultimate traffic load is transmitted to it through the intermediate layers. Hence, the durability of a highway pavement is a function of the bearing capacity and stability of the subgrade soil. On the other hand, Mc Knight (1993) defines soil as an infinitely varying mixture of weathered mineral particles, decaying organic matter, lying organisms and liquid solution. This definition illustrated how complex soil could be; therefore, because of the anisotropic and heterogeneity nature of soil it is difficult to conclude on the performance of soil without some laboratory investigations.

Various previous workers have stabilized natural soil both chemically and mechanically. Adeyemi and Abolurin (2000) also stated that cement stabilized samples exhibited the highest cured strength when compared with lime and some mixture of both. Gadzama (2009) also established that 4% cement can be recommended as an optimal content to stabilize soil from parts of Northern Nigerian.

Portland cement is the most important hydraulic cement utilized extensively in various types of cement stabilization of lateritic soils. Cement acts as a binder and provides the much desired hardening and strengthening properties. The addition of cement also increases compressive strength, the resistance of lateritic soils to freezing and thawing, wetting and drying. It also affects the particle size distribution of the soils by increasing the size of fine particles. In view of this, civil engineers must study the property of soil, such as grain size distribution, atterberg limit, strength, durability and ability to drain water (Braja, 1999; Bello et al., 2016; Bello and Olaore, 2017). This study is therefore aimed at investigating and evaluating the index and strength properties of the soils of Abeokuta South Local Government, Southwestern Nigeria with the aim of making recommendations as to the suitability of the soil as construction materials. Procedures for improving them if they are found deficient, as well as the types of structures that could be built on such with minimal foundation problems were outlined.

2 Materials and Method

2.1 Sample Collection

The soil samples used for this study were obtained within Abeokuta South Local government area of Ogun State, Nigeria. The samples were collected via trial pitting at eight different locations which include Itoko, Olumo rock, Oba Ademola Hospital, Ijeun, St. Pauls Igbore, Itoku and Imo Hill and these are represented as A1, A2, A3, A4, A5, A6, A7 and A8 respectively.

2.3 Geology and description of the study area

The geology in the western upland where Abeokuta South Local government is situated is underlain by rocks of the basement complex which forms a part of the African crystalline shield. The basement is composed predominantly of folded gneises, schists and quartzite of the precambrian age to which have been emplaced by charnockitic rocks from older granite by extrusion and replacement (Morawo, 2008). Abeokuta South Local government of Ogun State is bounded in the west by Ayetoro, in the north by Abeokuta North Local government, in the east by Sagamu Local Government and in the south by Obafemi Owode. Two types of seasons are experienced in Abeokuta South Local government, they are the wet (rainy) and dry season. The wet season occurs between March and November with the heaviest rainfall experiences during

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this period. The dry season occurs between November and February. During this period, the temperature is usually low. The dry season also brings about harmattan which is experienced between December and January; the harmattan is cold, dry, dusty and hazy. People of Abeokuta south are also noted for Adire (Kampala) ties and dye and even having a big market for Adire, which are Itoku market and Adire (Kampala) international market situated in Asero, Abeokuta (Morawo, 2008).

2.4 Test Methods

Eight trial pits of depth ranging from 0.6 – 1m were dug at various locations (Table 1). The following laboratory tests such as particle size distribution, atterberg limits, specific gravity, natural moisture content, compaction and California bearing ratio.

2.4.1 Natural moisture content

The soil sample used for this test was sealed in an airtight bag at the point of collection from a trail pit, to retain the actual moisture of a soil in natural state. The mass of the moisture can and wet soil was recorded (M2) and placed in the oven and the mass of the moisture can and dry soil (M3) was reweighed after 24 hours. The mass of the moisture can is taken as M1.

2.4.2 Sieve analysis (Wet sieving)

Soil sample of approximately 1000g (1kg) was used for this test; it was soaked for 24 hours, washed and oven dried. The sieving was done by mechanical method using an automatic shaker, a set of sieves (BS sieve Nos. 4, 8, 16, 30, 40, 50, 70, 120, 200) and a collecting pan.

2.4.3 Atterberg Limit

Liquid limit and plastic limits were done in line with recommendation of BS (1990)

2.4.4 Specific gravity

A 50ml pycnometer was used for the test and an air-dried soil sample passing through BS sieve No. 4 (4.75mm) was weighed to 20g (0.02kg); the mass of the pycnometer was recorded (M1), and the mass of the pycnometer and the soil sample (M2) was recorded separately, as well as the mass of the pycnometer and the soil sample and distilled water (M3), and also the mass of the pycnometer and distilled water (M4). Density of water is taken to be 1000kg/m3 or 1g/cm3.

2.4.5 Compaction (West African standard)

A 4.5kg rammer and 1000cm^3 (1 x 10^{-3}m^3) mould was used for this test. Air-dried soil sample passing through an opening of 20mm was weighed to 3000g (3kg) and the sample was mixed at the initial stage with a suitable amount of water, about 5% of the total mass of soil sample, and later increased to 7%, 9%, 11% and 13% depending on the water retaining capacity of each sample. The compaction of the soil was done in 5 layers, using 10 evenly distributed blows and at a height of drop of 450mm (0.450m). The dry density of soil was then plotted against the moisture content and the maximum dry density (MDD) and optimum moisture content (OMC) were determined at the highest peak of the graph.

2.4.6 California bearing ratio (CBR)

A 4.5kg rammer and 2340cm^3 (2.34 x 10^{-3}m^3) mould was used for this test. Air-dried soil sample passing through an opening of 20mm was weighed to 5000g (5kg) and the sample was mixed with the optimum moisture content that was obtained from compaction test. The compaction of the soil was done in 5 layers, using 56 evenly distributed blows and at a height of drop of 450mm (0.450m). Filter papers were placed at the top and bottom of the mould and it was then placed on a Compression machine. The soil sample was thus subjected to an axial loading from the top as well as from the bottom and load deformation was recorded at an interval of 0.25mm penetration to 12.5mm. The CBR value was then determined at 2.5mm and 5.0mm using a standard force of 13.24kN and 19.96kN respectively.

Three compaction efforts were used, the standard proctor (SP), West African standard (WAS) and the modified Proctor (MP) for the natural soil. The SP and WAS compaction efforts were considered for the stabilized soils. These laboratory tests were carried out in accordance with the procedures specified by the British Standard Institution (BS 1377, 1990; BS 1924, 1990) and Federal Republic of Nigeria General Specification (Road and Bridges) II of 1997. The samples that were deem unfit for subgrade construction were stabilized with ordinary Portland cement and thereafter compacted using SP and WAS.

Table 1: Sample Location and Description

Sample No.	Location	Depth (m)	Constituent Materials	Colour Description
A1	Itoko	0.7	Gravelly clay	Reddish brown
A2	Olumu rock	0.7	Gravelly sand	Reddish brown
A3	General Post Office	1.1	Silty clay	Yellowish brown
A4	Oba Ademola Hospital	1.0	Silty clay	Dark brown
A5	Ijeun	0.9	Sandy clay	Yellowish brown
A6	St. Paul's Igbore	0.9	Silty clay	Reddish brown
A7	Itokun	0.8	Sandy clay	Reddish brown
A8	Imo Hill	1.0	Gravelly clay	Yellowish brown

3 Results and Discussion

3.1 Natural Moisture Content

The natural moisture content of the samples ranged between 4.8 and 9.9% (Table 2). Sample A3 has the highest moisture content because soil particle consist of highest fine grains that has the greatest affinity for water retention while sample A5 has the lowest moisture content because it consists of loosely packed soil particle which has low retention water capability. When comparing the natural moisture content with the optimum moisture content (OMC) obtained from various compaction energy levels, it was observed that all the (OMC) for modified proctor compactive efforts were either equal to or less than the maximum value obtained from the natural moisture content while for the West African Standard, only sample A2 was found to be greater than the maximum value of the moisture content value. As for the standard Proctor, all the OMC of the samples are higher than the maximum value of the moisture content except for samples A8. From these foregoing, it can be suggested that if the samples were to be used as construction material, little or no extra moisture will be required to obtain the OMC if West African Standard and modified Proctor compaction energy levels were to be used.

3.2 Specific gravity

The results of the specific gravity range from 2.6 to 2.66. Samples A3 and A5 have the lowest values while sample A4 has the highest value which is dependent upon the minerals present in

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the soil. The values fall within the range of specific gravity of solid of light coloured sand, which is mainly made up of quartz as predominant mineral (Braja, 1998; Bello, 2012). This was also found to fall within the range of 2.55 to 4.6 as recommended by Maignien (1966) for lateritic soils (Table 3).

3.3 Particle size analysis

The result of the particle size analysis is shown in Figures. 1a and b. Using the Unified Soil Classification System, sample A4 has the highest value of 70.1% passing 0.075mm sieve size while sample A6 has the lowest value of 23.1% passing 0.075mm sieve size. Out of all the samples, the percentage passing 0.075mm sieve size for samples A1, A6, and A8 are less than 35% which showed that these samples are effective subgrade materials for Road and bridges (Gadzama, 2009). According to AASHTO (1986) soil classification system samples A2, A3, A3 and A7 were classified as A – 4, samples A1, A8 were classified as A – 2 – 5, sample A6 was classified as A – 2 - 7 while samples A5 was classified as A - 7 – 5 soils.

Table 2: Summary of test results of soil samples

Property	Quantity range
Specific gravity, Gs	2.60 – 2.66
Natural moisture content, %	4.8 – 9.9
Liquid limit, %	21.5 – 33.0
Plastic limit, %	15.4 – 20.3
Plasticity index, %	3.8 – 15.5
% Passing BS sieve, 2mm	70.0 - 87.4
% Passing BS sieve 0.425mm	38.6 – 76.4
% Passing BS sieve, 0.075mm	23.1 – 70.1
Maximum dry density (SP), Mg/m^3	1.89 – 2.07
Maximum dry density (WAS), Mg/m^3	1.98 – 2.10
Maximum dry density (MP), Mg/m^3	1.98 – 2.18
Optimum moisture moisture (SP), %	8.90 – 12.50
Optimum moisture contact (WAS), %	8.75 – 10.05
Optimum moisture contact (MP), %	7.50 – 9.90
Unconfined compressive strength (SP), kN/m^2	88 - 248
Unconfined compressive strength (WAS), kN/m^2	152 - 240
Unconfined compressive strength (MP), kN/m^2	201- 910
California bearing ratio (SP), %	5.0 – 24.50
California bearing ratio (WAS), %	7.0 - 9.0
California bearing ratio (BSH), %	9.0 – 71.5

Table 3: Natural moisture content and specific gravity of sample

Sample No.	A1	A2	A3	A4	A5	A6	A7	A8
N. M. C, %	8.2	7.9	9.9	9.2	4.8	9.6	9.5	8.8
Gs	2.61	2.63	2.69	2.66	2.60	2.62	2.63	2.63

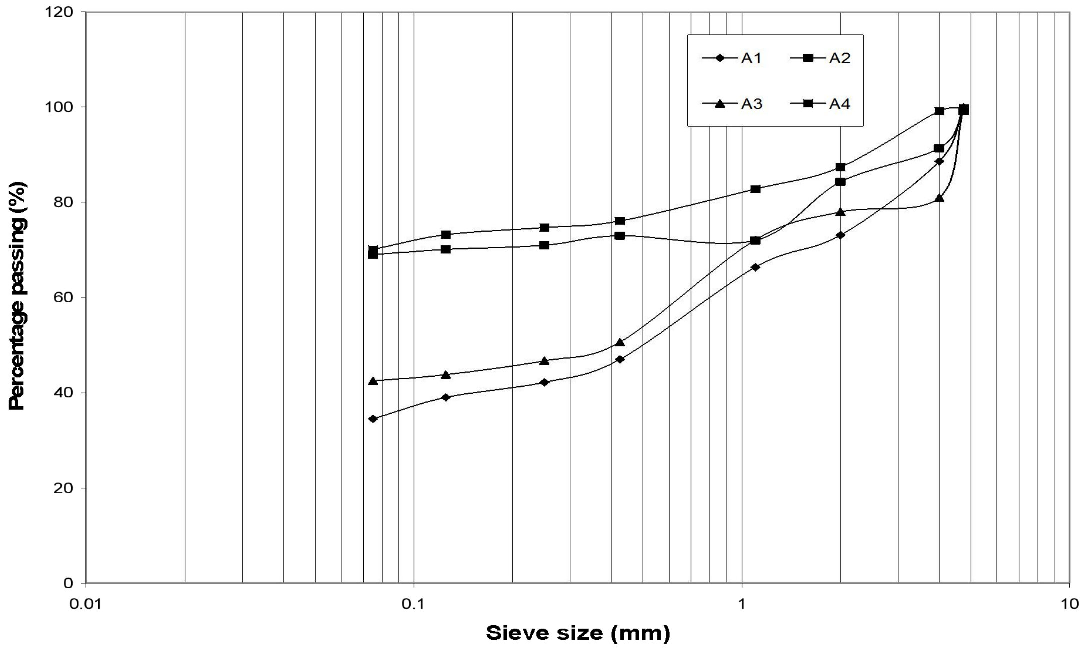

Figure. 1a: Particle size analysis for samples A1 - A4

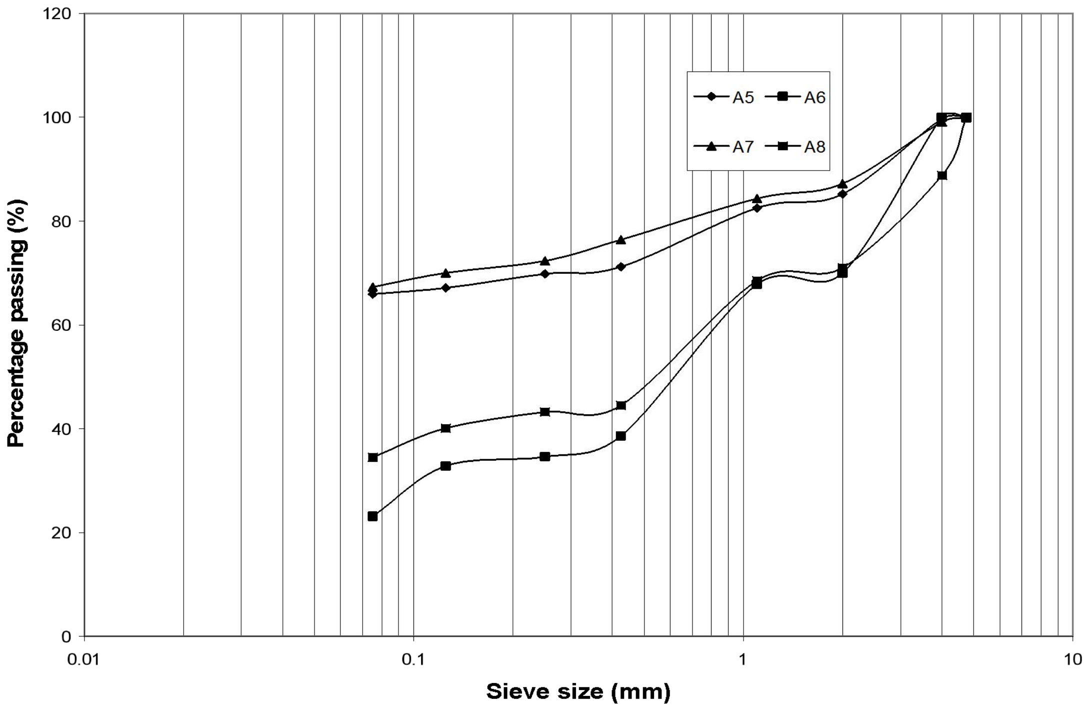

Figure 1b: Particle size analysis for samples A5 – A8

3.4 Atterberg limits

The results of Atterberg limits revealed that the liquid limit values ranged between 21.5 and 33.0% with samples having the highest and lowest values respectively A8 and A6 which according to Dillip and Subhrajit (2002) is noncritical. Plastic limit value for sample A7 was found to be 15.40% while that of A3 was found to be 20.30% as the lowest and highest values respectively (Table 4). The highest and the lowest plasticity indices were found to be 3.8% and 15.5% for A2 and A6 respectively which were classified as marginal by Dillip and Subhrajit and (2002). Also, the soils have low swelling potential in accordance with Ola (1980).

Table 4: AASHTO soil classification of the samples

Sample No.	Atterberg Limit (%)			% Passing BS sieve (mm)			Classification
	LL	PL	PI	2	0.425	0.075	of soil
A1	22.00	16.30	5.70	73.10	47.00	34.50	A – 2 – 5 (1)
A2	22.50	18.70	3.80	84.30	73.00	69.00	A – 4 (0)
A3	27.50	20.30	7.20	78.00	50.60	42.50	A – 4 (0)
A4	24.00	17.00	7.00	87.40	76.10	70.10	A - 4 (1)
A5	27.50	16.00	11.50	85.20	71.20	65.90	A – 7 – 5 (4)
A6	33.00	17.50	15.50	70.00	38.60	23.10	A – 2 – 7 (0)
A7	24.00	15.40	8.60	87.20	76.40	67.30	A – 4 (3)
A8	21.50	16.70	4.80	71.00	44.50	34.50	A – 2 – 5 (0)

4.5 Compaction Characteristics

The maximum dry density ranged between 1.89 and 2.07 Mg/m3 when standard Proctor compaction energy was used It ranged between 1.98 and 2.10 Mg/m3 when West African Standard was used and ranged between 1.98 and 2.18 Mg/m3 when modified Proctor was used (Table 5). In all, the maximum dry density increased with an increase in compaction effort, while the optimum moisture content decreases with increase in compaction efforts. This has been found to be true in all soils (Braja, 1998; Bello et al., 2015).

Table 5: Compaction characteristics for soil samples

Sample No.	SP		WAS		MP	
	MDD(Mg/m^3)	OMC(%)	MDD(Mg/m^3)	OMC(%)	MDD(Mg/m^3)	OMC (%)
A1	1.90	10.60	1.99	8.90	2.10	8.90
A2	1.89	12.60	1.98	10.05	1.98	9.90
A3	1.91	11.50	2.05	9.15	2.05	8.20
A4	2.05	10.33	2.03	9.40	2.15	9.80
A5	1.98	12.21	2.0	9.70	2.15	9.20
A6	1.97	11.15	2.05	9.30	2.10	8.00
A7	1.77	11.15	2.05	9.30	2.10	8.00
A8	2.07	8.90	2.10	8.75	2.18	7.50

3.6 California Bearing Ratio characteristics

Samples A1, A6 and A8 met the 15% minimum requirement to be used as a subgrade material using standard Proctor in accordance with Nigerian General Specification for roads and bridgeworks of 1997 (Table 6). No material met the requirement to be used as a subbase and base materials. When all compactive efforts were considered sample A8 has highest CBR values followed by A1 and A6. It was also observed that soils that had a higher liquid limit gave a lower

California bearing ratio value which was found to agree with Gadzama (2009). This implies that soils of lower liquid limit have appreciable higher bearing capacity, hence should be used for subgrade soil in road construction.

Table 6: CBR and Unconfined Compressive Strength of soil samples

Sample No.	CBR (%)			UCS (kN/m^2)		
	SP	WAS	MP	SP	WAS	MP
A1	19.20	25.3	63.50	200	580	870
A2	9.70	13.3	45.70	144	180	350
A3	9.2	12.7	28.50	120	440	550
A4	8.3	9.70	33.40	117	305	240
A5	5.0	7.0	9.0	88	152	210
A6	17.50	21.3	55.4	102	200	480
A7	7.5	11.5	25.9	195	490	770
A8	24.50	29.0	71.5	248	640	910

Attempts were made to improve the strength properties of other soil samples that failed to meet the minimum requirement for subgrade materials with ordinary Portland cement to stabilize the soils. The results are summarized in Table 7. It was also observed that sample A2 and A7 did not meet the minimum CBR value of 180% as specified by the Nigerian General Specification for roads and bridgeworks (1997) or stabilized soil using standard Proctor compactive effort at 4% Cement content. However, all the soil samples met the requirement using WAS compactive effort at 4% Cement content.

Table 7: California Beaming Ratio of cement stabilized soil

Sample No.	CBR (%) Standard Proctor					CBR (%) West African Standard				
	2%	4%	6%	8%	10%	2%	4%	6%	8%	10%
A2	98	170	220	249	298	115	197	213	270	340
A3	110	205	225	263	320	118	215	238	298	342
A4	125	227	280	325	408	140	269	302	394	470
A5	105	213	238	279	312	120	243	267	315	389
A7	90	172	210	270	315	110	236	259	302	357

3.8 Unconfined compressive strength characteristics

It was observed that (UCS) values increased with an increase in compaction energy. It was also observed that samples with lower optimum moisture content gave higher unconfined compressive strength and vice-versa which is in agreement with Braja (1999). Stabilized samples using the standard Proctor and West African Standard met the conventional UCS values of (1500-3000 kN/m^2) for base course of lightly trafficked roads not only at 2% Cement content but for all the ranges of stabilizers used (2-10%). Only samples A4 using WAS compactive effort at 10% cement content met the conventional UCS values of (3000-6000 kN/m^2) for base course of highly trafficked roads (Table 8).

Table 8: Unconfined Compressive Strength of cement stabilized soil

Sample No.	UCS (kN/m^2) Standard Proctor					UCS (kN/m^2) West African Standard				
	2%	4%	6%	8%	10%	2%	4%	6%	8%	10%
A2	1550	1650	1650	1800	2000	1600	1800	1850	2000	2100
A3	1600	1700	1750	1950	2100	1650	1700	1750	2100	2000
A4	1580	1640	1800	2000	2200	1700	1900	2010	2800	3050
A5	1800	1850	1700	1850	2000	1600	1650	2000	2100	2300
A7	1700	1780	1700	1600	2000	1550	1800	1700	1950	2950

4. Conclusion

Soil samples from Abeokuta South Local government area, Southwestern Nigeria have been investigated. The soil samples met the minimum values of liquid limit as specified by the Nigeria general specification for roads and bridgeworks. Samples A1, A6 and A8 met the minimum 15% requirements for subgrade material in accordance with the Nigeria general specification for road and bridgework while the conventional CBR values of 80% minimum has not been met: but upon stabilizing with Cement at 4% cement content using standard Proctor, all the samples met the minimum CBR value of 180% with the exception of samples A2 and A7. When the samples were compacted using West African Standard (WAS), all the samples met the requirement. The maximum dry density increases with compactive efforts while the optimum moisture content decreased with compactive effort for the samples. The Unconfined Compressive Strength (UCS) values increased with compactive effort and decreased with increase in degree of saturation of the soil samples. On stabilizing the soil samples with cement, the samples met the conventional UCS values of (1500-3000 kN/m^2) for base course of lightly trafficked roads while only sample A4 compacted at 10% cement content using WAS compactive effort met the minimum (3000 - 6000 kN/m^2) for base course of highly trafficked road.

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