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Assessment of the Mechanical Properties of Subgrade Stabilized with Cement Kiln Dust and Coconut Coir on Silty Clayey Soil

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Abstract Soft soils are undesirable soils that are not suitable for road construction due to their low shear strength and high compressibility level. Remediation is very essential to avoid potential pavement failure due to traffic and climatic condition because strength and volume stability are important properties in subgrade construction. This research investigates the assessment of the mechanical properties of subgrade stabilized with CKD and CF on silty clayey soil. Samples collected from No7 Ekpenyong Abasi Street, Off Palace Road Anatigha, Calabar South, Cross River. Cement kiln dust and coir fiber have been used as a stabilizing agent in this work and their effect on the physical and geotechnical properties of the soft soil have been measured using the Grain Size Distribution Test, Consistency Limit Test, Specific Gravity Test, Compaction Parameters ((OMC) and (MDD), California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS). The tests were performed using replacement method which content combination of soil of varying percentages of (100%, 90%, 80%, 70%, 60%, 50% and 40%) and varying percentages of CKD of (0%, 10%, 20%, 30%, 40%, 50% and 60%) and a fixed CF of (0.5%). The dried soil (3000g) by dry weight with the required water content were mixed and then different dosages of CKD was added to the soil, soil was replaced with CKD at a constant dosage of CF was added at each mixed. The dried soil of (3000g) by dry weight with required water content was also mixed without admixture to compare the CBR test results. After the compaction the samples treated with CKD and CF were tested for soaked and unsoaked CBR. The UCS samples were cured for 0 days, 7 days and 14 days. The test results indicated that the MDD progresses from 0% CKD, 0% CF and 0% Soil material to 50% CKD, 50% soil at a fixed CF of 0.5% before dropping showing that the maximum workability at its peak for both materials by percentage replacement is 50% each for CKD and soil material at a fixed CF of 0.5%, thus the soaked and unsoaked CBR and UCS also showed the same characteristics properties.

Keywords Cement Kiln Dust, Coir Fiber, Subgrade, Clay Soil, CBR, UCS, OMC, MDD

1. Introduction

In the pavement structure, the subgrade layer represents the lowest layer that is located underneath the base course or surface course, relying on the pavement type. This layer, generally, constructed from different soil materials that can be either soft or wet [6].

The special features of this soil are the high degree of compressibility and low permeability compared to other soil types. However, firm subgrade is very important in road construction and properties such as volume, stability and strength of the subgrade play a significant role in the overall pavement performance. While soft subgrade is unable to support pavement loading and thus represent the primarily responsible factor for the failure of many road pavements [4].

Abandoned sites due to undesirable soil bearing capacities dramatically increased in some part of South Region in Nigeria, and the outcome of this is the scarcity of land and increased demand for natural resources. Affected areas include those areas covered with soft clay and organic soils of high plasticity level.

However, in most geotechnical projects, it is very rear to obtain a construction site that will meet the design requirements without ground modification. The current practices are to modify the engineering properties of the native problematic clayey soil in order to meet the design specification and standard. Now a day, soils such as, soft clays and organic soils can be improved to the civil engineering requirements and standard.

There are various types of soil available having different properties. Few are having good strength and stability while few having properties of high volume change due to change in moisture content. So, it can be accepted that all soils do not possess all the desirable qualities of soil subgrade for pavement. Soil with poor subgrade qualities should be avoided as much as possible. But when it's unavoidable its subgrade performance should be increased and treated.

Incorporating reinforcement inclusions within soil is also an effective and reliable technique in order to improve the engineering properties of soil.

[2], conducted laboratory tests for testing the compaction, consistency limits and strength of sandy soil stabilized with 2-24% of cement kiln dust content, the outcome of the study resulted in an increment in the optimum moisture content, and a reduction in the maximum dry density and plasticity index. Also, upon increasing the cement kiln dust content from 0-24% by the dry weight of the soil, the CBR value increased from 22% to 80%.

Both cement kiln dust (CKD) and lime kiln dust (LKD) can be used as activators in pozzolanic stabilized base mixtures.

More importantly, coconut coir fiber reinforcement soil exhibit greater toughness and ductility and smaller loss of pot-peak strength, as compared to soil alone. Therefore, the coconut fiber can be considered as a significant modification and improvement in the engineering properties of soil.

However, more work is necessary to compare the influence of coir fiber inclusion on the mechanical behavior of cemented and un-cemented soils, especially the interfacial interactions between fiber surface and reinforcement soil matrix.

1.2. Background of the Study

The subgrade must be able to support loads transmitted from pavement structure with deformation being within allowable limits under the action of heavy traffic load and adverse climatic conditions.

For different moisture content it should not show volume changes as it may lead to uneven strength and uneven settlement, it should possess good drainage system so as to avoid excessive moisture retention.

Therefore, it is necessary to evaluate the strength properties of subgrade soil, this system helps to adopt suitable values of strength parameters for design purpose and specification.

A potential solution for such problematic clayey soil is the replacement with high-quality fill materials. However, the replacement of soft subgrade soil is not always the effective option because of the high cost of excavation and imported materials.

Base on this note, researchers have been driven to look for the best alternative and cost-effective methods, which include the process of soil stabilization**.**

Soil stabilization is the process of amending the physical and geotechnical characteristics such as (strength, permeability, compressibility and bearing capacity) of a problematic (soft) soil either mechanically or by the addition of suitable chemical stabilizers such that it permanently becomes suitable for construction and meets the engineering design standards.

The quality of the subgrade soils used in pavement application is classified into 5 types (soft, medium, stiff, very stiff, and hard) depending on unconfined compressive strength value [7].

The subgrade soils, which are classified as A7-5 and A7-6 have general rating as fair to poor according to America Association of State Highway and Transportation Official (AASHTO), these types of soils are considered as unstable subgrade and need to be improved and stabilized, especially in terms of pavement applications [8]

Consequently, roads running through regions covered with these clays and organic soils are subjected to severe distress resulting in poor performance and increased maintenance cost. These behaviors are attributed to the presence of clay minerals with expanding lattice structure. Among them are montmorillonite, the most common of all the clay minerals in expansive clay soils.

Over the years, progress have been made as different types of stabilizers have achieved different levels of performance. Cement and lime are still among the most effective stabilizers in use, although many studies have been made for nontraditional stabilizers, such as fly ash, cement kiln dust, coconut coir or combination of this materials with varied degree of success [41].

Cement kiln dust is a by-product in the production of Portland cement clinker. Disposal of cement kiln dust is an environmental problem. The utilization of the waste material has relieved increasing attention because it's not only solves a potential solid waste problem but also provides an alternatives stabilization agent using in chemical stabilization of problematic clay soil and provides an alternative construction material.

The use of cement kiln dust for chemical stabilization application may be an environmental solution of the problems associated with the disposal process where a very huge amount of the cement kiln dust as by-product

is daily produced from the cement factory in United Cement Company of Nigeria, (Unicem) Nfamoseng, Calabar, Nigeria.
The composition of the cement kiln dust is similar to raw materials of Portland cement but the amount of alkalis, chlorides and sulfate is usually considerably higher in the cement kiln dust.
In ancient times, coir fiber was used for reinforcing soils. Early civilizations, added plant roots to soil bricks to improve the properties, although their mechanisms were not fully understood.
However, modern geotechnical engineering has focused on the use of reinforcement. The reinforcing of soil with discrete fibers is still a relatively new technique in geotechnical projects [1], one of the natural fibers that are often used as a material for soil reinforcement is coconut coir fiber. Coir fiber has good strength, characteristic and resistance to biodegradation for a long period of time. Coir fiber has high buoyancy, is resistance to bacteria, salt water, while its weaknesses cannot be twisted properly and belong to a rigid fiber [2].
Coconut fiber itself is consider cheap and easy to get it especially in Southern Region of Nigeria, (Akwa Ibom State), this is biodegradable and hence do not crate disposal problem in environment.
Coconut coir fiber is a natural fiber extracted from the husk of coconut and used in products such as floor mates, doormats, brushes and mattresses. Coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. The fibers are normally 50-350mm long and 0.5 in diameter which consist mainly of lignin, tannin, cellulose, and other water-soluble substances.
Previous studies related to soil reinforcement, especially with coconut fiber has been widely practiced. The mechanical properties of fiber (synthetic and natural) reinforced soil have been investigated by various researchers. All previous studies have shown that addition of fiber reinforcement causes significant improvement in strength of poor clay soil and increases its stiffness.

1.3. Statement of the Problem

The life span of pavement depends upon the subgrade soil strength and its stability. If subgrade strength is less effective and unstable, it may lead to the propagation of cracks and failure on the pavement surface. The selected materials for this study must have the ability to provide reinforcement and thus increases the subgrade strength. Also, coconut coir fiber and cement kiln dust improve the California bearing ratio values and thus reduces the pavement thickness, instability on the subgrade soil, construction cost and maintenance. This study will highlight the improvement in poor subgrade reddish-brown silty clayey soil using cement kiln dust and coconut coir fiber in South-South Region of Nigeria.

1.4. Objective of the Study

The objectives of this present study are to assessed the mechanical properties of subgrade stabilized with cement kiln dust and coconut coir fiber with soil of reddish-brown silty clayey in accordance with the unified soil classification system. This infers the following objectives which can be put forth as follows:

1. To determine the optimum dosages of cement kiln dust and a fixed coir fiber mixed with soil to improve the CBR of locally studied soil of reddish-brown silty clay.
2. To check whether silty clayey soil threated with cement kiln dust and coir fiber mixtures are economically prefer to be used as subgrade material than material from borrow-pit.
3. To compare the differences in CBR results for soaked and unsoked of locally silty clays oil with admixture of additives i.e. CKD and CF with ordinary silty clayey soil without admixture of additives.

1.5. Scope of the Study

In this present study, an attempt is made to study how cement kiln dust and coconut coir fiber may be effectively utilized in combination with locally studied reddish-brown silty clayey soil of high plasticity level to get an improve and quality material which may be use to stabilized poor subgrade soil.
The soil to be used in this investigation is obtained from No7 Ekpenyong Abasi Street, off Palace Road Antigha, Calabar South, Cross River, Nigeria.
Coconut husk is obtained from Ikot Ekpene Local Government Area of Akwa Ibom StateSouth South Nigeria, from local vendors that due local supply in the market.
Cement kiln dust from United Cement Company of Nigeria (Unicem) located in Nfamoseng in Akamkpa Local Government Area of Cross River State Nigeria.
The main goal of this study is to assess the mechanical properties of subgrade stabilized with cement kiln dust and Coir Fiber with reddish-brown silty clayey soil to reduce its swelling and improves its geotechnical properties.

1.6. Justification of the Study

This study will contribute to the best alternative method of treatment and improvement of poor subgrade clayey silty soil using cement kiln dust and coconut coir fiber for both flexible and rigid pavements.

I strongly hope that this research study will encourage the expatriate Engineers and local Engineers to be drawn to this new method of stabilizing problematic subgrade clayey silty soil around the Bonny Island, Kolo Creek, Ekulama I&II and Calabar South in South-South Region of Nigeria and adopt it as an effective way that will benefits the construction industries, the consulting firms and the oil and gas industries.

The outcomes to be considered on this research study consist of the following**:** the addition of cement kiln dust and coconut coir fiber into the clayey soil will surly improves the CBR, reduces cost of projects, maintenance cost, and reduces intensity of stress on poor subgrade soil.

1.7. Limitation of the Study

The incorporation of cement kiln dust and coir fiber has not been utilized in Nigeria roads, in spite of it abundance in the country, based on the typical strength and durability requirements for materials used in pavement structural layers, the cement kiln dust materials and coir fiber can qualify for high-volume civil engineering applications, as long as they are well designed and compacted to achieved 100% compaction. This important work will help to reduce over dependence on borrow-pit materials and create others means of stabilizing available soil materials for road work construction, especially in South- South Region of Nigeria.

The stabilized cement kiln dust and coir fiber can be qualified for subgrade layer depending on degrees of compaction achieved. Nevertheless, the applications of cement kiln dust and coir fiber for pavement subgrade are much more not utilized in Nigeria. The other possible applications and contributions of this work; include but are not limited to embankment, reduced the rate of potholes deformation, landfill construction, and construction site leveling, where strength requirements are not high.

2. Material and Methodology

This chapter includes brief description of the materials to be used for the research study. Various tests to be carried out on the soil sample mixed with different dosages of cement kiln dust of (small increment) and constant coir fiber of (0.5%) on the locally reddish-brown clayey silty soil are briefly to be discuss with their respective procedures.

The Main objective of this research study is to assessed the mechanical properties of reddish-brown clayey silty soil with high plasticity level stabilized with optimum dosages of cement kiln dust at (0%, 10%, 20%, 30%, 40%, 50% and 60%) by dry weight, and a constant coir fiber of (0.5%) by dry weight to be mixed with reddish-brown clayey silty soil with a through the various soil properties to be conducted in the laboratory.

3. Materials

3.1. Soil

In the experimental research work, the soil samples (disturbed) used in this investigation is alocalsilty clayey soil in accordance with the unified soil classification system. Twenty (20) soil samples were collected from seven (7) different boreholes by excavating the ground surface at the depth of 2.7m to 2.8m using spade and trowel. The soil sample is collected from different locations at No7 Ekpenyong Abasi Street, off palace road Anatigha, Calabar South, Cross River State Nigeria, having Latitude4 54’ 64.665’’N and Longitude 8 19’ 37.992’’E, with average elevation of 1 meter above the sea level. Cross River hasaland mass area of 264 km^2 and a population of 1,191,630 based on 2006 census.

The soil samples were place in an empty clean cement bags of 15kg each, the mouth of the cement bags was seal to avoid loss of moisture then transported to the laboratory same day for the research work. On arrival at the laboratory the natural moisture content of the studied soil samples was taken and recorded in the research booklet for further use. This was done according to the BS EN ISO 17892-1:2014 for stabilization of poor soil. While the remaining soil samples was oven dried the same day at 105-degreecensus for 48 hours, and stock-pile for laboratory work.

At the beginning, the properties of the natural soil were established by carrying out the following tests ((I) particle size distribution according to the BS EN ISO 17892-4:2014), ii), consistency limits according to BS 1377-2 and 4:1990), iii) compaction and CBR according to the BS 13772 and 4: 1990). The Liquid limits (LL) were reported to be 39.5% while the plastic limit (PL) were 26.8%, and plasticity index (PI) was also found to be 12.7%. This is in accordance with the unified soil classification system (USCS), the soil was classified as reddish-brown silty clayey soil.

Plate No. 1: Map of Calabar South, Cross River State

Plate No. 2: collection of soil samples Area

Plate No. 3: Fresh and Dry soil samples in the laboratory

Table 1: Physical and Engineering properties of the studied soil samples

S/No	Properties	Values
1	Natural moisture content	14.89
2	Specific gravity	2.66
3	Grain size analysis	
	% passing 63mm	38.1%
4	Consistency Test	
	LL	36.8
	PL	20.4
	PI	16.8
5	Maximum dry density (MDD)	1.32
6	Optimum dry density (OMC)	13.9
7	Shrinkage limit	12.02
8	CBR value	
	Unsoaked	6.4
	Soaked	4.2
9	IS classification	Silty clayey

Plate No. 4: Coconut Husk and it Coir Fiber

3.2. Coconut Coir

The coconuts husk was purchase from local market in Ikot Ekpene district of Akwa Ibom State Nigeria, from local coconut coir vendors, which the fibers were extracted manually from coconuts husk and separated into strands for the study. The coconut fiber used for the study were added at a constant dosage of 0.5% by dry weight of the silty clayey soil sample with an increment dosage of cement kiln dust. Since the coir fibrous is hard, it was softened and gets swollen by soaking the fibrous in an open GP tank filled with fresh water for 48 hours in the laboratory, after then the fibrous were removed from the water and dried under sunlight for 72hours at varying temperature of 25 to27 ^{o}C and stock- pile for laboratory use.

Table 2: Property of Coconut Coir Fiber used for the studied

S. No.	Description	Value
1	Diameter	0.15-0.20mm
2	Cut Length	1.0mm
3	Cut Length	1.3

3.4. Cement Kiln Dust

The fresh cement kiln dust sample is used as primary stabilizer in this research study. The CKD was collected from United Cement Company of Nigeria (Unicem), located at Nfamoseng in Akamkpa, Cross River State Nigeria. In this study we focused mainly on untreated(dry) cement kiln dust powder.The cement kiln dust used for the study was added as a replacement of equal proportion of soil removed in dosages of(0%, 10%, 20%, 30%, 40%, 50% and 60%) by dry weight of the clayeysilty soil sample and coconut coir fiber.

Cement kiln dust as the name implies, is fine powder-like by-product of Portland cement production. Cement kiln dust for this research was collected from the stacks of high temperature rotary kiln by the federally mandated dust collection system (cyclones, electrostatic precipitators). Large quantity of cement kiln dust is produced during the manufactures of cementclinker by the dry process. Cement kiln dust obtained from dry process has a higher amount of Calcium than that from the wet process. Cement kiln dust consists mainly of Lime, Silica, Alumina and Iron with high alkalinity making it an excellent activator.

Plate No. 5: Production Plant and it Waste Cement Kiln Dust

Table 3: Physical properties of Cement Kiln Dust used for this Research Study

1.	Liquid limits	22.8%
2.	Plastic limits	Non-Plastic
3.	Specific Gravity	2.68
4.	Fineness	525m^2/kg

Table 4: The chemical composition of cement kiln dust used in this research work is shown below (Unicem Nfamoseng Akamkpa, Nigeria)

Oxide	CaO	Al_2O_3	SiO_2	FeO_3	Mn_2O_3	Na_2O	K_2O	Loss of ignition
Concentration	51.81	4.73	17.20	1.92	0.002	0.001	1.35	34.03

3.5. Methodology

The scope of this research study is limited to the laboratory tests using soil of silty clayey in accordance with the Unified soil classification system, cement kiln dust and coconut coir fiber.

Basic tests such as**:** Specific Gravity test, Atterberg Limits test, Shrinkage limit test, Consistency limit test, Grain Size Analysis test, compaction test, California bearing ratiotest and Unconfined Compressive Strength test are carried out on the un-treated clayey silty soil samples. Modified Proctor compaction tests for determining Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), California Bearing Ratio (CBR) tests and Unconfined Compressive Strength test, were performed in the laboratory to determine the properties of the studied soil samples stabilized with cement kiln dust and coconut coir fiber. The CBR samples for soaked sample were immersed in water for 96 hours before testing commenced.

Table 5: Mix proportion

Mix proportion (%)			Proportion of soil by weight (g)	Proportion of CKD by weight (g)	Proportion of CF by weight (g)	% of water used	Proportion of water by weight (g)
CKD	SOIL	CF					
0	100	0	3000	0	0		300
10	90	0.5	2700	300	15		300
20	80	0.5	2400	600	15		300
30	70	0.5	2100	900	15	2% * 5	300
40	60	0.5	1800	1200	15		300
50	50	0.5	1500	1500	15		300
60	40	0.5	1200	1800	15		300

In the preparation of all specimen types, the oven dried soil of 3000g by dry weight with the required water content were prepared (mixed) first, and then different dosages of cement kiln dust (small increments) was added on each mixed to the soil samples with CKD which was replace with soil, and soil with optimized cement kiln dust was further mixed with a small increments of coir reinforced fiber of fixed dosage of 0.5%.

The oven dried soil sample of 3000g by dry weight with the required water content was also mixed without admixtures to compare the CBR tests results. All mixing was done manually and proper care was taken to ensure homogeneous mixtures at each stages of mixing. After the compaction, the samples treated with cement kiln dust and coir fiber were immersed in water for 96hours for the soaked CBR before testing commenced. A brief discussion about these tests is presented in the following sections.

3.5.1. Determination of Grain Size Distribution

In order to determine the content of coarse grain and fine grain this test was conducted.

- Sieve analysis
- Hydrometer

Sieving was done to determine the coarser content of the soil which determines gravel and sand proportion in the soil sample. This was done by using various sizes ranging from 40mm sieve size to .075mm and hydrometer test was also conducted to determine the content of silt and clay in the soil.

Test Procedures

- A definite weight of the material was taken and record as wet weight
- The sample was washed with water carefully to remove the silty part of the material remaining the sharp sand and the sand was allowed to oven dry for 24hrs.
- The sieves were arranged according to the apertures from the highest to the lowest as may be considered necessary for the test, then the dry sample was introduced to the first sieve being the highest and allowed to shake in the electric sieve shaker for 5 minutes.
- The weight retained in the consecutive sieves were weighed and recorded as weight retained and are then used for further computation.

Plate No. 6: Dry and Wet Sieve Analysis

3.5.2. Determination of Consistency Test

To determine the liquid limit, plastic limit and shrinkage limit of soil tests was conducted with reference to IS: 2720 (Part V)-1985.

Liquid limit is the minimum water content at which soil has a tendency to flow and all soil possess a negligible shear strength at the liquid limit, it is performed with the help of Casagrande's apparatus in the Lab.

Plastic limit refers to that water content at which soil sample would just begin to crumble when rolled into a thread of approximately 3mm in diameter.

Shrinkage limits is the smallest value of water content at which soil mass is completely saturated.

Plasticity index is equal difference of liquid limit and plastic limits.

Test Procedures

- The lateritic material was oven dry to remove all forms of moisture.
- A portion of the sample was grinded and passed through sieve 425micon to obtain the silty clay below the sieve.
- Water was gradually added the silty clay portion of the sample until it forms a complete moist paste.
- The paste material was introduced to the casagrande device with the aid of spatulas, a straight groove was made vertically with the aid of the grooving tool.
- The casagrande device was wheeled up and down repeatedly to close the groove line, the number of times of the up and down movement is read at the calibrated end of the device as number of blows. The test was repeated for 4 consecutive times and values recorded for further computation.

Plate No. 7: Determination of consistency test

3.5.3. Specific Gravity Determination

Specific gravity was determined by soil fraction passing through 4.75mm IS Sieve with the help of Pycnometer as per instruction of IS: 2720 (part III) 1980.

It is defined as the ratio of the weight of a given volume of solids to the weight of the equipment volume of water.

Plate No. 8: Determination of Specific Gravity

3.5.4. Maximum Dry Density Test

This test was performed in the laboratory to determine the relation between Moisture Content and Dry Density of soil samples for a specific comp-active effort. The comp-active effort is the amount of mechanical energy that is applied to the soil samples.

The apparatus uses for conducting this test comprises of cylindrical metal mould of capacity 1000cm3 with detachable base plate, metal rammer, removal collar balances, oven mixing tools.

The standard procedures for the standard proctor test, as explained in Indian Standard Code (IS: 2720 part vii-1980) was adopted for this research study.

Test Procedures

- The dry soil sample was weighed to compliment the size of the mould to be used for the compaction, the weight of the empty mould was equally recorded.
- The control water of 2% of the total weight of material was chosen, and the 2% calculated water was gradually added to the dry soil sample and mixed thoroughly.
- Two moisture containers were used to take moisture at round of the test, weighed and allowed to dry for 24hrs.
- The wet sample was divided into 3 layers and was compacted one after the other with a 4.5kg rammer at 25 blows per layer.
- The compacted sample was weighed with the mould and recorded. The test was repeated for other rounds until the sample was saturated with water.

The dry density is determined and plot against water content to find optimum moisture content (OMC) and maximum dry density (MDD) of the soil sample mixed with cement kiln dust and coir fiber.

Plate No 9: Compaction test analysis

3.5.5. Procedure for California bearing ratio

This test was conducted to determine the California bearing ratio values under soaked and unsoaked conditions for the studied sample. The apparatus includes cylindrical mould with a detachable collar, displacer disc, metal rammer, steel collar, surcharge weight, filter paper and loading devices.

The standard procedures for the California bearing ratio test are explained in Indian Standard Code (IS: 2720 part xvi-1987) was adopted for this research study.

For calculating soaked California bearing ratio value, an extensions collar was adjusted over the mould. A displacer disc was inserted over the base and a filter paper will pit on its top.

Test Procedures

- The dry soil sample was weighed to compliment the size of the mould to be used for the compaction, the weight of the empty mould was equally recorded.
- An optimum water of 6% of the total weight of material was chosen, and the 6% calculated water was gradually added to the dry soil sample and mixed thoroughly.
- The wet sample was divided into 3 layers and was compacted one after the other with a 4.5kg rammer at 25 blows per layer.
- The compacted sample was weighed with the mould and introduced to the CBR machine.
- The CBR machine has a proving ring factor of 0.0025KN, a force recording dial and penetration recording dial. At each 0.25mm of the plunger penetration, the corresponding force (KN) was recorded and this was repeated at a consistent oscillation till 6.00mm plunger penetration.

The penetration was recorded and converted into standard units with the help of calibration chart. In order to get reading of soaked sample, both sides of the mould was cover with filter paper. Then the mould was place in water for 96 hours and the observation was recorded explain above.

Plate No. 10: The soaked CBR Test and CRB setup in the soaking container

3.5.6. Procedures for Unconfined Compressive Strength Test

This test helps in determining the failure stress of the sample. The apparatus used for conducting the test includes compression device, proving ring, dial gauge, oven and weighting balance. The standard procedure for the 'Unconfined Compressive Strength Test' as explained in Indian Standard Code (IS: 2720 Part X-1991) was referred for the study. The sample was prepared at optimum moisture content and it initial length and diameter were measured. Then it was put on the bottom plate of loading device. The upper plate was adjusted to make contact with samples. The load readings were taken at specified values of deformation dial gauge. The load reading was converted into acceptable units with the help of a calibration chart.

Table 5: Experimental Programmed for Selected Tests

S/No	Mixture	Test	No of Sample
	Unsterilized soil (Natural)		
		Specific gravity	1
		Particles size distribution	2
		Consistency limits	1
		Atterberg limit	1
		Moisture content	1
		Compaction test	1
		CBR (Soaked and Unsoaked)	1
1	Soil+0%CKD+0%CF		1
2	Soil+10%CKD+0.5%CF	Compaction test	1
		CBR (Soaked and Unsoaked)	1
3	Soil+20%CKD+0.5%CF	Compaction test	1
		CBR (Soaked and Unsoaked)	1
4	Soil+30%CKD+0.5%CF	Compaction test	1
		CBR (Soaked and Unsoaked)	1
5	Soil+40%CKD+0.5%CF	Compaction test	1
		CBR (Soaked and Unsoaked)	1
6	Soil+50%CKD+0.5%CF	Compaction test	1
		CBR (Soaked and Unsoaked)	1
7	Soil+60%CKD+0.5%CF	Compaction test	1
		CBR soaked	1

4. Analysis and Interpretation of Results

4.1. General

This chapter presents the results of various laboratory tests conducted on soil and soil mixed with relative to the addition of varying proportions of cement kiln dust and coconut coir fiber on the silty clayey soil.

Furthermore, the following conclusions have been made from the analysis.

Table 6 shows the natural Moisture content of the fresh soil sample.

The average moisture content for the fresh soil samples used for the analysis is recorded as 14.89.

Table 6: Natural Moisture Content Test

S/N	1	2	3	4	5	6
Depth of Sample (2.8m)						
Chainage No						
Location (Antigha Calabar south)						
Can No	W7	B8	BTC	WM	AKZ	GV
Wet Wt Sample + Can (gm)	55	48	47	48	57	50

Dry Wt Sample + Can (gm)	47	42	42	42	52	46
Can Wt(gm)	7	7	6	6	8	7
Wt of Water (gm)	8	6	5	6	5	4
Wt of Dry Sample (gm)	40	35	36	36	44	39
Moisture Content (%)	20.00	17.14	13.89	16.67	11.36	10.26
Average MC (%)	14.89					

The Grain Size Distribution Analysis

Sieving was done both wet and dry in order to determine the coarser content of the soil which determines silt and sand proportion in the soil sample. This was done by using various sieve sizes ranging from 3.4mm sieve size to 0.75mm, and hydrometer test was also conducted to determine the content of silt and clay in the soil sample. From the grain size distribution analysis, the hydrometer test analysis shows that silt content of the soil sample was 38.1% representing the percentage of clay passing sieve 0.075mm. According to 'Indian' standard soil classification system, soil was classified as silty clayey soil. The wet weight of the sample was 1000g, dry weight was 625g and the absolute weight was 619g.

Absolute weight = total weight of sample – weight passing sieve 0.075mm

% Retained = weight retained / total weight retained * 100

% Passing = 100 - % retained

Table 7: Sieve analysis for using wet sieve metho**d**

Sieve (mm)	**Mass (g)**	**% retained**	**% Passing**
3.4	0	0.0	100.0
2.4	1	0.1	99.9
1.2	23	2.3	97.6
0.6	150	15.0	82.6
0.43	160	16.0	66.6
0.30	125	12.5	54.1
0.21	90	9.0	45.1
0.150	42	4.2	40.9
0.075	28	2.8	38.1
pan	381	38.1	
Total	1000		

Table 8: Sieve analysis for using dry sieve method

Sieve (mm)	**Mass (g)**	**% retained**	**% Passing**
3.4	0	0.0	100.0
2.4	29	2.9	97.1
1.2	60	6.0	91.0
0.6	95	9.6	81.5
0.43	56	5.6	75.8
0.30	71	7.2	68.7
0.21	102	10.3	58.4
0.150	188	18.9	39.5
0.075	101	10.2	29.3
pan	291	29.3	
Total	1000		

Consistency Test

The Liquid limit is the maximum water of saturation at which soil tends to lose its workability. Is the state of saturation where soil pores can no longer hold water?

Similarly, the Plastic limit is the limit at which the clay content of the soil can retained water and still maintain its binding ability. Plastic limit values are shown in the table below.

Table 9: Liquid limit and Plastic limit test results

Liquid Limit Test						**Plastic Limit Test**		
At: 25 Blows		**LL**	**LL**	**LL**	**LL**		**PL**	**PL**
Number of Blows		15	30	42	50			
Moisture Content TIN Number		A	XC	VF	N		M16	C6
Weight of TIN + Wet Soil	g	57	51	56	58		44	38
Weight of TIN + Dry Soil	g	42	39	43	45		36	32
Weight of TIN	g	8	9	9	9		8	8
Weight of Water	g	15	12	13	13		8	6
Weight of dry Soil		34	30	34	36		28	24
Moisture Content	%	44	40	38	36		28.6	25.0
One Point Method	Factor	**Average LL: 39.5%**				**Average PL**	26.8%	

The liquid limit of soil was observed as 39.5%, plastic limit of the soil sample was 26.8% and plasticity index (PI) of soil was 12.7%. Shrinkage limit of soil was observed as 11.2%. The results of LL, PL and PI for the soil that would be treated with the various percentages of CKD and a constant CF.

Determination of Specific Gravity

The specific gravity of solid particles is determined in the laboratory using the following methods

1. Density bottle method
2. Pycnometer method

Density Bottle Method

Density bottle of 50ml capacity is used IS: 2720 (part II) 1980 and BS.1377:1975. The specific gravity of solid particle can be determined in the laboratory using density bottle fitted with a stopper. The bottle is emptied, washed and refilled with distilled water. The bottle must be filled to the same mark as in the previous case. The mass of the bottle filled with water is then taken. The temperature should be the same.

Let:

M1 = mass of empty bottle

M2 = mass of bottle + dry sample

M3 = mass of bottle + sample + water

M4 = mass of bottle filled with water

Table 10 showed specific gravity analysis.

Table 10: Specific Gravity Test

S/No		**A**	**B**
Sample No			
Location (Anatigha Calabar South)			
Mass of Bottle (M_1)	g	486	486
Mass of Bottle + Sample (M_2)	g	887	880
Mass of Bottle + Sample + Water (M_3)	g	1874	1880
Mass of Bottle Full of Water (M_4)	g	1631	1629
Mass of Water Used ($M_3 - M_2$)	g	987	1000
Mass of Sample Used ($M_2 - M_1$)	g	405	394
Specific Gravity, GS = $\frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$		2.56	2.76
GS Average		**2.66**	

Pycnometer test was also conducted on the soil samples to determine its specific gravity. It was observed that the specific gravity of soil was 2.66.

4.2. Maximum Dry Density Test Results

Compaction is the process by which the soil particles are packed close to each other. The determination of the compaction parameters (i.e. the MDD and OMC of the soil plays an important role since their values are utilized in other experiment, such as CBR and Unconfined compressive strength. These tests were performed using combination of soil and varying percentages of CKD and a constant CF. The results obtained have been used to draw conclusion under category of mixes as follows.

Table 11: Wet Density, Dry Density and Mean MC

100% Soil	Wet Density	1.27	1.38	1.44	1.49	1.38	Average Values	1.39
	Dry Density	1.19	1.24	1.29	1.32	1.18		1.24
	Mean MC	6.8	10.9	11.9	13.8	16.7		12.0
10% CKD & 90% Soil	Wet Density	1.27	1.49	1.66	1.41	1.29	Average Values	1.42
	Dry Density	1.17	1.36	1.48	1.21	1.08		1.26
	Mean MC	8.7	10.1	12.1	16.1	19.2		13.2
20% CKD & 80% Soil	Wet Density	1.36	1.76	1.69	1.66	1.49	Average Values	1.59
	Dry Density	1.23	1.57	1.47	1.40	1.23		1.38
	Mean MC	10.3	12.2	15.3	18.3	21.5		15.5
30% CKD & 70% Soil	Wet Density	1.58	1.80	1.91	1.99	1.86	Average Values	1.83
	Dry Density	1.44	1.61	1.69	1.73	1.56		1.61
	Mean MC	9.6	11.5	13.3	15.1	19.2		13.7
40% CKD & 60% Soil	Wet Density	1.78	1.84	1.99	2.13	2.07	Average Values	1.96
	Dry Density	1.69	1.71	1.78	1.83	1.75		1.75
	Mean MC	5.8	7.3	9.6	12.3	14.2		9.8
50% CKD & 50% Soil	Wet Density	1.80	2.00	2.14	2.22	2.10	Average Values	2.05
	Dry Density	1.66	1.80	1.88	1.90	1.76		1.80
	Mean MC	8.2	11.4	14.1	16.7	19.6		14.0
60% CKD & 40% Soil	Wet Density	1.95	2.15	2.16	2.13	1.95	Average Values	2.07
	Dry Density	1.76	1.88	1.85	1.75	1.60		1.77
	Mean MC	10.9	14.6	16.9	19.8	21.7		16.8

From figure 1, shows that the maximum dry density (MDD) and optimum moisture content (OMC) and wet density respectively of the soil sample under study.

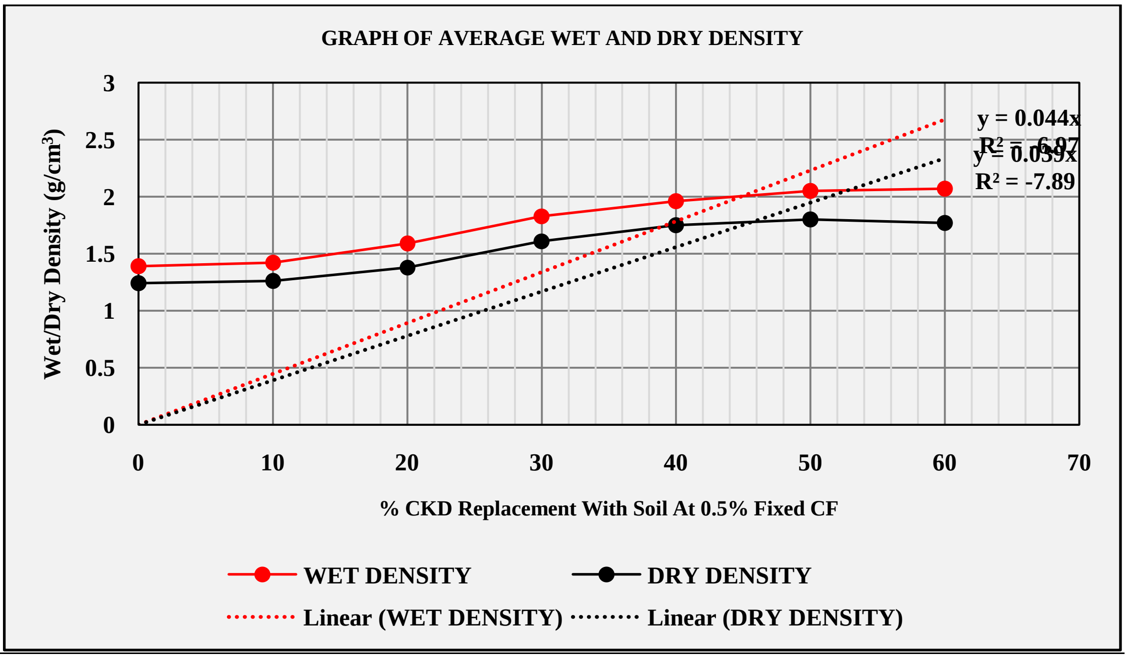

Figure 1

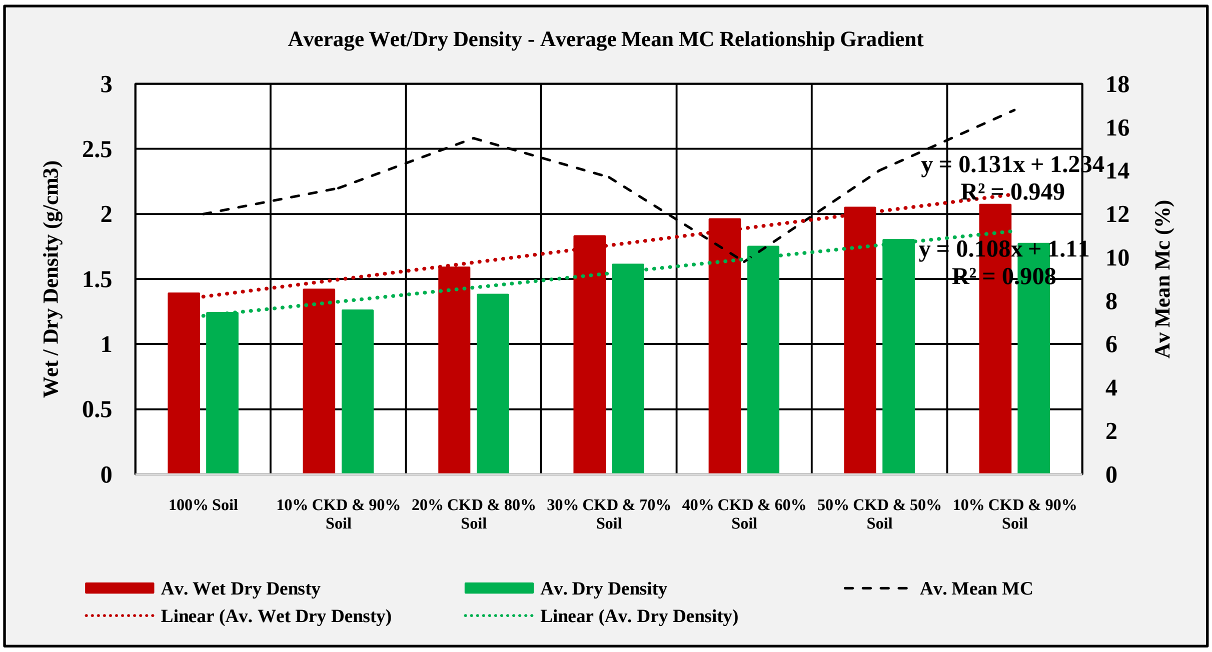

Figure 2

Table 12: MDD and OMC at various composition

% Composition			MDD	OMC
CKD	CF	SOIL	(g/cm^3)	(%)
0	0	100	1.32	13.9
10	0.5	90	1.48	11.9
20	0.5	80	1.57	12.4
30	0.5	70	1.73	14.8
40	0.5	60	1.83	12.2
50	0.5	50	1.90	16.0
60	0.5	40	1.88	14.5

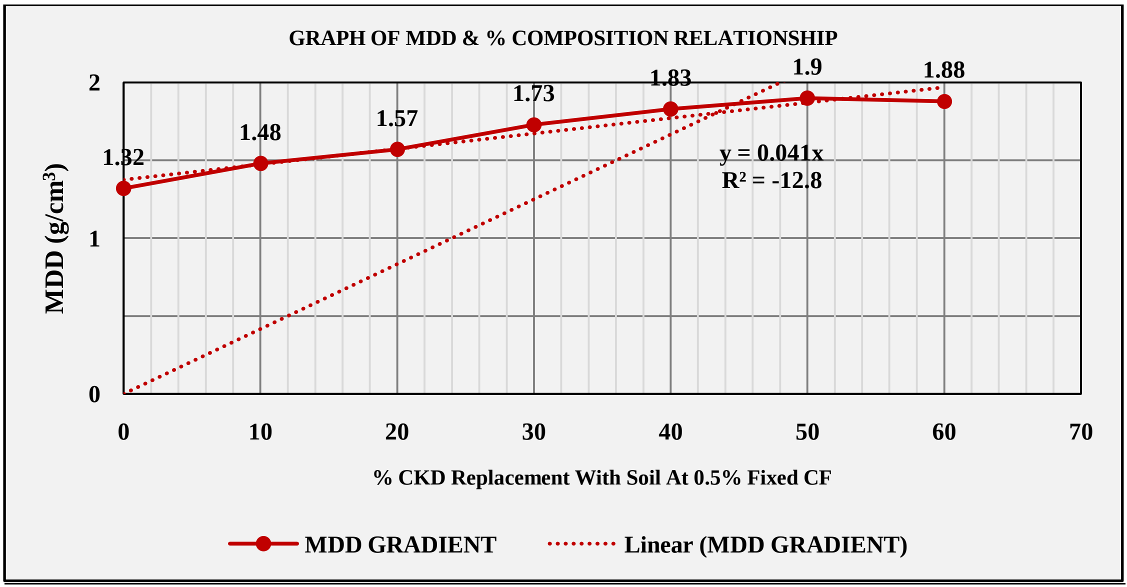

Figure 3

Table 13: MDD, OMC, CBR – RELATIONSHIP

% Composition			MDD	OMC	CBR (%)	
CKD	CF	SOIL	(g/cm^3)	(%)	Unsoak	Soaked
0	0	100	1.32	13.9	6.6	4.2
10	0.5	90	1.48	11.9	23.7	11.6
20	0.5	80	1.57	12.4	28.6	14.8
30	0.5	70	1.73	14.8	38.8	16.1
40	0.5	60	1.83	12.2	34.7	19.6
50	0.5	50	1.90	16.0	63.2	43.7
60	0.5	40	1.88	14.5	57.8	29.5

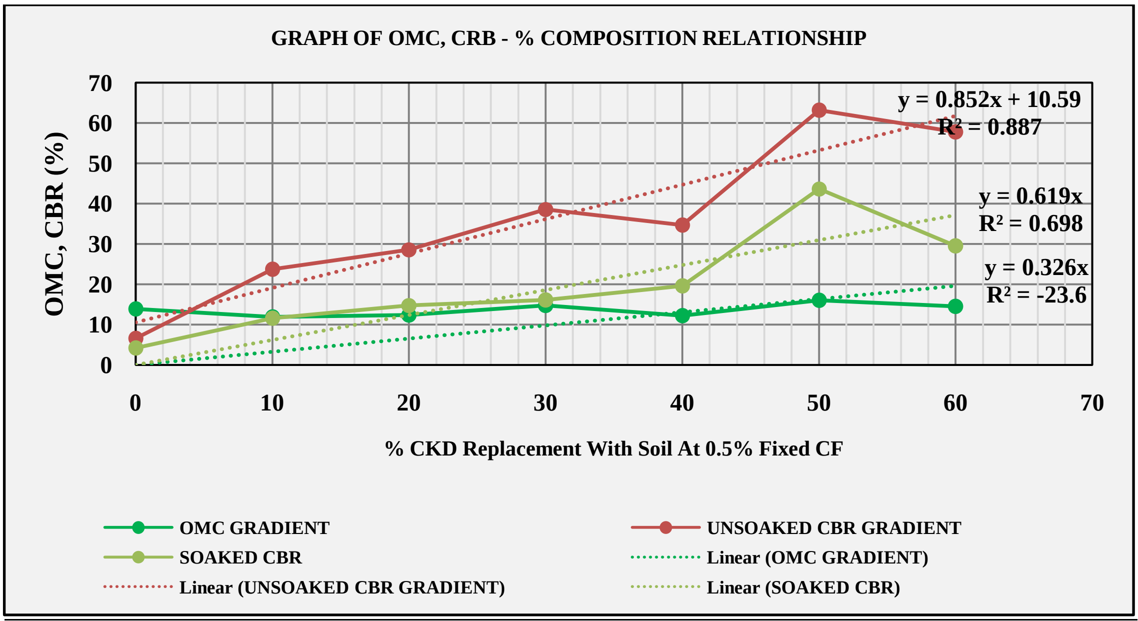

Figure 4

4.6. California Bearing Ratio Test Results

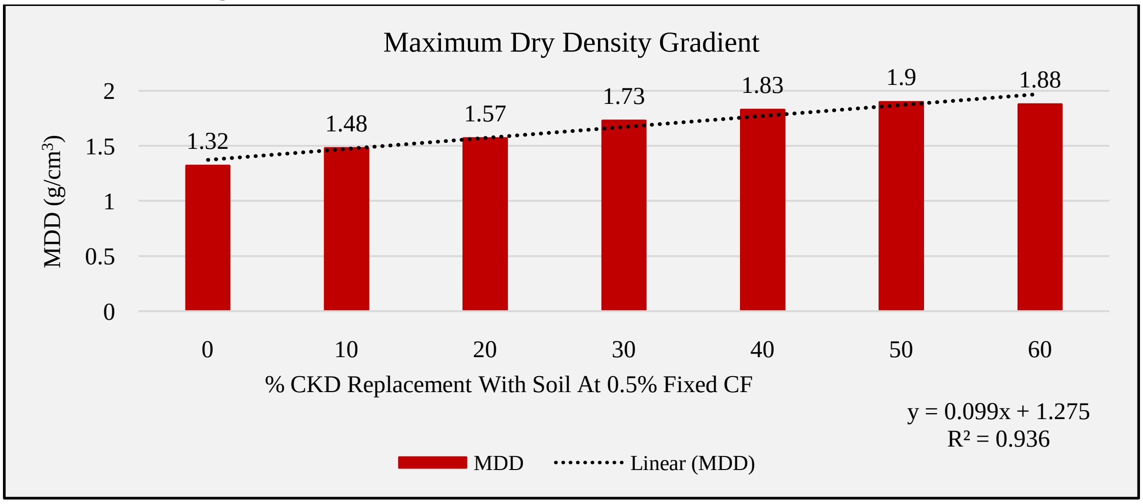

Figure 5

California bearing ratio tests were conducted to evaluate the strength of materials that were proposed to be used in the construction of road. These tests were performed using various combinations of soil with CKD and fixed CF samples. The results obtained have been used to draw inferences under each category of mixes as follows;

Table 14: % Composition and CBR (%)

% Composition			CBR (%)	
CKD	**CF**	**SOIL**	**Unsoak**	**Soaked**
0	0	100	6.6	4.2
10	0.5	90	23.7	11.6
20	0.5	80	28.6	14.8
30	0.5	70	38.8	16.1
40	0.5	60	34.7	19.6
50	0.5	50	63.2	43.7
60	0.5	40	57.8	29.5

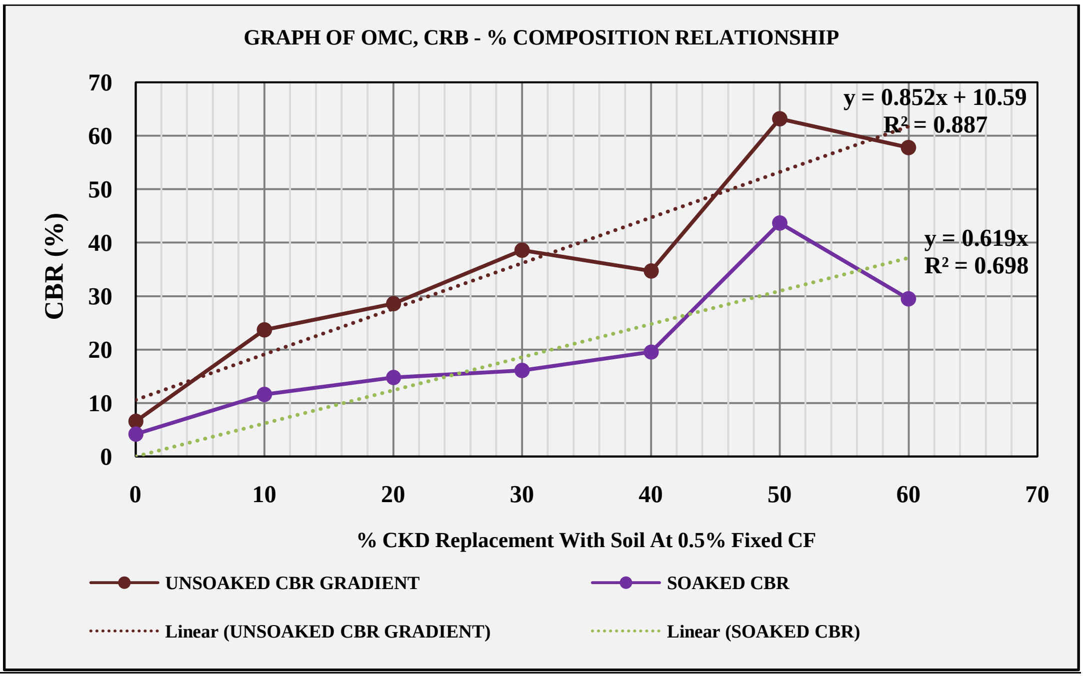

Figure 6

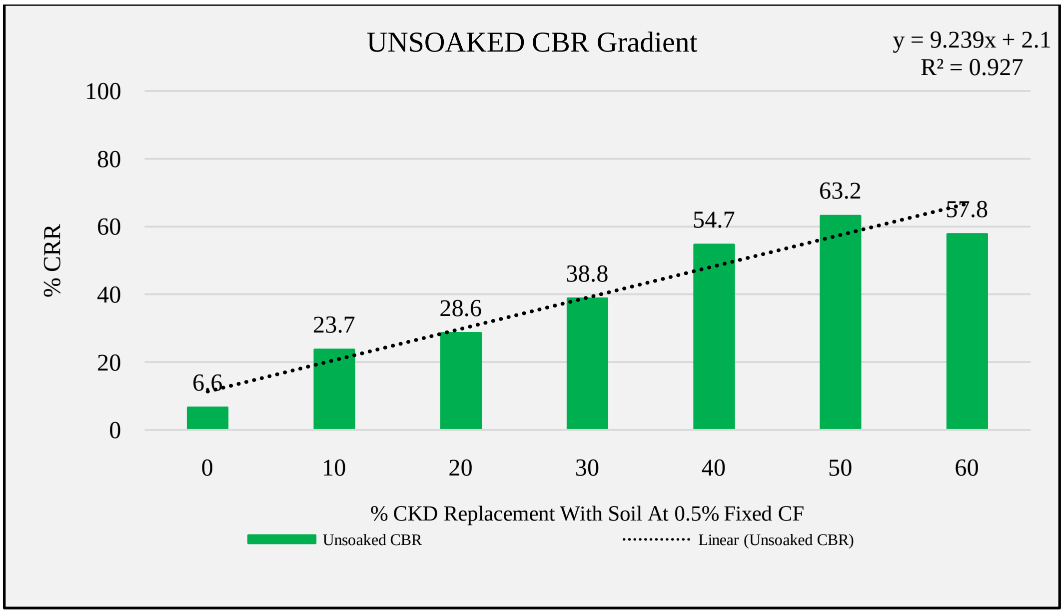

Figure 7

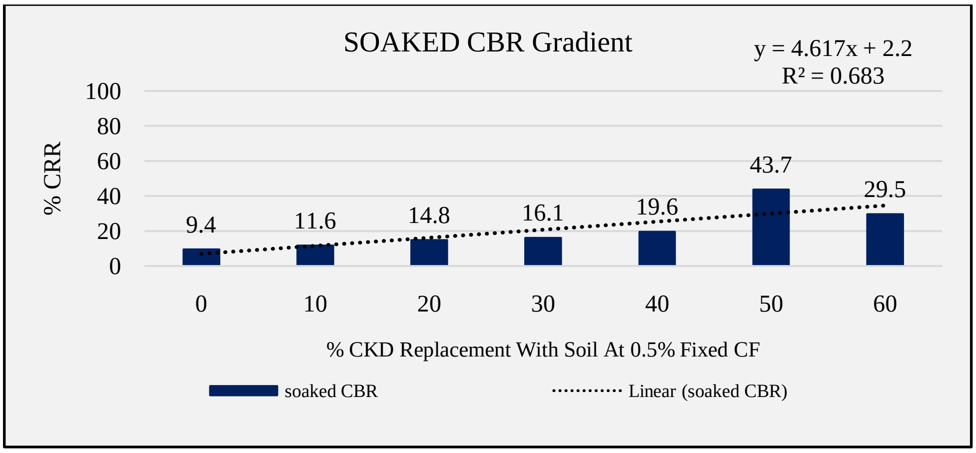

Figure 8

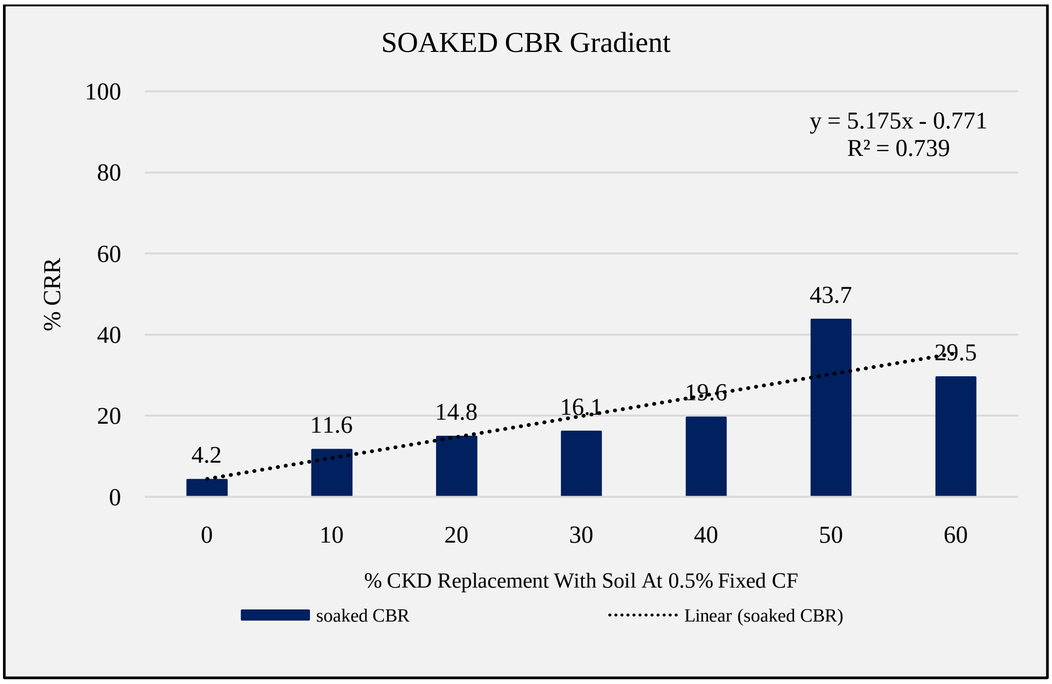

Figure 9

Unconfined Compressive Strength Test

Treating Soil with CKD and coirFiber improves the Geotechnical properties of the soil such as UCS, specific gravity, Density, porosity etc. The UCS of soil is increase with the inclusion of the fiber and the CKD mix decrease the brittleness and improves the ductility behavior. The strength is increase to about 10% with the inclusion of the fiber and CKD. The peak strain at failure is increase with increase of CKD mix.

Mixing soil with CKD and fibre leads to increase in the specific gravity of the mix because addition of low density materials and other materials give a mix with a more density value. It was found that cohesive stress increase as CKD ratio increases in soil mix with days as shown in the table of results below.

Table 15: @Day 0

CKD (%)	CF (%)	UCS (KN/m^2)
0	0.5	189
10	0.5	207
20	0.5	215
30	0.5	219
40	0.5	228
50	0.5	234
60	0.5	248

Table 16: @Day 7

CKD (%)	CF (%)	UCS (KN/m^2)
0	0.5	267
10	0.5	291
20	0.5	316
30	0.5	337
40	0.5	372
50	0.5	395
60	0.5	409

Table 17: @ Day 14

CKD (%)	CF (%)	UCS (KN/m^2)
0	0.5	288
10	0.5	322
20	0.5	346
30	0.5	379
40	0.5	416
50	0.5	435
60	0.5	456

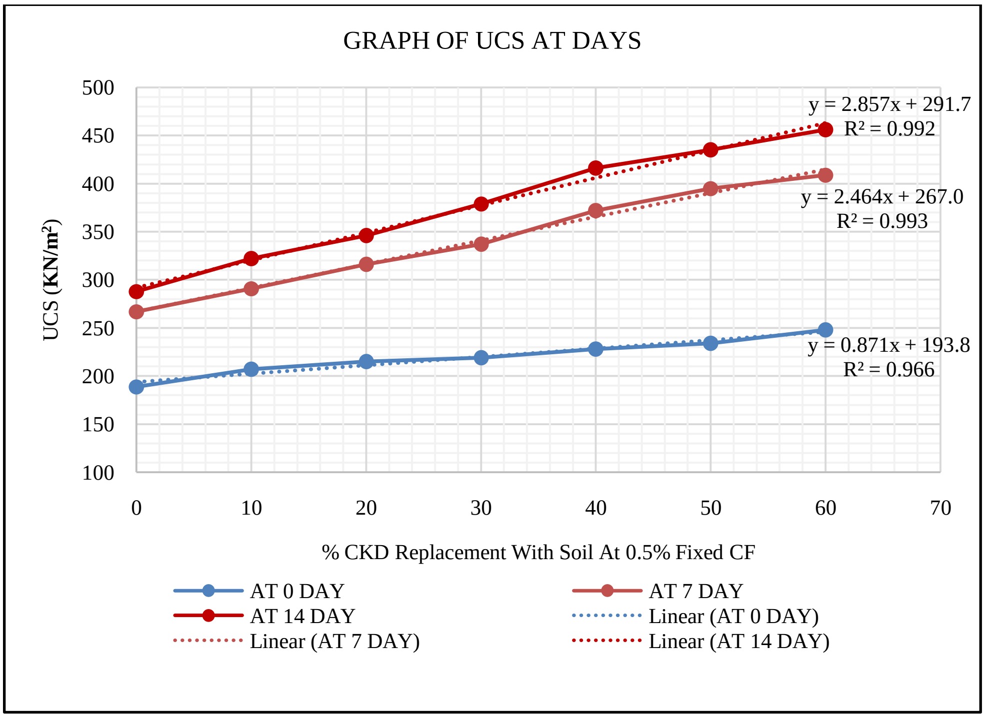

Figure 10

5. Conclusion and Recommendations

Various tests were performed on soil and soil mixed with varying percentages of CKD and a fixed CF. The following tests were performed (1) standard proctor test, (2) California bearing ratio and unconfined compressive strength test.

Table 18: Results of soil and soil mixed with different % of CKD and a Fixed FC

S. No	Mix samples	Parameters Studied										
		LL %	PL %	PI %	G	OMC %	MDD %	CBR %		UCS (KN/M^2		
								UNS	SO	0	7	14
1	soil100% +0%ckd+0%cf	39.5	26.8	12.7	2.66	13.9	1.32	6.6	4.2	189	267	288
2	soil90%+10%ckd+0.5%cf					11.9	1.48	23.7	11.6	207	291	322
3	soil80%+20%ckd+0.5%cf					12.4	1.57	28.6	14.8	215	316	346
4	soil70%+30%ckd+0.5%cf					14.8	1.78	38.8	16.1	219	337	379
5	soil60%+40%ckd+0.5%cf					12.2	1.83	34.7	19.6	228	372	416
6	soil50%+50%ckd+0.5%cf					16.0	1.90	63.2	43.7	234	395	435
7	soil40%+60%ckd+0.5%cf					14.5	1.88	57.8	29.5	248	409	456

5.1. Conclusion

Experiments were carried out to assess the mechanical properties of treated and untreated soil. The result indicated significantly higher improvements in the mechanical and associated strength properties when CKD and CF was added and mixed with the soil rather than using soil alone, this indicate that the activation of CKD and CF is viable. Based on the result generated from the laboratory analysis as an effort to characterize the soil under study, the following variables were deduced in their different categories. The results are summaries in table 5.1 as follows.

At 100% soil material, 0%CKD and 0%CF the result obtained are as follows; Particles Size Distribution (% Passing =0.075mm) for Wet Sieve Method =38.1% and Dry Sieve Method=29.3%, Liquid limit =36.8%, plastic limit =20.4%, plasticity index =16.8%, shrinkage limit =11.2%, Maximum Dry Density (MDD) =1.32g/cm^3 =Optimum Moisture Content (OMC) =13.9%, the CBR for Unsoaked =6.4% and CBR for Soaked =4.4%, Unconfined compressive strength (UCS) for 0Days =189, for 7days =267 and for 14days =288. From the parameters above it shows that at 100% soil material, 0%CKD and 0%CF the soil has high level of porosity and low strength in terms of it workability from the CBR results which means that the soil material is poor and need to be treated with additives to suit it engineering purposes.

At 90% soil, 10%CKD and 0.5%CF, the MDD =1.48% and OMC is =11.9%, the CBR unsoaked =23.7% and soaked =11.6%, UCS for 0days =207, 7days =291 and 14days =322, this shows that OMC followed decreasing trend and MDD followed increasing trend with increasing percentages of CKD and CF and also the CBR and USC followed increasing trend which shows that the soil material is gaining it stability after the enclosure of CKD and CF has additive materials

Result for 20% CKD, 0.5% CF and 80% Soil material obtained are as follows; maximum dry density (MDD) = 1.57g/cm^3, optimum moisture content (OMC) = 12.4%, CBR (unsoaked = 28.6%, soaked = 14.8%).

Result for 30% CKD, 0.5% CF and 70% Soil material obtained are as follows; maximum dry density (MDD) = 1.73g/cm^3, optimum moisture content (OMC) = 14.8%, CBR (unsoaked = 38.8%, soaked = 16.1%).

Result for 40% CKD, 0.5% CF and 60% Soil material obtained are as follows; maximum dry density (MDD) = 1.83g/cm^3, optimum moisture content (OMC) = 12.2%, CBR (unsoaked = 34.7%, soaked = 19.6%).

Result for 50% CKD, 0.5% CF and 50% Soil material obtained are as follows; maximum dry density (MDD) = 1.90g/cm^3, optimum moisture content (OMC) = 16.0%, CBR (unsoaked = 63.2%, soaked = 43.7%).

Result for 60% CKD, 0.5% CF and 40% Soil material obtained are as follows; maximum dry density (MDD) = 1.88g/cm^3, optimum moisture content (OMC) = 14.5%, CBR (unsoaked = 57.8%, soaked = 29.5%).

On the basis of the laboratory result, the MDD progresses from 0% CKD, 0. % CF and 0% Soilmaterial to 50% CKD, 50% soil material at a constant CF of 0.5% before dropping (falling) showing that the maximum peak workability of both materials (CKD, CF and soil material) by percentage replacement is 50% CKD, 50% soil material at a fixed CF of 0.5%, thus, the CBR shows the same characteristic properties.

In Engineering, design consideration is always based on designing for the worse condition, hence the (soaked CBR) is considered more in this investigation because it determined the actual strength of the soil, andthe CBR result showed that the peak workability of the soil material is still at 50% CKD and 50% of soil by percentage of material replacement. The result of this work is subject for further investigation, however, there may be variation in the result after onward review based on the method deployed for the investigation.

5.2. Recommendations

From the results obtained from the laboratory analysis of the materials, the following recommendations were reached;

1. On the basis of the material characterization, it is recommended that the soil material, CKD and CF within the same range of classification can be used to achieve same or similar result as contained in this research work.
2. To achieve adequate relative dry density, the range of workability of 10:90 to 50:50 by percentage of material replacement should be considered depending on the choice of material strength requirement for the particular design, hence, within the range specified above the material does not need any further additives to stabilize it.
3. Based on the laboratory result, the material is suitable for pavement designs and other engineering works, but it is advisable not to over saturate it with moisture.

5.3. Scope of Further Study

1. More preliminary test i.e. tri-axial compression test, flexural toughness test, direct tension test, permeability test of the soil can be experimented to improve the soil properties.
2. A wider range of compaction energy and curing time should be considered for developing more reliable design
3. More research needs to be carry out to use CKD, CF and Soil for civil engineering constructions considering study for more geotechnical parameters.

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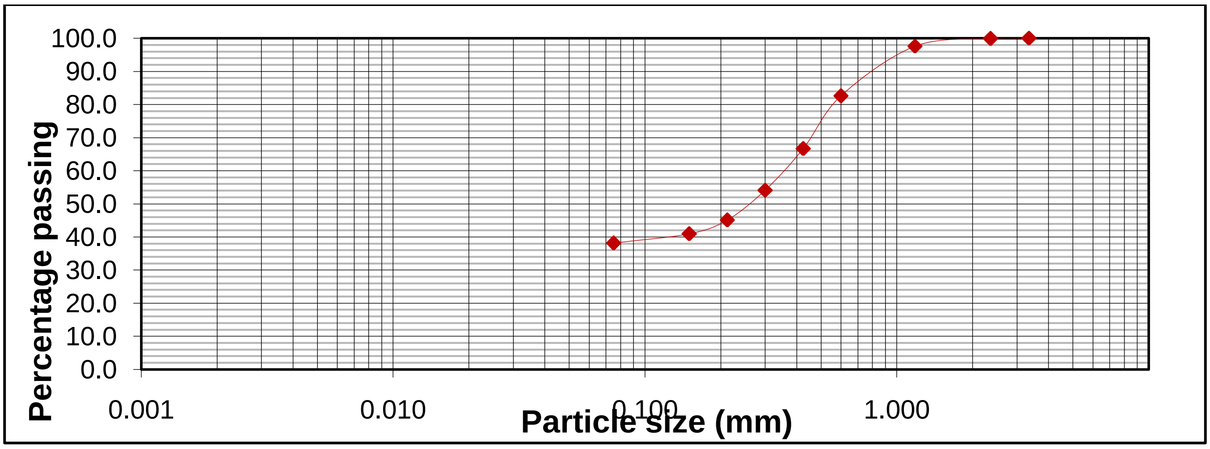
APPENDICES

APPENDIX A

SAMPLE NO. = 1 (wet sieve)
WET WEIGHT OF SAMPLE = 1000g
DRY WEIGHT OF SAMPLE = 625g
ABSOLUTE WEIGHT OF SAMPLE = 619g

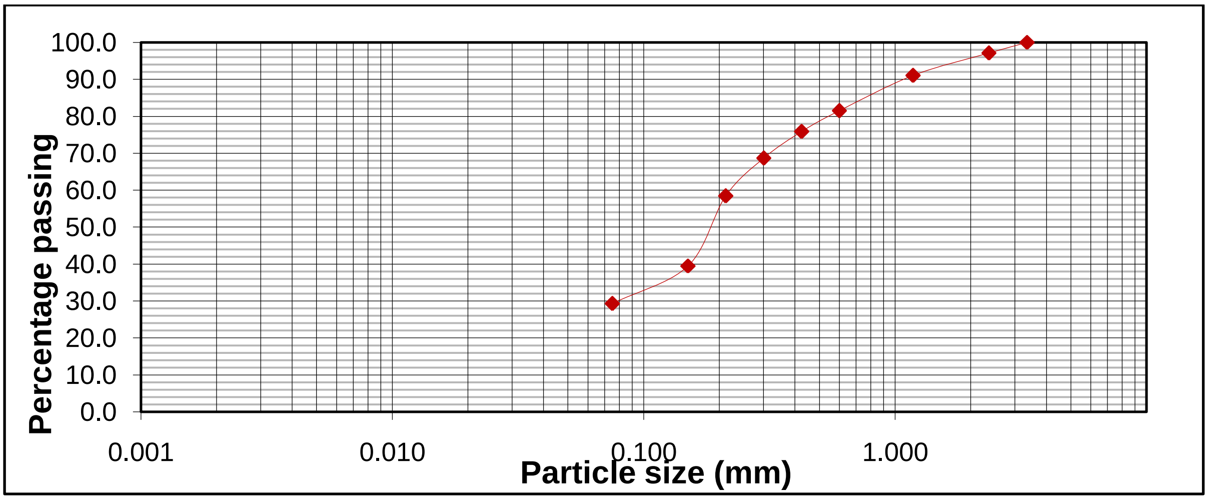
Sieve (mm)	Mass (g)	% retained	% passing
3.4	0	0.0	100.0
2.4	1	0.1	99.9
1.2	23	2.3	97.6
0.6	150	15.0	82.6
0.43	160	16.0	66.6
0.30	125	12.5	54.1
0.21	90	9.0	45.1
0.150	42	4.2	40.9
0.075	28	2.8	38.1
Pan	381	38.1	
TOTAL	1000		



APENDIX A2

SAMPLE NO. = 1 (dry sieve)
DRY WEIGHT OF SAMPLE = 1000g
ABSOLUTE WEIGHT OF SAMPLE = 1000g

Sieve (mm)	Mass (g)	% retained	% passing
3.4	0	0.0	100.0
2.4	29	2.9	97.1
1.2	60	6.0	91.0
0.6	95	9.6	81.5
0.43	56	5.6	75.8
0.30	71	7.2	68.7
0.21	102	10.3	58.4
0.150	188	18.9	39.5
0.075	101	10.2	29.3
pan	291	29.3	
TOTAL	1000		



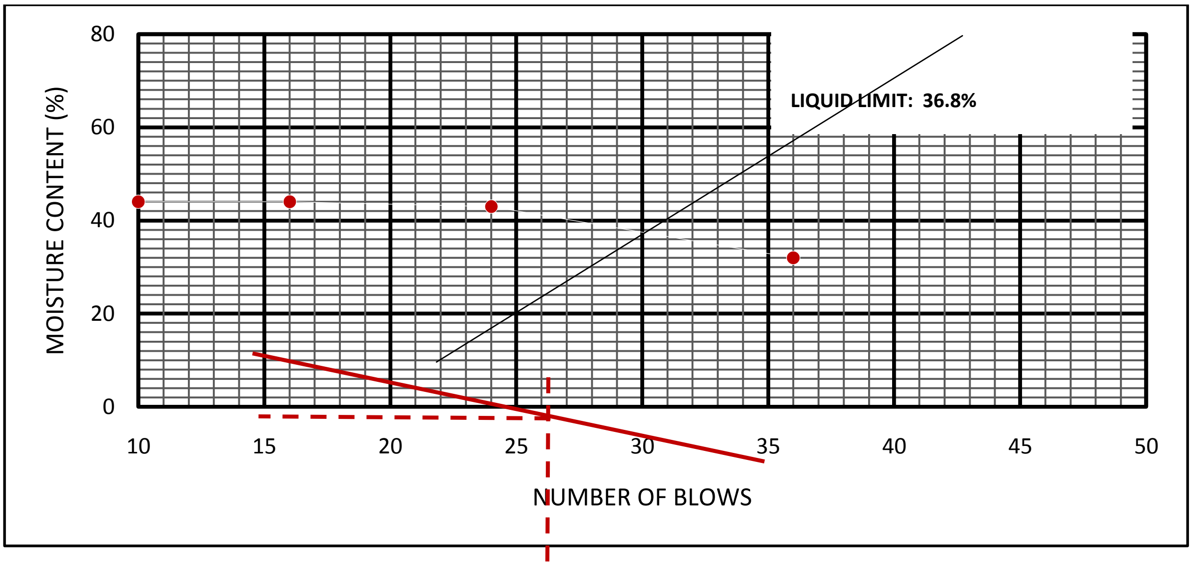
APENDIX B1

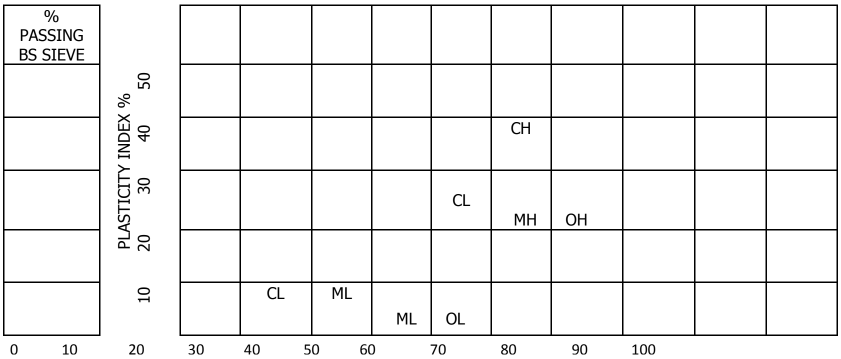
SAMPLE COMPOSITION: 0% CKD, 0% COIR FIBER& 100% SOIL
SAMPLE DESCRIPTION: BROWN SILTY CLAY

LIQUID LIMIT TEST					
At: 25 BLOWS		**LL**	**LL**	**LL**	**LL**
NUMBER OF BLOWS		10	16	24	36
MOISTURE CONTENT TIN NUMBER		W5	IN	CA	ZZ
WEIGHT OF TIN + WET SOIL g		30	33	37	38
WEIGHT OF TIN +DRY SOIL g		23	25	28	29
WEIGHT OF TIN g		7	7	7	7
WEIGHT OF WATER g		7	8	9	7
WEIGHT OF DRY SOIL		16	18	21	22
MOISTURE CONTENT %		44	44	43	32
ONE POINT METHOD	FACTOR	**AVERAGE LL: 40.8%**			

PLASTIC LIMIT TEST		
	PL	**PL**
	V55	PQ2
	37	32
	32	28
	8	8
	5	4
	24	20
	20.8	20.0
AVERAGE PL	20.4%	

APENDIX B2





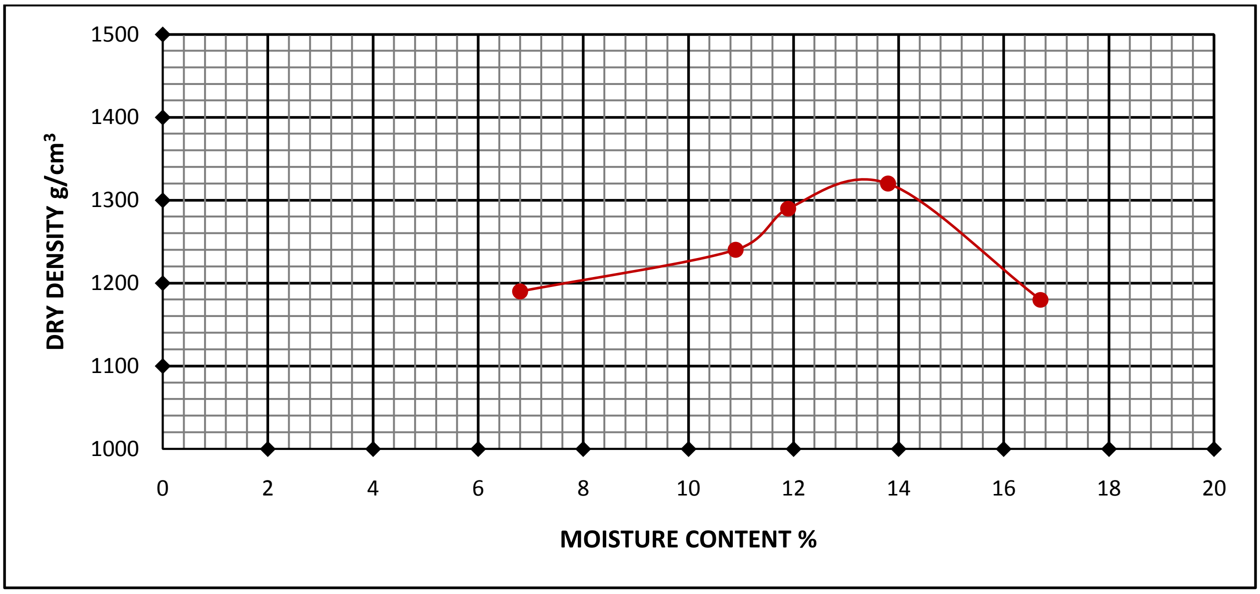
APENDIX B3

SAMPLE COMPOSITION: 0% CKD, 0% COIR FIBER& 100% SOIL
SAMPLE DESCRIPTION: BROWN SILTY CLAY
LAB NO: 1

MOISTURE DENSITY RELATIONSHIP

	Type of mould: MODIFIED PROCTOR						Number of layers: 3					
	Number of blows per layer: 25						Weight of hammer: 4.5Kg					
A	Wt of mould + wet soil *(W_1)*	Kg	3000		3100		3150		3200		3100	
B	Wt of empty mould *(W_2)*	Kg	1.850		1.850		1.850		1.850		1.850	
C	Wt of wet sample *(W_1 - W_2)*	Kg	1.150		1.250		1.300		1.350		1.250	
D	Wet Density *$P=(W_1 - W_2) / V$*	Kg/m^3	1274		1384		1440		1495		1384	
E	Moisture Content	TIN	DE	WA	Q	AS	ZX	CC	TE	ON	MB	JU
F	Wt of wet Soil +TIN (M)	g	30	30	44	42	54	55	62	60	54	52
G	Wt of Dry soil +TIIN (M_2)	g	28	29	39	40	49	50	55	54	48	45
H	Wt of Water (M_1 – M_2)	g	2	1	5	2	5	5	7	6	6	7
I	Wt of TIN (M_3)	g	6	7	7	8	8	7	7	8	8	6
J	Wt of Dry soil *(M_2-M_3)*	g	22	22	32	32	41	43	48	46	40	38
K	Moisture Content *(M)*	%	9.09	4.55	15.63	6.25	12.20	11.63	14.58	13.04	15.00	18.42

L	Mean M/C	%	6.8	10.9	11.9	13.8	16.7
M	Dry Density GM/CMMG/M^3	g/cm^3	1.19	1.24	1.29	1.32	1.18



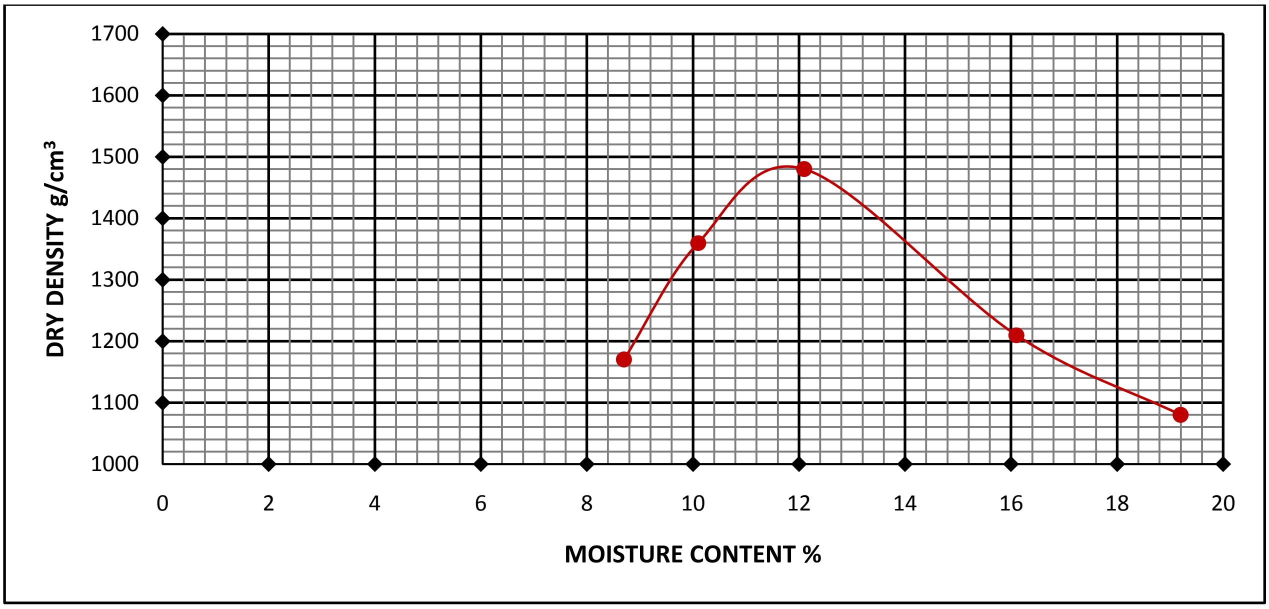
COMPACTION STANDARD: B.S
MAXIMUM DRY DENSITY: 1.32g/cm^3
OPTIMUM MOISTURE CONTENT (%): 13.9

APENDIX B4

SAMPLE COMPOSITION: 10% CKD, 0.5% COIR FIBER & 90% SOIL
SAMPLE DESCRIPTION: BROWN SILTY CLAY + CKD AND COIR FIBER
LAB NO: 2

MOISTURE DENSITY RELATIONSHIP

	Type of mould: MODIFIED PROCTOR						Number of layers: 3				
	Number of blows per layer: 25						Weight of hammer: 4.5Kg				
A	Wt of mould + wet soil *(W_1)*	Kg	3000		3200		3350		3120		3015	
B	Wt of empty mould *(W_2)*	Kg	1.850		1.850		1.850		1.850		1.850	
C	Wt of wet sample *(W_1 - W_2)*	Kg	1.150		1.350		1.500		1.270		1.165	
D	Wet Density *$P=(W_1 - W_2) / V$*	Kg/m^3	1274		1495		1661		1406		1290	
E	Moisture Content	TIN	G	OP	BV	FG	AZ	D5	OX	H5	G4	TA
F	Wt of wet Soil +TIN (M)	g	44	43	52	50	54	53	62	61	66	66
G	Wt of Dry soil +TIIN (M_2)	g	41	40	48	46	49	48	54	54	57	56
H	Wt of Water (M_1 – M_2)	g	3	3	4	4	5	5	8	7	9	10
I	Wt of TIN (M_3)	g	6	6	8	7	7	7	7	8	7	7
J	Wt of Dry soil *(M_2-M_3)*	g	35	34	40	39	42	41	47	46	50	49
K	Moisture Content *(M)*	%	8.57	8.82	10.00	10.25	11.90	12.20	17.02	15.22	18.00	20.41
L	Mean M/C	%	8.7		10.1		12.1		16.1		19.2	
M	Dry Density GM/CMMG/M^3	g/cm^3	1.17		1.36		1.48		1.21		1.08	



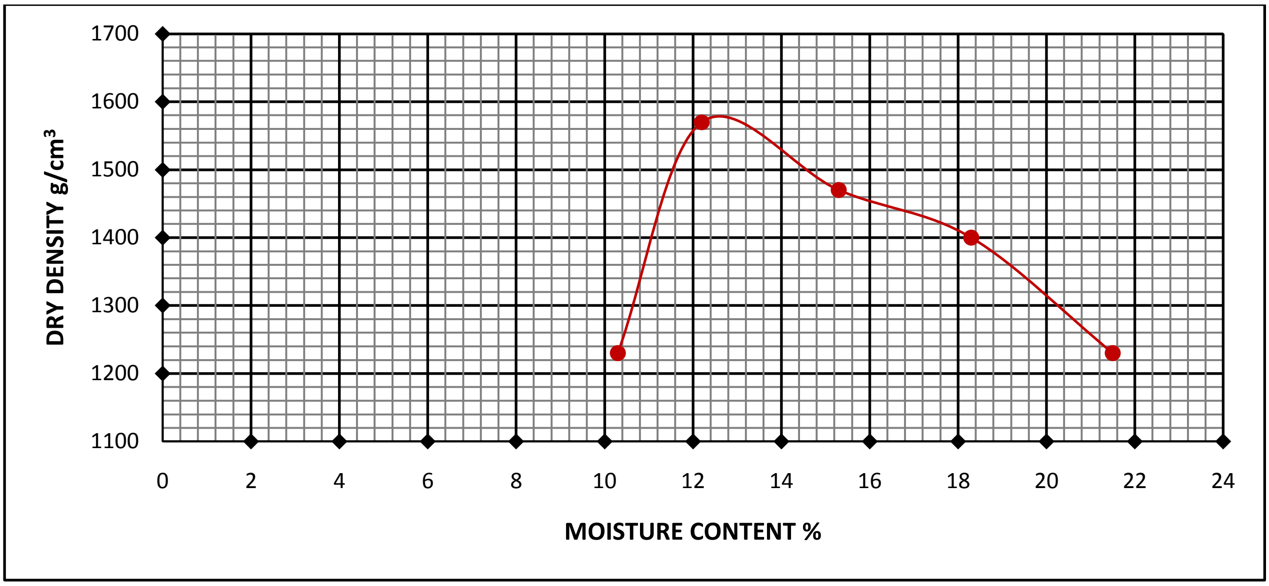
COMPACTION STANDARD: B.S
MAXIMUM DRY DENSITY: 1.48g/cm^3
OPTIMUM MOISTURE CONTENT (%): 11.9

APENDIX B5

SAMPLE COMPOSITION: 20% CKD, 0.5% COIR FIBER & 80% SOIL
SAMPLE DESCRIPTION: BROWN SILTY CLAY + CKD AND COIR FIBER
LAB NO: 3

MOISTURE DENSITY RELATIONSHIP

	Type of mould: MODIFIED PROCTOR						Number of layers: 3					
	Number of blows per layer: 25						Weight of hammer: 4.5Kg					
A	Wt of mould + wet soil *(W_1)*	Kg	3082		3440		3380		3350		3200	
B	Wt of empty mould *(W_2)*	Kg	1.850		1.850		1.850		1.850		1.850	
C	Wt of wet sample *(W_1 - W_2)*	Kg	1.230		1.590		1.530		1.500		1.350	
D	Wet Density $P=(W_1 - W_2) / V$	Kg/m^3	1362		1761		1694		1661		1495	
E	Moisture Content	TIN	FG	ZE	TIN	B4	Z	DT	PQ	SV	F3	AB
F	Wt of wet Soil +TIN (M)	g	50	50	48	47	48	48	50	54	57	54
G	Wt of Dry soil +TIIN (M_2)	g	46	46	44	43	43	42	44	46	49	45
H	Wt of Water (M_1 – M_2)	g	4	4	4	5	5	6	6	8	8	9
I	Wt of TIN (M_3)	g	7	7	7	6	7	6	8	6	9	6
J	Wt of Dry soil *(M_2-M_3)*	g	39	39	37	37	36	36	36	40	40	39
K	Moisture Content *(M)*	%	10.25	10.25	10.81	13.51	13.89	16.67	16.67	20.00	20.00	23.08
L	Mean M/C	%	10.3		12.2		15.3		18.3		21.5	
M	Dry Density GM/CMMG/M^3	g/cm^3	1.23		1.57		1.47		1.40		1.23	



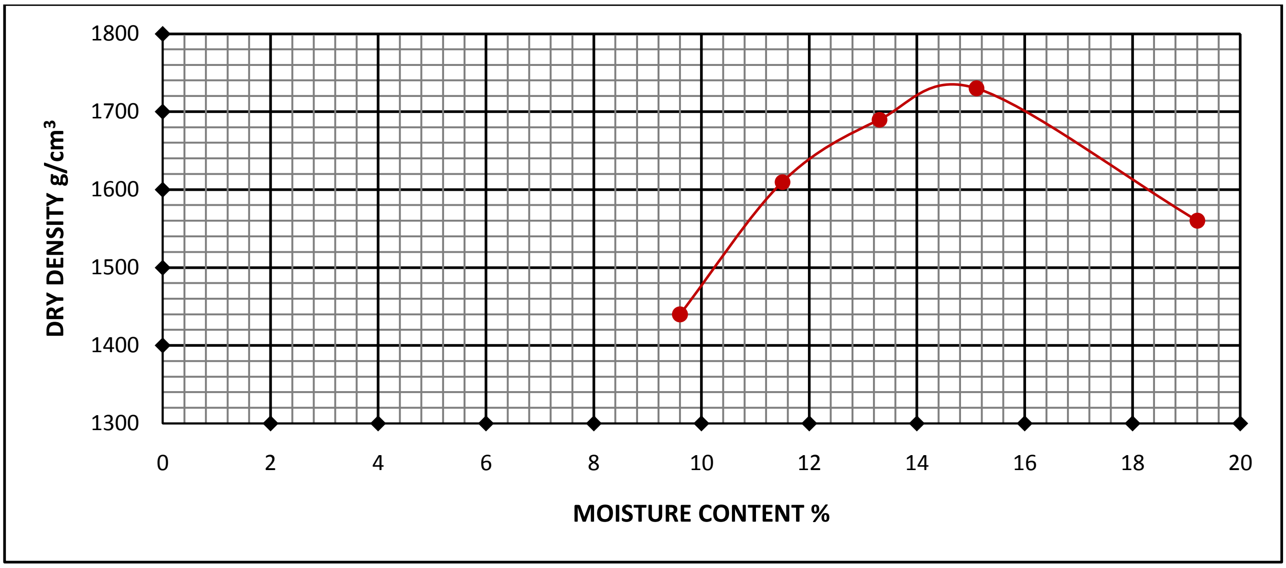
COMPACTION STANDARD: B.S
MAXIMUM DRY DENSITY: 1.57g/cm^3
OPTIMUM MOISTURE CONTENT (%): 12.4

APENDIX B6

SAMPLE COMPOSITION: 30% CKD, 0.5% COIR FIBER & 70% SOIL
SAMPLE DESCRIPTION: BROWN SILTY CLAY + CKD AND COIR FIBER
LAB NO: 4

MOISTURE DENSITY RELATIONSHIP

	Type of mould: MODIFIED PROCTOR						Number of layers: 3					
	Number of blows per layer: 25						Weight of hammer: 4.5Kg					
A	Wt of mould + wet soil (W_1)	Kg	3330		3528		3626		3700		3580	
B	Wt of empty mould (W_2)	Kg	1.900		1.900		1.900		1.900		1.900	
C	Wt of wet sample $(W_1 - W_2)$	Kg	1.430		1.628		1.726		1.800		1.680	
D	Wet Density $P=(W_1 - W_2) / V$	Kg/m^3	1584		1803		1911		1993		1860	
E	Moisture Content	TIN	SO	UM	SU	ZZ	SM	CA	SP	E10	SQ	G6
F	Wt of wet Soil +TIN (M)	g	46	47	58	55	68	67	76	77	96	92
G	Wt of Dry soil +TIIN (M_2)	g	42	44	52	51	61	60	68	67	80	80
H	Wt of Water $(M_1 – M_2)$	g	4	3	6	4	7	7	8	10	16	12
I	Wt of TIN (M_3)	g	6	7	8	8	8	8	8	8	7	7
J	Wt of Dry soil (M_2-M_3)	g	36	37	44	43	53	52	60	59	73	73
K	Moisture Content (M)	%	11.11	8.11	13.64	9.30	13.21	13.46	13.33	16.95	21.92	16.44
L	Mean M/C	%	9.6		11.5		13.3		15.1		19.2	
M	Dry Density GM/CMMG/M^3	g/cm^3	1.44		1.61		1.69		1.73		1.56	



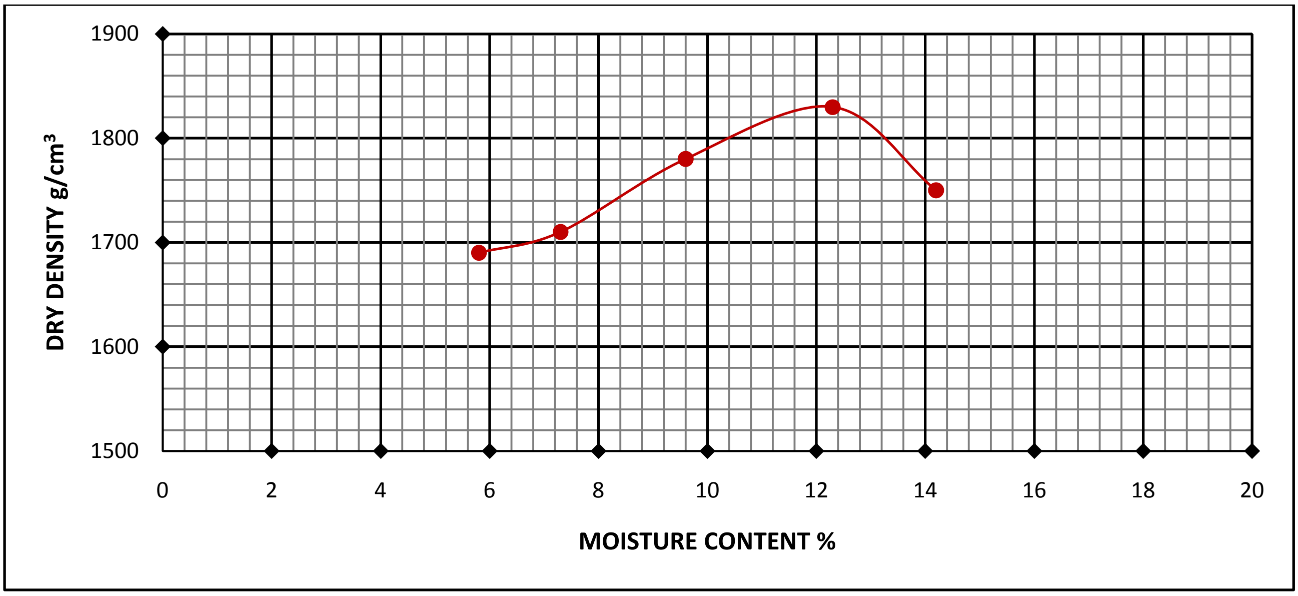
COMPACTION STANDARD: B.S
MAXIMUM DRY DENSITY: 1.73g/cm^3
OPTIMUM MOISTURE CONTENT (%): 14.8

APENDIX B7

SAMPLE COMPOSITION: 40% CKD, 0.5% COIR FIBER & 60% SOIL
SAMPLE DESCRIPTION: BROWN SILTY CLAY + CKD AND COIR FIBER
LAB NO: 5

MOISTURE DENSITY RELATIONSHIP

	Type of mould: MODIFIED PROCTOR						Number of layers: 3				
	Number of blows per layer: 25						Weight of hammer: 4.5Kg				
A	Wt of mould + wet soil (W_1)	Kg	3654		3708		3860		4000		3945
B	Wt of empty mould (W_2)	Kg	1876		1876		1876		1876		1876
C	Wt of wet sample $(W_1 - W_2)$	Kg	1778		1832		1984		2124		2073
D	Wet Density $P=(W_1 - W_2) / V$	Kg/m^3	1782		1836		1985		2128		2073
E	Moisture Content	TIN	KO	Z	B3	M	AD	KO	Z	B3	M	AD
F	Wt of wet Soil +TIN (M)	g	47	47	44	43	38	47	47	44	43	38
G	Wt of Dry soil +TIIN (M_2)	g	45	45	41	41	35	45	45	41	41	35
H	Wt of Water $(M_1 – M_2)$	g	2	2	3	2	3	2	2	3	2	3
I	Wt of TIN (M_3)	g	8	8	8	9	8	8	8	8	9	8
J	Wt of Dry soil (M_2-M_3)	g	37	37	33	32	27	37	37	33	32	27
K	Moisture Content *(M)*	%	5.4	5.4	9.1	6.3	11.1	5.4	5.4	9.1	6.3	11.1
L	Mean M/C	%	5.8		7.3		9.6		12.3		14.2	
M	Dry Density GM/CMMG/M^3	g/cm^3	1.69		1.71		1.78		1.83		1.75	



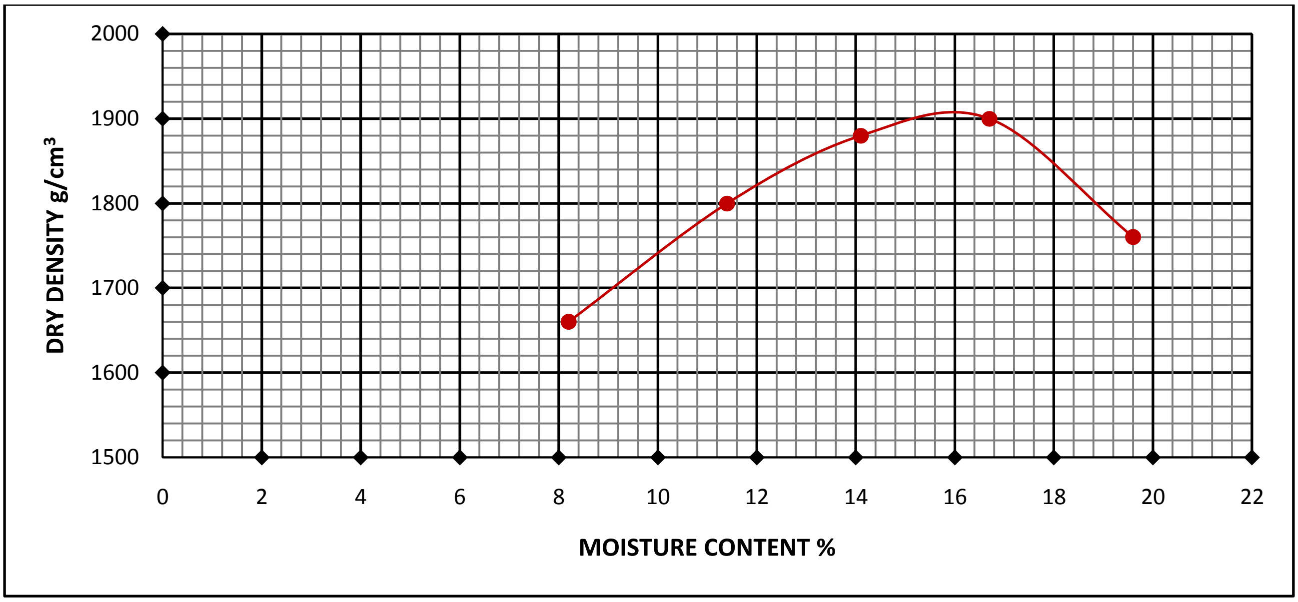
COMPACTION STANDARD: B.S
MAXIMUM DRY DENSITY: 1.83g/cm^3
OPTIMUM MOISTURE CONTENT (%): 12.2

APENDIX B8

SAMPLE COMPOSITION: 50% CKD, 0.5% COIR FIBER & 50% SOIL
SAMPLE DESCRIPTION: BROWN SILTY CLAY + CKD AND COIR FIBER
LAB NO: 6

MOISTURE DENSITY RELATIONSHIP

	Type of mould: MODIFIED PROCTOR						Number of layers: 3					
	Number of blows per layer: 25						Weight of hammer: 4.5Kg					
A	Wt of mould + wet soil *(W_1)*	Kg	3525		3710		3835		3900		3800	
B	Wt of empty mould *(W_2)*	Kg	1.900		1.900		1.900		1.900		1.900	
C	Wt of wet sample *(W_1 - W_2)*	Kg	1.625		1.810		1.935		2.00		1.900	
D	Wet Density *$P=(W_1 - W_2)/V$*	Kg/m^3	1800		2004		2143		2215		2104	
E	Moisture Content	TIN	DF	TV	CD	SA	WE	QW	AS	BB	GT	KM
F	Wt of wet Soil +TIN (M)	g	56	51	46	67	80	78	86	84	62	62
G	Wt of Dry soil +TIIN (M_2)	g	52	48	42	61	70	70	76	72	52	54
H	Wt of Water ($M_1 – M_2$)	g	4	3	4	6	10	8	10	12	10	8
I	Wt of TIN (M_3)	g	8	7	7	8	6	6	8	8	7	7
J	Wt of Dry soil *(M_2-M_3)*	g	44	41	35	53	64	64	68	64	45	47
K	Moisture Content *(M)*	%	9.09	7.32	11.43	11.32	15.63	12.50	14.70	18.75	22.22	17.02
L	Mean M/C	%	8.2		11.4		14.1		16.7		19.6	
M	Dry Density GM/CMMG/M^3	g/cm^3	1.66		1.80		1.88		1.90		1.76	



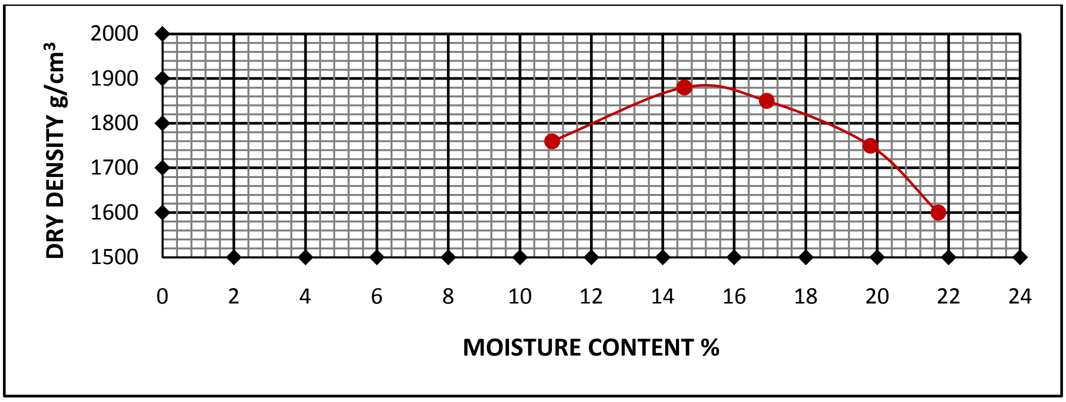
COMPACTION STANDARD: B.S	
MAXIMUM DRY DENSITY: 1.90g/cm^3	
OPTIMUM MOISTURE CONTENT (%): 16.0	

APENDIX B9

SAMPLE COMPOSITION: 60% CKD, 0.5% COIR FIBER & 40% SOIL
SAMPLE DESCRIPTION: BROWN SILTY CLAY + CKD AND COIR FIBER
LAB NO: 7

MOISTURE DENSITY RELATIONSHIP

	Type of mould: MODIFIED PROCTOR						Number of layers: 3					
	Number of blows per layer: 25						Weight of hammer: 4.5Kg					
A	Wt of mould + wet soil *(W_1)*	Kg	3610		3795		3860		3715		3608	
B	Wt of empty mould *(W_2)*	Kg	1.850		1.850		1.850		1.850		1.850	
C	Wt of wet sample *(W_1 - W_2)*	Kg	1.760		1.945		1.950		1.925		1.758	
D	Wet Density *P=(W_1 - W_2) / V*	Kg/m^3	1949		2154		2159		2132		1947	
E	Moisture Content	TIN	FD	CS	FT	GF	WR	QA	Y	TE	OK	MO
F	Wt of wet Soil +TIN (M)	g	63	63	62	62	58	55	62	61	66	66
G	Wt of Dry soil +TIIN (M_2)	g	57	58	55	55	51	48	53	52	56	55
H	Wt of Water (M_1 – M_2)	g	6	5	7	7	7	7	9	9	10	11
I	Wt of TIN (M_3)	g	8	6	7	7	8	8	7	7	7	7
J	Wt of Dry soil *(M_2-M_3)*	g	49	52	48	48	43	40	46	45	49	48
K	Moisture Content *(M)*	%	12.24	9.62	14.58	14.58	16.28	17.50	19.57	20.00	20.40	22.92
L	Mean M/C	%	10.9		14.6		16.9		19.8		21.7	
M	Dry Density GM/CMMG/M^3	g/cm^3	1.76		1.88		1.85		1.75		1.60	

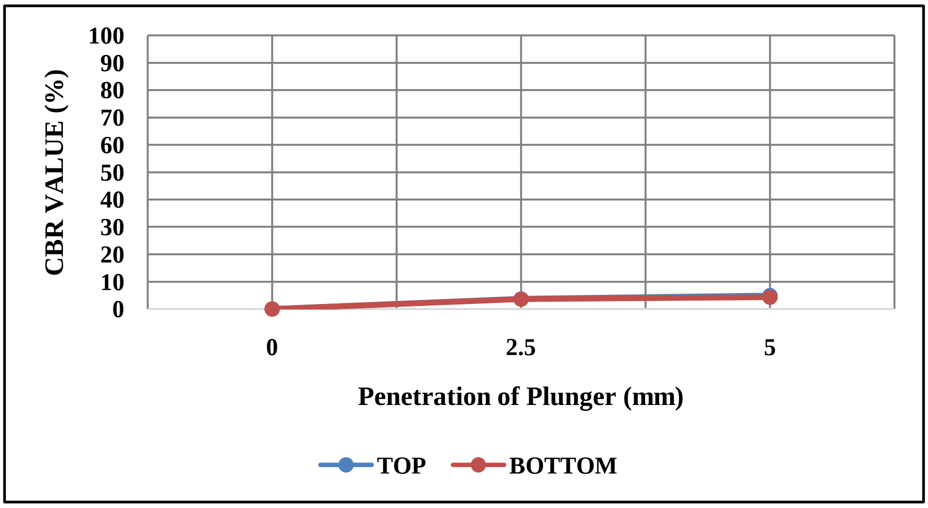


COMPACTION STANDARD: B.S
MAXIMUM DRY DENSITY: 1.88g/cm^3
OPTIMUM MOISTURE CONTENT (%): 14.5

APENDIX C1

SAMPLE COMPOSITION: 0% CKD, 0% COIR FIBER
LAB NO. 1
CBR – TEST METHOD = **Soaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.10	0.52	2.75	0.52	0.67
0.50	0.15	0.53	3.00	0.54	0.69
0.75	0.17	0.55	3.25	0.56	0.71
1.00	0.22	0.57	3.50	0.59	0.74
1.25	0.25	0.58	3.75	0.61	0.76
1.50	0.35	0.60	4.00	0.64	0.79
1.75	0.44	0.61	4.25	0.67	0.80
2.00	0.47	0.63	4.50	0.69	0.84
2.25	0.49	0.64	4.75	0.71	0.87
2.50	0.50	0.65	5.00	0.74	0.88

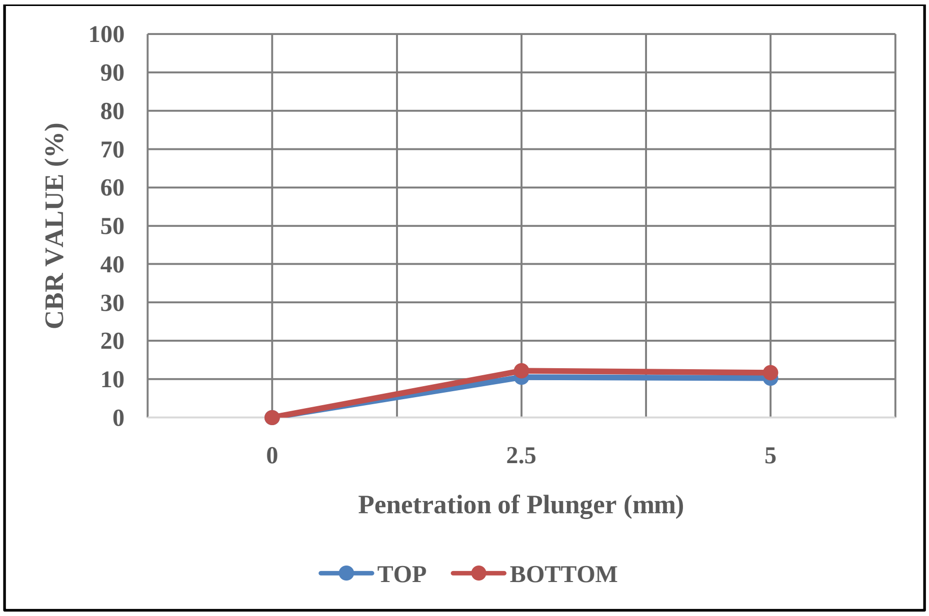


	As Molded	Soaked	Description of Soil: silty clay					
Mold + Wet Soil		3063	No. of Blows 25 Surcharge 5.825 kg					
Wt of Wet Soil		1582	Volume of Mold 903 cm^3					
Cont. + Wet Sample		71	Weight of Mold 1.481 kg					
Cont. + Dry Sample		61	Mod Proctor Compaction 6.6 %					
Tare of Container		7						
Wt of Dry Sample		54	Swelling Test					
Wt of Water		10	Date	10	Date	10	Date	10
Moisture Content %		18.5		18.5		18.5		18.5
Wt of Dry Soil		1752		1752		1752		1752
Dry Density of Soil		1.48		1.48		1.48		1.48

APENDIX C2

SAMPLE COMPOSITION: 10% CKD, 0.5% COIR FIBER& 90% SOIL
LAB NO. 2
CBR – TEST METHOD = **Soaked**

Penetration of Plunger (mm)	Force of Plunger Top (KN)	Force of Plunger Bottom (KN)	Penetration of Plunger (mm)	Force of Plunger Top (KN)	Force of Plunger Bottom (KN)
0.25	0.13	0.15	2.75	1.60	1.65
0.50	0.25	0.33	3.00	1.68	1.72
0.75	0.38	0.45	3.25	1.73	1.81
1.00	0.45	0.58	3.50	1.80	1.86
1.25	0.50	0.77	3.75	1.84	1.93
1.50	0.63	1.10	4.00	1.90	2.02
1.75	0.78	1.20	4.25	2.00	2.09
2.00	1.00	1.43	4.50	2.13	2.18
2.25	1.33	1.53	4.75	2.20	2.27
2.50	1.55	1.63	5.00	2.25	2.33



	2.5mm	5.0mm
TOP	11.5	11.2
BOTTOM	12.1	11.6
AV. CBR	11.6%	

CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: brownish silty clay
Mold + Wet Soil		3249	No. of Blows 25 Surcharge 5.825 kg
Wt of Wet Soil		1768	Volume of Mold 903 cm^3

Cont. + Wet Sample		70	Weight of Mold				1.481	kg
Cont. + Dry Sample		61	Mod Proctor Compaction				7.5	%
Tare of Container		7	Swelling Test					
Wt of Dry Sample		54						
Wt of Water		9	Date	Time	Days	Reading	Swelling (mm)	Swell %
Moisture Content %		16.7						
Wt of Dry Soil		1858						
Dry Density of Soil		1.59						

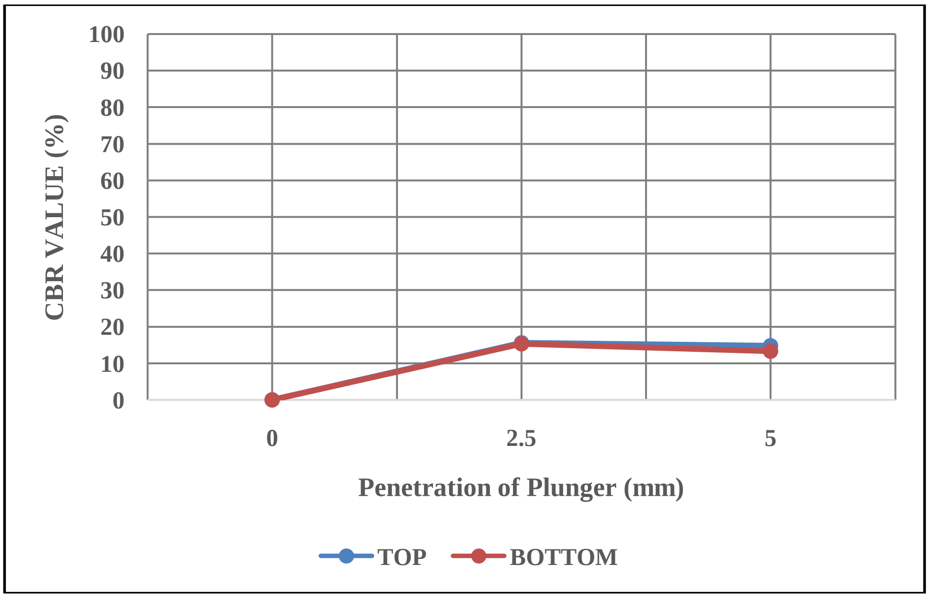
APENDIX C3

SAMPLE COMPOSITION: 20% CKD, 0.5% COIR FIBER& 80% SOIL

LAB NO. 3

CBR – TEST METHOD = **Soaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.30	0.20	2.75	2.15	2.08
0.50	0.40	0.33	3.00	2.21	2.10
0.75	0.50	0.40	3.25	2.26	2.12
1.00	0.75	0.60	3.50	2.30	2.14
1.25	1.10	0.70	3.75	2.33	2.15
1.50	1.20	0.95	4.00	2.43	2.33
1.75	1.40	1.08	4.25	2.63	2.38
2.00	1.63	1.25	4.50	2.75	2.53
2.25	1.85	1.75	4.75	2.88	2.63
2.50	2.10	2.05	5.00	2.98	2.68



	2.5mm	5.0mm
TOP	15.6	14.8
BOTTOM	15.3	13.3
AV. CBR	14.8%	

CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: Reddish brown silty clay		
Mold + Wet Soil		3320	No. of Blows 25 Surcharge	5.825	kg
Wt of Wet Soil		1839	Volume of Mold	903	cm^3
Cont. + Wet Sample		66	Weight of Mold	1.481	kg
Cont. + Dry Sample		58	Mod Proctor Compaction	8.0	%
Tare of Container		7	Swelling Test		
Wt of Dry Sample		51			

Wt of Water		8	Date	Time	Days	Reading	Swelling (mm)	Swell %
Moisture Content %		15.7						
Wt of Dry Soil		2037						
Dry Density of Soil		1.76						

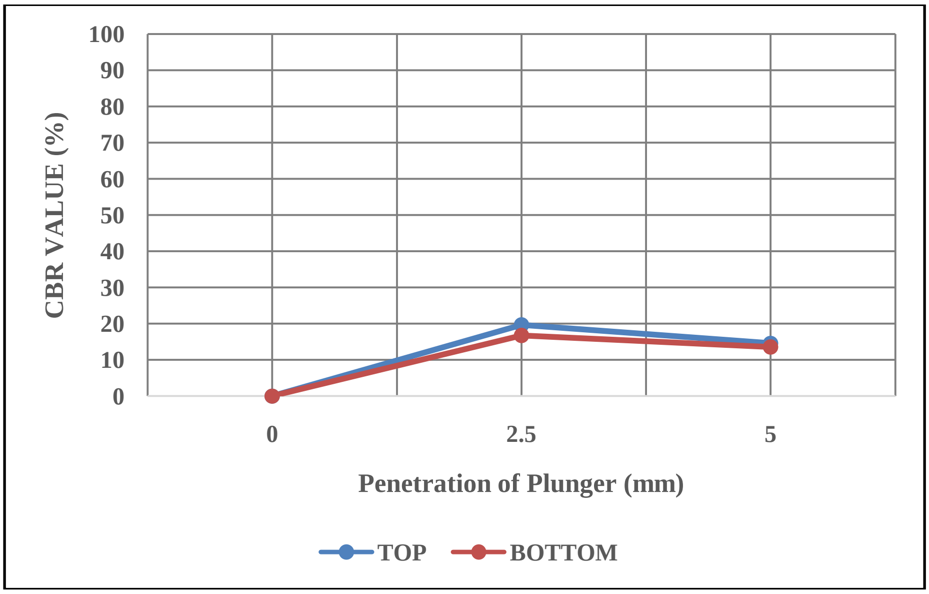
APENDIX C4

SAMPLE COMPOSITION: 30% CKD, 0.5% COIR FIBER& 70% SOIL

LAB NO. 4

CBR – TEST METHOD = **Soaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.13	0.08	2.75	2.65	2.28
0.50	0.50	0.25	3.00	2.70	2.30
0.75	1.13	0.38	3.25	2.73	2.33
1.00	1.50	0.70	3.50	2.75	2.35
1.25	1.18	1.10	3.75	2.80	2.38
1.50	2.15	2.00	4.00	2.83	2.45
1.75	2.25	2.05	4.25	2.85	2.50
2.00	2.38	2.10	4.50	2.88	2.58
2.25	2.50	2.13	4.75	2.90	2.68
2.50	2.63	2.25	5.00	2.95	2.73



	2.5mm	5.0mm
TOP	19.6	14.6
BOTTOM	16.7	13.5
AV. CBR	16.1%	

CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: brownish silty clay					
Mold + Wet Soil		3187	No. of Blows 25 Surcharge 5.825 kg					
Wt of Wet Soil		1706	Volume of Mold 903 cm^3					
Cont. + Wet Sample		69	Weight of Mold 1.481 kg					
Cont. + Dry Sample		64	Mod Proctor Compaction 8.0 %					
Tare of Container		8						
Wt of Dry Sample		56	Swelling Test					
Wt of Water		5	Date	Time	Days	Reading	Swelling (mm)	Swell %
Moisture Content %		8.9						
Wt of Dry Soil		1889						
Dry Density of Soil		1.74						

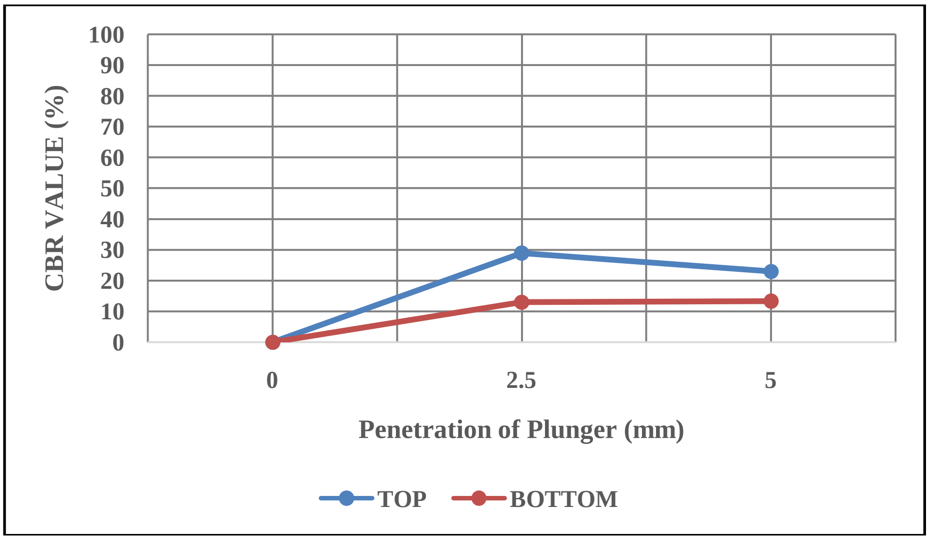
APENDIX C5

SAMPLE COMPOSITION: 40% CKD, 0.5% COIR FIBER& 60% SOIL

LAB NO. 5

CBR – TEST METHOD = **Soaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.35	0.13	2.75	4.00	1.88
0.50	0.88	0.33	3.00	4.10	1.95
0.75	1.13	0.45	3.25	4.20	2.00
1.00	2.00	0.58	3.50	4.25	2.05
1.25	2.50	0.95	3.75	4.33	2.10
1.50	2.75	1.40	4.00	4.38	2.15
1.75	3.05	1.50	4.25	4.45	2.30
2.00	3.38	1.60	4.50	4.50	2.45
2.25	3.68	1.65	4.75	4.58	2.58
2.50	3.88	1.75	5.00	4.63	2.68



	2.5mm	5.0mm
TOP	28.9	23.0
BOTTOM	13.0	13.3
AV. CBR	19.6%	

CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: brownish silty clay					
Mold + Wet Soil		3095	No. of Blows 25 Surcharge 5.825 kg					
Wt of Wet Soil		1814	Volume of Mold 903 cm^3					
Cont. + Wet Sample		50	Weight of Mold 1.481 kg					
Cont. + Dry Sample		48	Mod Proctor Compaction 6.4 %					
Tare of Container		7	Swelling Test					
Wt of Dry Sample		41						
Wt of Water		2	Date	Time	Days	Reading	Swelling(mm)	Swell %
Moisture Content %		4.9						
Wt of Dry Soil		2009						
Dry Density of Soil		1.92						

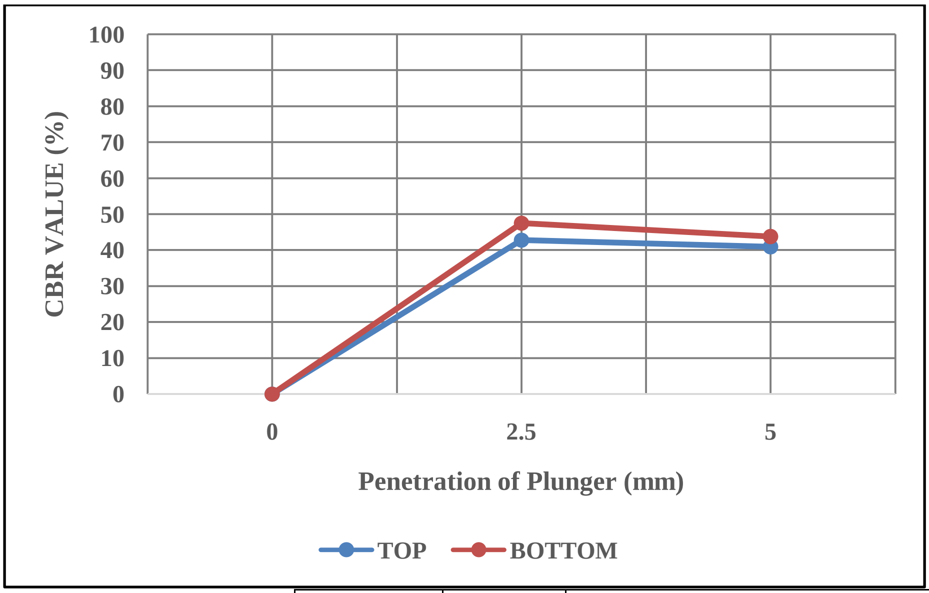
APENDIX C6

SAMPLE COMPOSITION: 50% CKD, 0.5% COIR FIBER& 50% SOIL

LAB NO. 6

CBR – TEST METHOD = **Soaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.53	0.58	2.75	6.38	6.55
0.50	0.63	1.25	3.00	6.70	6.85
0.75	1.13	1.45	3.25	6.90	7.00
1.00	1.95	2.13	3.50	7.00	7.25
1.25	3.23	3.38	3.75	7.05	7.50
1.50	3.55	3.90	4.00	7.15	7.75
1.75	4.50	4.63	4.25	7.25	8.13
2.00	5.00	5.10	4.50	7.75	8.33
2.25	5.63	5.80	4.75	8.13	8.50
2.50	5.75	6.38	5.00	8.25	8.80



	2.5mm	5.0mm
TOP	42.8	40.9
BOTTOM	47.5	43.7
AV. CBR	43.7%	

CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: reddish brown gravelly clay					
Mold + Wet Soil		3565	No. of Blows 25 Surcharge 5.825 kg					
Wt of Wet Soil		2084	Volume of Mold 903cm^3					
Cont. + Wet Sample		62	Weight of Mold 1.481 kg					
Cont. + Dry Sample		55	Mod Proctor Compaction 8.0 %					
Tare of Container		7	Swelling Test					
Wt of Dry Sample		48						
Wt of Water		7	Date	Time	Days	Reading	Swelling (mm)	Swell %
Moisture Content %		14.6						
Wt of Dry Soil		2308						
Dry Density of Soil		2.02						

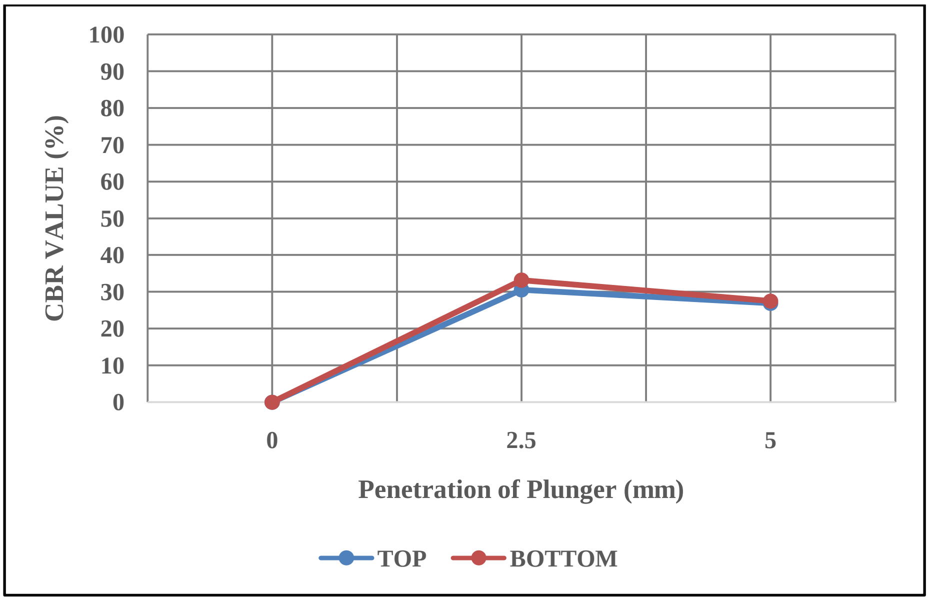
APENDIX C7

SAMPLE COMPOSITION: 60% CKD, 0.5% COIR FIBER& 40% SOIL

LAB NO. 7

CBR – TEST METHOD = **Soaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.35	0.60	2.75	4.38	4.75
0.50	0.55	0.88	3.00	4.50	4.83
0.75	0.85	1.55	3.25	4.60	4.90
1.00	0.98	2.33	3.50	4.73	5.00
1.25	1.23	2.85	3.75	4.88	5.13
1.50	2.05	3.40	4.00	5.00	5.25
1.75	2.75	3.85	4.25	5.15	5.35
2.00	3.28	4.10	4.50	5.25	5.45
2.25	3.75	4.30	4.75	5.38	5.50
2.50	4.10	4.45	5.00	5.43	5.55



	2.5mm	5.0mm
TOP	30.5	26.9
BOTTOM	33.1	27.5
CBR	29.5%	

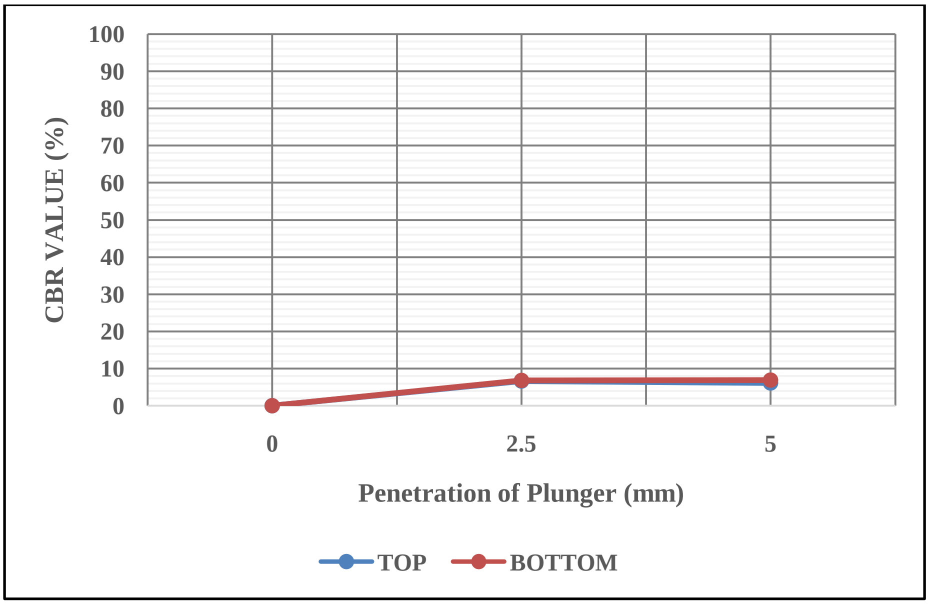
CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: silty clay					
Mold + Wet Soil		3307	No. of Blows 25			Surcharge 5.825		kg
Wt of Wet Soil		1826	Volume of Mold				903	cm^3
Cont. + Wet Sample		64	Weight of Mold				1.481	kg
Cont. + Dry Sample		60	Mod Proctor Compaction				6.4	%
Tare of Container		7						
Wt of Dry Sample		53	Swelling Test					
Wt of Water		4	Date	Time	Days	Reading	Swelling (mm)	Swell %
Moisture Content %		7.5						
Wt of Dry Soil		2022						
Dry Density of Soil		1.88						

APENDIX C8
SAMPLE COMPOSITION: 0% CKD, 0% COIR FIBER& 100% SOIL
LAB NO. 1a

CBR – TEST METHOD = **Unsoaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.23	0.25	2.75	0.91	0.98
0.50	0.32	0.35	3.00	0.97	1.08
0.75	0.40	0.45	3.25	0.99	1.12
1.00	0.44	0.58	3.50	1.00	1.18
1.25	0.51	0.62	3.75	1.05	1.22
1.50	0.55	0.78	4.00	1.10	1.28
1.75	0.59	0.81	4.25	1.12	1.34
2.00	0.67	0.85	4.50	1.17	1.36
2.25	0.79	0.88	4.75	1.20	1.39
2.50	0.88	0.90	5.00	1.23	1.40



	2.5mm	5.0mm
TOP	6.6	6.1
BOTTOM	6.8	6.9
AV. CBR	6.6%	

CBR VALUE AT OMC

	As Molded	Soaked
Mold + Wet Soil	3754	
Wt of Wet Soil	2281	
Cont. + Wet Sample	48	
Cont. + Dry Sample	42	
Tare of Container	8	
Wt of Dry Sample	34	
Wt of Water	6	
Moisture Content %	17.6	
Wt of Dry Soil	1.94	
Dry Density of Soil	1.65	

Description of Soil: brownish silty clay

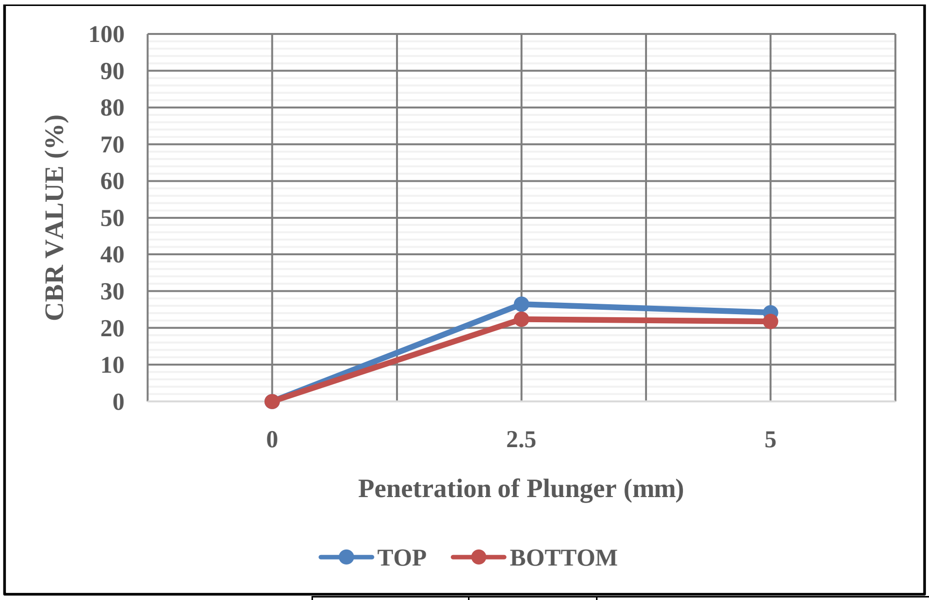
No. of Blows 25 Surcharge	5.825	kg
Volume of Mold	903	cm^3
Weight of Mold	1.481	kg
Mod Proctor Compaction	7.5	%

Swelling Test

Date		Date		Date	

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.45	0.38	2.75	3.58	2.27
0.50	0.88	0.70	3.00	3.60	2.28
0.75	1.25	1.08	3.25	3.63	3.30
1.00	2.00	1.75	3.50	3.65	3.38
1.25	2.70	2.45	3.75	3.70	3.45

1.50	3.10	2.70	4.00	3.75	3.50
1.75	3.25	3.00	4.25	3.95	3.55
2.00	3.38	3.10	4.50	4.13	3.75
2.25	3.45	3.18	4.75	4.35	4.30
2.50	3.55	3.25	5.00	4.50	4.38



	2.5mm	5.0mm
TOP	26.4	22.3
BOTTOM	24.2	21.7
AV. CBR	23.7%	

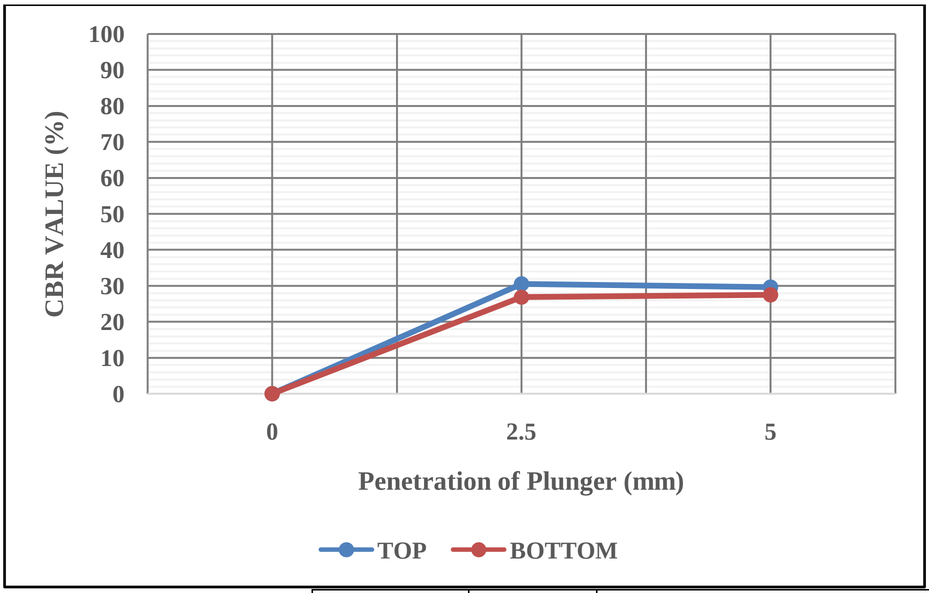
CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: reddish brown gravelly clay					
Mold + Wet Soil	3336		No. of Blows 25 Surcharge 5.825 kg					
Wt of Wet Soil	1855		Volume of Mold 903 cm^3					
Cont. + Wet Sample	66		Weight of Mold 1.481 kg					
Cont. + Dry Sample	60		Mod Proctor Compaction 7.0 %					
Tare of Container	8		Swelling Test					
Wt of Dry Sample	52							
Wt of Water	6		Date		Date		Date	
Moisture Content %	11.5							
Wt of Dry Soil	2054							
Dry Density of Soil	1.84							

APENDIX 10
SAMPLE COMPOSITION: 20% CKD, 0.5% COIR FIBER& 80% SOIL
LAB NO. 3a
CBR – TEST METHOD = **Unsoaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.35	0.60	2.75	4.38	4.75
0.50	0.55	0.88	3.00	4.50	4.83
0.75	0.85	1.55	3.25	4.60	4.90
1.00	0.98	2.33	3.50	4.73	5.00
1.25	1.23	2.85	3.75	4.88	5.13
1.50	2.05	3.40	4.00	5.00	5.25

1.75	2.75	3.85	4.25	5.15	5.35
2.00	3.28	4.10	4.50	5.25	5.45
2.25	3.75	4.30	4.75	5.38	5.50
2.50	4.00	4.34	5.00	5.41	5.53



	2.5mm	5.0mm
TOP	30.5	26.9
BOTTOM	29.6	27.5
AV. CBR	28.6%	

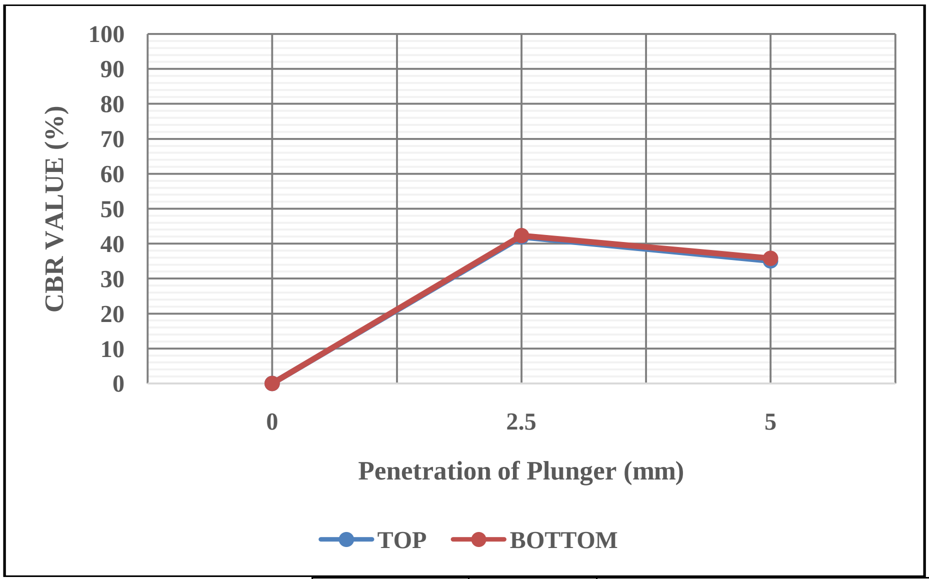
CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: reddish brown gravelly clay					
Mold + Wet Soil	3307		No. of Blows 25 Surcharge 5.825 kg					
Wt of Wet Soil	1826		Volume of Mold 903 cm^3					
Cont. + Wet Sample	64		Weight of Mold 1.481 kg					
Cont. + Dry Sample	60		Mod Proctor Compaction 6.4 %					
Tare of Container	7		Swelling Test					
Wt of Dry Sample	53							
Wt of Water	4		Date		Date		Date	
Moisture Content %	7.5							
Wt of Dry Soil	2022							
Dry Density of Soil	1.88							

APENDIX C11
SAMPLE COMPOSITION: 30% CKD, 0.5% COIR FIBER& 70% SOIL
LAB NO. 4a
CBR – TEST METHOD = **Unsoaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.25	0.30	2.75	5.75	5.93
0.50	0.94	0.96	3.00	5.88	6.03
0.75	1.38	1.40	3.25	6.00	6.10
1.00	2.38	2.40	3.50	6.13	6.24
1.25	3.00	3.13	3.75	6.20	6.30
1.50	3.75	3.90	4.00	6.50	6.40
1.75	4.25	4.35	4.25	6.63	6.73
2.00	4.75	4.80	4.50	6.75	6.94

2.25	5.08	5.10	4.75	6.75	7.09
2.50	5.63	5.68	5.00	7.08	7.22



	2.5mm	5.0mm
TOP	41.9	35.1
BOTTOM	42.3	35.8
AV. CBR	38.8	

CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: reddish brown gravelly clay					
Mold + Wet Soil	4310		No. of Blows: 25 Surcharge: 4800 kg					
Wt of Wet Soil	2940		Volume of Mold: 1280 cm^3					
Cont. + Wet Sample	59		Weight of Mold : 1370 kg					
Cont. + Dry Sample	53		Mod Proctor Compaction : 6.0 %					
Tare of Container	8							
Wt of Dry Sample	45		Swelling Test					
Wt of Water	6		Date		Date		Date	
Moisture Content %	13.3							
Wt of Dry Soil	2297							
Dry Density of Soil	2.03							

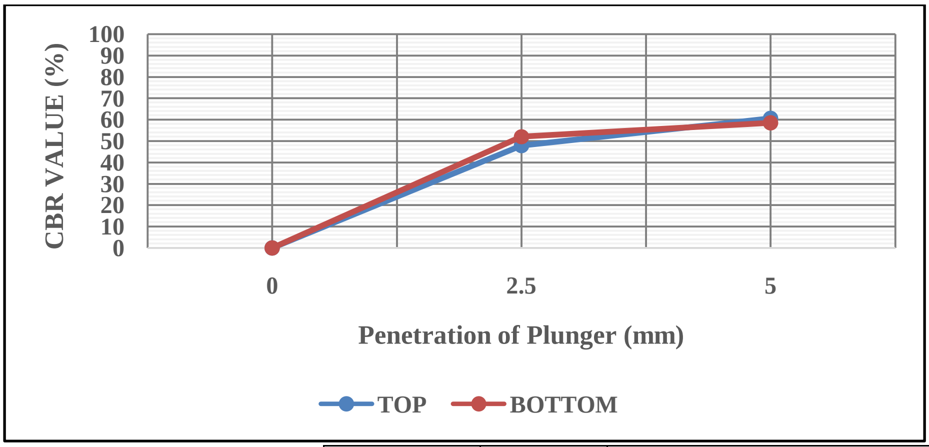
APENDIX C12

SAMPLE COMPOSITION: 40% CKD, 0.5% COIR FIBER& 60% SOIL

LAB NO. 5a

CBR – TEST METHOD = **Unsoaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.80	1.03	2.75	7.64	9.10
0.50	1.05	1.13	3.00	7.93	9.50
0.75	1.20	1.38	3.25	8.26	9.80
1.00	1.86	2.36	3.50	8.52	10.20
1.25	1.95	2.25	3.75	8.74	10.55
1.50	2.20	2.84	4.00	8.96	10.95
1.75	3.91	4.02	4.25	9.26	11.25
2.00	4.54	5.11	4.50	9.38	11.40
2.25	5.50	6.64	4.75	10.00	11.62
2.50	6.33	8.02	5.00	10.50	11.80



	2.5mm	5.0mm
TOP	47.8	52.1
BOTTOM	60.6	58.5
AV. CBR	54.7%	

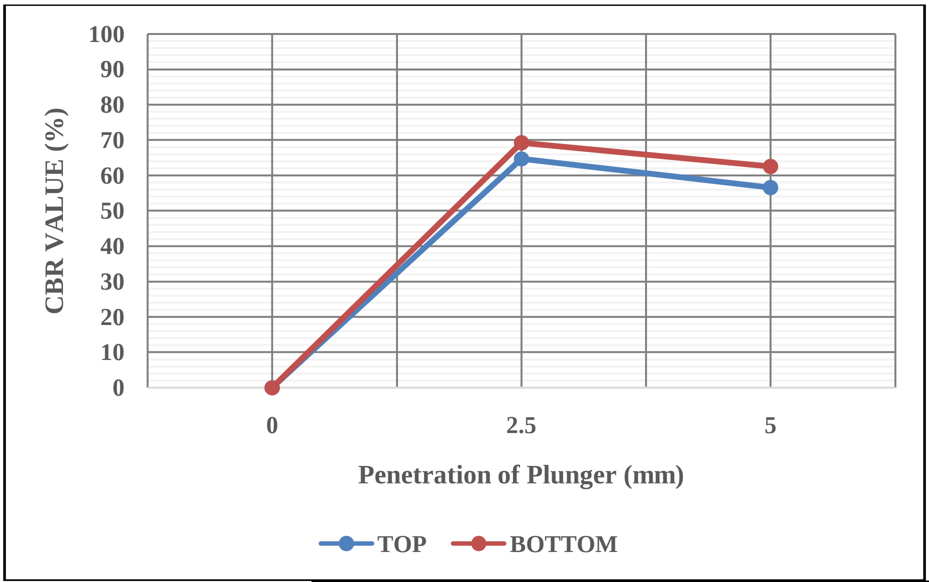
CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: reddish brown gravelly clay					
Mold + Wet Soil	3800		No. of Blows: 25 Surcharge: 5922 kg					
Wt of Wet Soil	2200		Volume of Mold: 942 cm^3					
Cont. + Wet Sample	50		Weight of Mold : 1600 kg					
Cont. + Dry Sample	44		Mod Proctor Compaction : 8.0 %					
Tare of Container	8		Swelling Test					
Wt of Dry Sample	36							
Wt of Water	6		Date		Date		Date	
Moisture Content %	16.7							
Wt of Dry Soil	2335							
Dry Density of Soil	2.01							

APENDIX C13

SAMPLE COMPOSITION: 50% CKD, 0.5% COIR FIBER& 50% SOIL
LAB NO. 6a
CBR – TEST METHOD = **Unsoaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.68	1.25	2.75	9.00	9.50
0.50	0.95	2.05	3.00	9.40	9.95
0.75	1.25	3.10	3.25	9.65	10.82
1.00	1.86	3.75	3.50	9.99	11.10
1.25	2.20	4.90	3.75	10.13	11.55
1.50	2.80	5.60	4.00	10.26	12.00
1.75	4.70	6.40	4.25	10.50	12.25
2.00	5.20	7.00	4.50	10.88	12.50
2.25	7.10	8.50	4.75	11.03	12.55
2.50	8.70	9.30	5.00	11.40	12.60



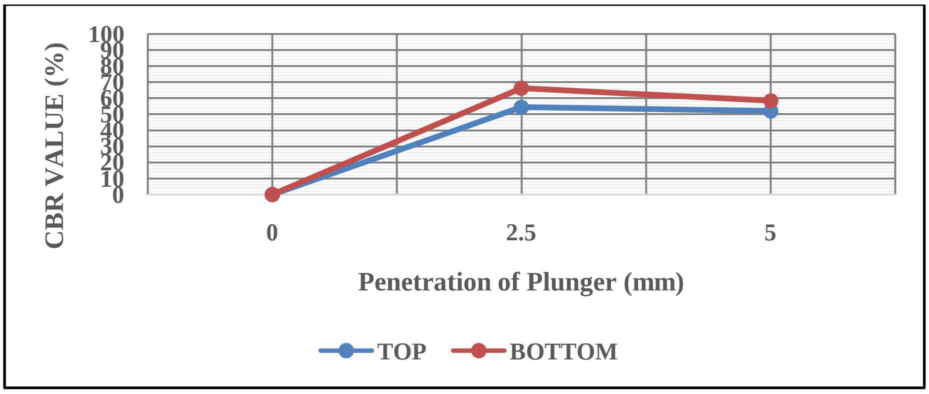
	2.5mm	5.0mm
TOP	64.7	56.5
BOTTOM	69.2	62.5
AV. CBR	63.2%	

CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: reddish brown gravelly clay					
Mold + Wet Soil	3777		No. of Blows: 25 Surcharge: 5922 kg					
Wt of Wet Soil	2177		Volume of Mold: 942 cm^3					
Cont. + Wet Sample	39		Weight of Mold : 1600 kg					
Cont. + Dry Sample	36		Mod Proctor Compaction : 8.0 %					
Tare of Container	8		Swelling Test					
Wt of Dry Sample	28							
Wt of Water	3		Date		Date		Date	
Moisture Content %	10.7							
Wt of Dry Soil	2317							
Dry Density of Soil	2.09							

APENDIX C14
SAMPLE COMPOSITION: 60% CKD, 0.5% COIR FIBER& 40% SOIL
LAB NO. 7a
CBR – TEST METHOD = **Unsoaked**

Penetration of Plunger (mm)	Force of Plunger		Penetration of Plunger (mm)	Force of Plunger	
	Top (KN)	Bottom (KN)		Top (KN)	Bottom (KN)
0.25	0.80	1.03	2.75	7.64	9.10
0.50	1.05	1.13	3.00	7.93	9.50
0.75	1.20	1.38	3.25	8.26	9.80
1.00	1.86	2.36	3.50	8.52	10.20
1.25	2.20	3.10	3.75	8.74	10.55
1.50	3.00	4.90	4.00	8.96	10.95
1.75	4.80	5.25	4.25	9.26	11.25
2.00	5.13	6.40	4.50	9.38	11.40
2.25	6.33	7.25	4.75	10.00	11.62
2.50	7.33	8.90	5.00	10.50	11.80

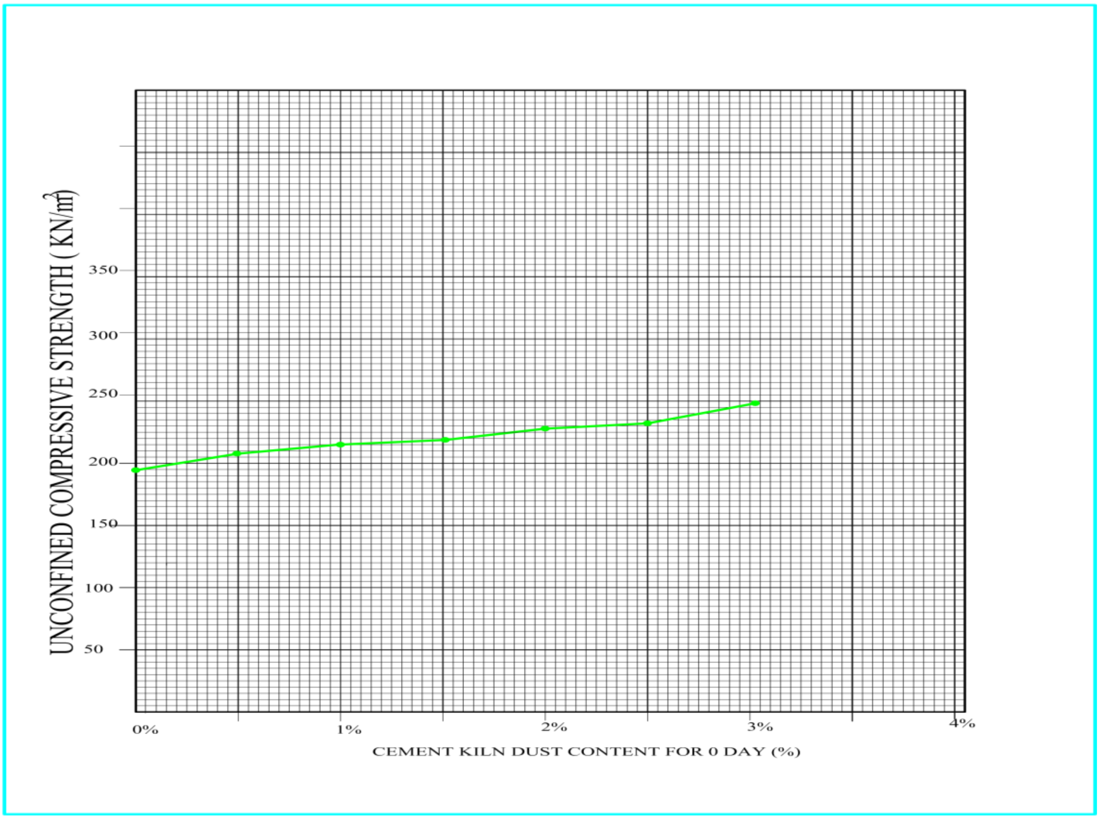


	2.5mm	5.0mm
TOP	54.5	52.1
BOTTOM	66.2	58.5
AV. CBR	57.8%	

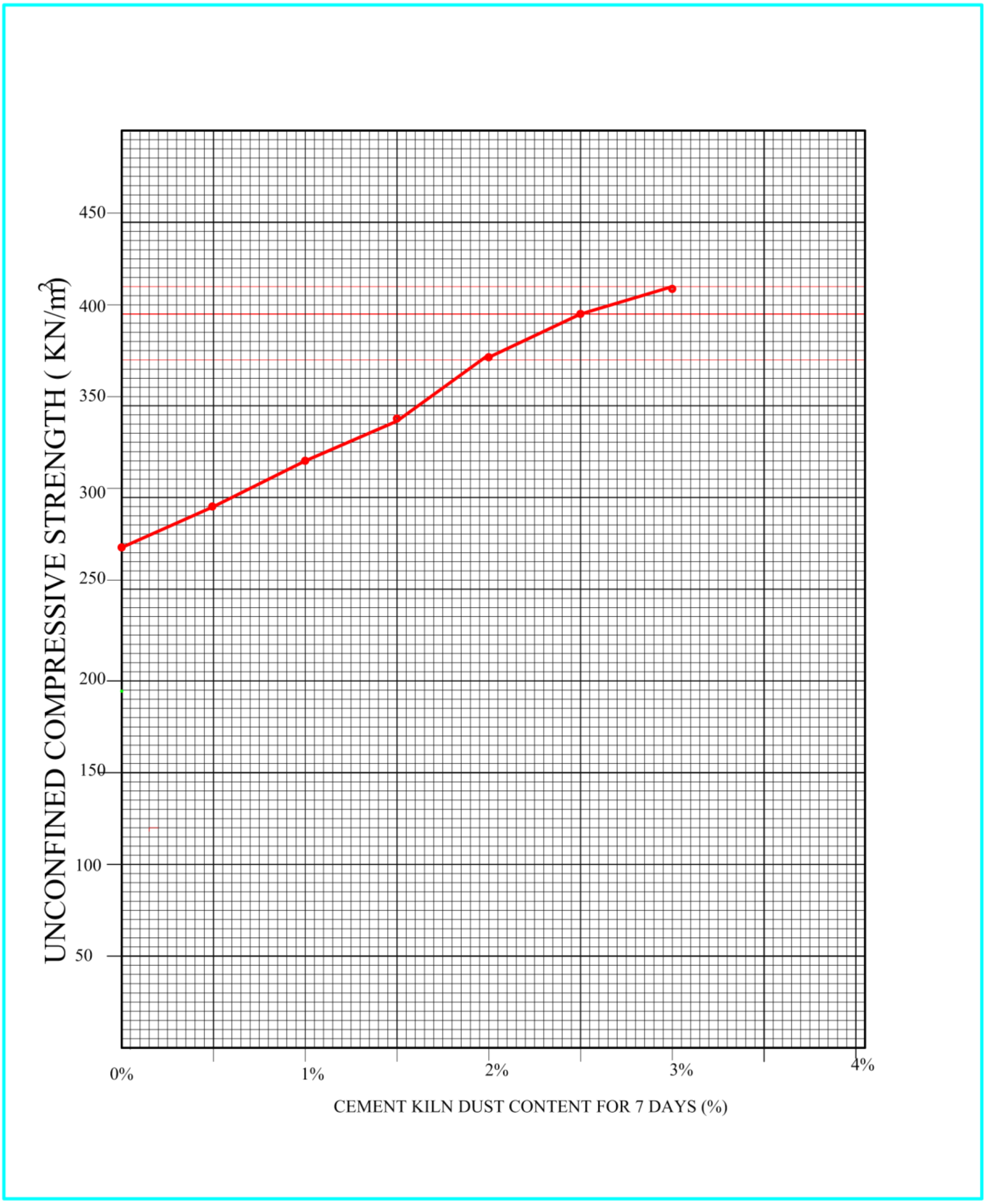
CBR VALUE AT OMC

	As Molded	Soaked	Description of Soil: reddish brown gravelly clay					
Mold + Wet Soil	3800		No. of Blows: 25 Surcharge: 5922 kg					
Wt of Wet Soil	2200		Volume of Mold: 942 cm^3					
Cont. + Wet Sample	50		Weight of Mold : 1600 kg					
Cont. + Dry Sample	44		Mod Proctor Compaction : 8.0 %					
Tare of Container	8		Swelling Test					
Wt of Dry Sample	36							
Wt of Water	6		Date		Date		Date	
Moisture Content %	16.7							
Wt of Dry Soil	2335							
Dry Density of Soil	2.01							

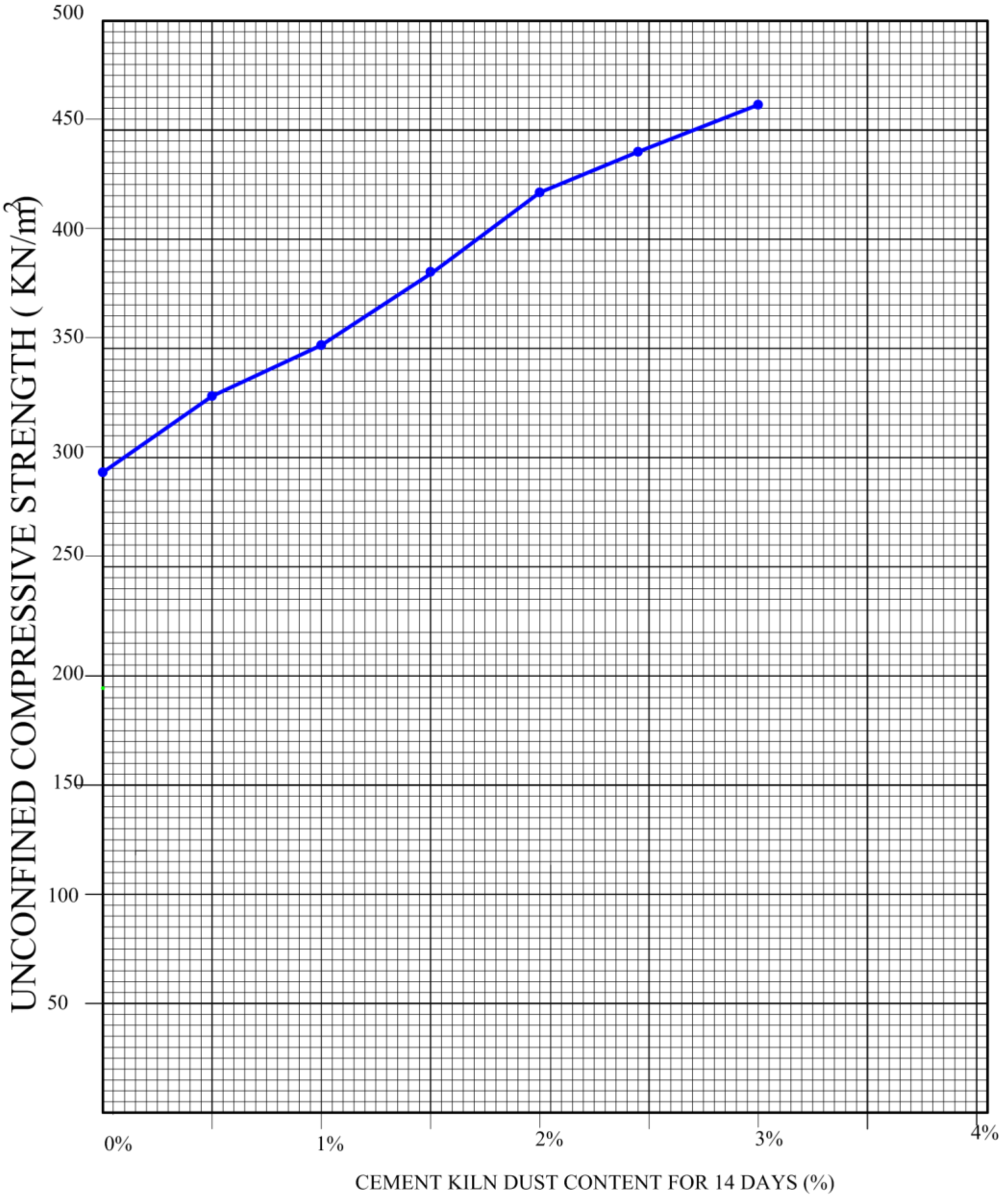
APENDIX D1



APENDIX D2


UNCONFINED COMPRESSIVE STRENGTH (KN/m^2)
450
400
350
300
250
200
150
100
50
0%
1%
2%
3%
4%
CEMENT KILN DUST CONTENT FOR 7 DAYS (%)

APENDIX D3


500
450
400
350
300
250
200
150
100
50
UNCONFINED COMPRESSIVE STRENGTH (KN/m^2)
0%
1%
2%
3%
4%
CEMENT KILN DUST CONTENT FOR 14 DAYS (%)