EFFECT OF CURING TIME ON STRENGHT DEVELOPMENT OF BLACK COTTON SOIL TABILIZED WITH QUARRY FINES AND CEMENT KILN DUST

BY

OSU, ABDlJl1{J.\DIR SABO

PGD/CIVl1/2009/064

DEPAR"rrv1EN1" OF crvu ENGINEERlr+JG

FEDERAl1jNI\lERS~T~~{()F 'rt'(:HNOIOG'V'~

" f\11iNN jJ+. " ~;,,' ,,'',;~', "

EFFECTOF CURING TIME ON STRENGHT DEVELOPMENT OF BLACK COTTON SOIL STABILIZED WITH QUARRY FINES AND CEMENT KILN DUST

BY

OSU, ABDULKADIR SABO

PGD/CIVIL/2009/064

A RESEARCH PROJECT SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF POST GRADUATE DIPLOMA (PGD) IN CIVIL ENGINEERING

MARCH, 2012

DECLARATION

I hereby declare that this research project titled: Effect of curing time on Strength Development of Black Cotton Soil stabilized with Quarry Fines and Cement Kiln Dust is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources has been duly acknowledged.

OSU, ABDULKADIR SABO

PGD/CIVIL/2009/064

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

A.f_IQ~ 1«0l.f(/2

Signature/date

CE·R,!'!FICA TION

The research project tided: Effcl-:t of curing time 01_l Strength Development of Black Cotton Soil stabilized. with Quarry l?ines and Cement Kiln Dust by OSU, ABDUl,KADIR SABO (PGD/Ch'i1!2009l064), meets the regulations governing the award of Postgraduate Diploma in Civil Engineering of the Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

ENGR DR A. A. AMADI
PROJECT SUPERVISOR — Signature/Date

ENGR PROF S. SADIKU
HEAD OF DEPARTMENT — Signature/Date

ENGR PROF M.S. ABOLARIN
DEAN, SCHOOL OF ENG'G & ENG'G TECHNOLOGY — Signature/Date

PROF (MRS) S.N. ZUBAmU
DEAN, POSTGRADUATE SCHOOL — Signature/Date

EXTERNAL EXAMINER — Signature/Date

ACKNOW1,EDGE~1E~TS

I am grateful to God AJmighty, the Omnipotent and Omniscient - the custodian and distributor of all knowledge, wisdom end understanding.

My profound gratitude goes to my supervisor, Engr Dr A A Amadi for his patience to read the manuscript and his invaluable guidance throughout the conduct of this research work.

Much thanks goes to the Head, Department of Civil Engineering, Engr Professor S. Sadiku. Special appreciation goes to Engr Prof. O.D. Jimoh, Engr Dr T.Y.Tsado, Engr Dr P.N. Ndoke, Engr Dr S.M. Auta, Dr A. Abdullahi, Engr Dr 1.1. Agua, Engr S.F.Oritola, O. james, AO. Busari, A Sanni, W.T.Adejumo, M. Alhassan, M.A.Mohammed, S.S. Kolo, S.Mohammed, Engr A.R. Adesiji, Mrs O.A. Gbadeb, Engr Abdulkadir and Baba Umaru for their inspiration, encouragement and stamina throughout the duration of my studies.

My special thanks goes to my elder brothers; Mallam Abdullahi and Ahmed Osu whose barrage of prayers, moral support and invaluable pieces of advice, have helped to give me a sense of direction, thus making this project work a success.

I wish to specially thank Hajiya Amina Wada for her hospitality throughout the duration of my studies in Minna.

My regards also goes to my course mates in Federal University of Technology, Minna and my colleagues at Federal Polytechnic, Nasarawa, whose contributions and advice has made this project work possible.

Finally, I am most indebted to my amiable wife, Mrs Hadiza M. Abdulkadir for her support and fervent prayers.

ABSTRACT

Black Cotton Soils (BCS). create problems for structures built.on.them due to high swelling and shrinkage charac eristics. I~ generally has 10',1/ shear strength and hence low bearing capacity..Preliminary tests 0; the Black Cotton Soil, collected from Damsa, Adamawa State, show that it belongs to .4.-7-6 in the AASHfO Soil Classification system and has index properties that indicate an inadequacy for most practical engineering use. Cement Kiln Dust (CKD) in step concentrations ofO, 4,8,12 and 16% each by dry weight of soil with Quarry Fines (QF) blend of 10%, was used to treat the soil. Soil samples were subjected to general classification test. Compaction was carried out using British Standard Light (BSL) energy and the criterion for the evaluation of strength (UCS) was considered. Results showed that Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) reduced with increase in CKD contents. The MDD increased while the OMC reduced with increase in CKD contents. The UCS values recorded from 96.11, 136.71, 194.81, 219.29 and 257.*17kN/m2,* for the unstabilized soil, to 222.20, 315.87, 417.94, 530.26 and *755.65kN/m2* for the stabilized soil, when cured for 0, 7, 14, 21 and 28 days respectively. The strength development of UCS increased with curing ages, thus indicating that the blend has potential for time-dependent increase in strength. The study found that the use of CKD was potentially promising in stabilizing soils for engineering applications.

''

TABLE OF CONTENTS

CHAPTER ONE

CHAI~TERTWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

''

LIST 0)" TABLES

~

LIST OF FiGURES

~

NOTA TJONSI ABBREVIA nONS

BS: British Standards

BSL: British Standard Light

BCS: Black Cotton Soil

CKD: Cement Kiln Dust

LL: Liquid Limit

PL: Plastic Limit

PI: Plasticity Index

QF: Quarry Fines ~

MDD: Maximum Dry Density

OMC: Optimum Moisture Content

UCS: Unconfined Compressive Strength

FIG: Figure

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Black Cotton Soils are expansive clays with potentials for shrinkage and swelling characteristic under changing moisture condition. The swelling and shrinkage properties exhibited by the Blac Cotton Soils have been causing damages to various civil engineering structures constructed with o on these deposits. The experiences with the construction and the subsequent deleterious effect observed in them have induced the research workers and engineers alike, to investigate into th complexities associated with the peculiar behaviour of these soils (Kulkarni, 2008). It generally ha low shear strength and hence low bearing capacity.

The Nigerian expansive soil is formed from basic igneous rock material. They are so named Blac Cotton Soils because of their suitability of growing cotton. The Black Cotton Soils of north-easter Nigeria derive their origin from basalts of the upper Benue trough which covers a wide are extending north and east of the Jos, Plateau and from quaternary sediments of lacustrine origin fro the Chad basin consisting mainly of shales and clay sediments (Osinubi, Ijimdiya and Nmadu 2009). Specifically, Nigerian Black Cotton Soils are formed from the weathering of shaly an clayed sediments and basaltic rocks. According to Ola (1983), the Nigerian Black Cotton soi contain more of the montmorillonite and kaolinite minerals with subsequent manifestation of swe properties and expansive tendencies. These properties results cracks in soils without any warnin opening during the dry seasons which are more than 25mm wide and 1m deep have been observe and may extend up to 3m in case of high deposit (Oriola and Moses, 2011). These cracks clos during the wet season and uneven soil surface is produced by irregular swelling and heaving. Suc soils are especially troublesome as pavement sub-grades and embankments. The soils are the maj problem soils in Nigeria where they occupy an estimated area of 104 X 10^3 km^2 in the north-eastern part. (Oriola and Moses, 2011).

Cement is one of the most effective in reducing the swelling properties of the soils. Stabilization of soils with ordinary Portland cement produces hardened materials which are capable of bearing loads for engineering purposes (Eberemu, Oyelakin and Osinubi, 2011).

1.2 Aim and Objectives of Study

1.2.1 Aim

The aim of this research project is to evaluate the effect of curing time on strength development of Black Cotton Soil stabilized with Quarry Fines and Cement Kiln Dust.

1.2.2 The Objectives of Study

The objectives of study include:

1. To conduct preliminary tests on the natural and stabilized soil to determine the index properties; Grain size, Specific Gravity, Liquid Limit, Plastic Limit and Plasticity Index.

2. To conduct laboratory tests on the natural and stabilised soils to determine the Unconfined Compressive Strength (UCS) for 0, 7, 14,21 and 28 days curing periods.

1.3 Statement of the Problem

Buildings and Road structures constructed over expansive clays generally shows poor engineering performance as a result of low shear strength, swelling and shrinkage characteristics under changing moisture condition.

The introduction of quarry fines/cement kiln dust improves the strength development thereby rendering it useful for engineering application.

1.4 Justification for the Study

Sites dominated by Black Cotton Soils (BCS) for engineering purposes needs to be improved/ stabilized so that it Gall serve the engineering performance thus avoiding nuisance and uneconomical cost. The current study is one of such research efforts. Useful applications of CKD will minimize waste disposal which may pose threat to the environment.

1.5 Scope and Limitation

1. Preliminary tests of the Black Cotton Soil such as natural moisture content, specific gravity, sieve analysis and Atterberg's limits were conducted.

2. Cement kiln dust (CKD) in stepped concentrations of 0,4, 8, 12 and 16% each by dry weight of soil with 10% Quarry Fines blend, was used to treat the soil. Compaction and Unconfined Compressive Strength tests were considered.

HAPTERTWO

LITERATURE REVIEW

2.1 Black Cotton Soil

The problem of expansive clay also known as Black Cotton Soils is widespread throughout world. They are found in the north eastern parts of Nigeria, Cameroon, Lake Chad Basin, Sudan, Ethiopia, Kenya, South Zimbabwe, India, South Western U.S.A., South Africa and Israel (Murthy, 2009). The name black cotton soil is derived from the fact that cotton plant thrives well on it. The clay mineral that is responsible for expansiveness belongs to the montmorillonite group. Expansive soils cause more damage to structures than any other natural hazard, including earthquakes and floods (Osinubi, Ijimdiya and Nmadu, 2009).

2.1.1 General characteristics of Black Cotton Soils

Black Cotton Soils are expansive clays. They absorb water heavily, swell, become soft and lose strength. They are easily compressible when wet and possesses a tendency to heave during wet season. They shrink heavily on drying and develop cracks on the surface. The maximum width of these cracks may be up to 20mm or more and travel deep into the ground. A lump of dry black cotton soils requires a hammer to break (Murthy, 2009). During rainy season, these soils become very sticky and very difficult to traverse. Their colour varies from dark-grey to black probably due to iron and titanium compounds present. It is classified as an A-7-6 soil according to the AASHTO classification system and has index properties that are poor for engineering use.

Expansive soils are residual soils which are the result of weathering of the parent rock. The depths of these soils in some regions may be up to 6m or more. Typical oxide composition of Black Cotton Soil collected from Numan, Adamawa State, Nigeria is presented in Table 2. 1.

~

Table 2.1: Oxide Composition of Black Cotton Soil

Oxide	Percentage composition
AhO	14.0
$Si0_2$	54.1
S03	0.21
K_20	1.67
CaO	3.83
Ti02	2.27
$V20_S$	0.097
MnO	0.24
Fe203	20.0
ZnO	0.12
AfS20	2.29
BaO	0.25
EU203	0.29
Re207	0.2
Cr203	0.033

Source: Numan-gombe in Numan LGA of Adamawa State, lat. 10'19N long.11'30E northeast, Nigeria.

2.1.2. Strength Properties of Black Cotton Soil

Shear strength refers to the resistance of a soil to deformation. Shear strength is the principal engineering property which controls the stability of a soil mass under loads. The California Bearing Ratio (CBR) and the Unconfined Compressive Strength tests are most common procedures to assess strength gain in stabilized soils. In Black Cotton Soils, negative pore pressure develops during shear, and the undrained strength is more than the drained strength. The $\varphi_u = 0$ concept, therefore, this results in a subsiantiar oecrease in shear strength (Arora, 2009). Black Corron SOlis, therefore, generally has low shear strength.

In pavement design, it is important to evaluate the strength requirements as well as rate of design in stabilized expansive clays under field conditions. Different requirements of strength for expansive clays to be used as road bases have been suggested. It has been suggested a minimum unconfined compressive strength of 250psi for the base (Maclean, 1956) used for assessing stabilized expansive clays from Nigeria.

2.2 CURING

This is very important method and it is common in the use of concrete to attain optimum strength which is equally applicable in soils. The curing procedure being the control of the temperature and moisture content in and out of the soil.

Tensile and compressive strengths are affected by the curing process. The soil to gain strength, adequate curing must be established since strength increases with curing age (Iyere, 2003).

2.3 Cement Kiln Dust (CKD)

Cement Kiln Dust (CKD) is a fine powdery, solid, highly alkaline-material similar in appearance to Portland cement removed from cement kiln exhaust gas by scrubbers (filtration baghouses and/or electrostatic precipitators). It is an industrial waste from cement production. Much of the material comprising CKD is incompletely reacted raw material, including a raw mix at various stages of burning, and particles of clicker. Several factors influence the chemical and physical properties of CKD. Because plant operation differs considerably with respect to raw feed, type of operation dust collection facility, and type of fuel used, the use of the terms typical or average CKD when comparing different plants can be misleading. The dust from each plant can vary markedly in chemical, mineralogical and physical composition (Klemm, 1993).

. 2.3. Cement Kiln Dust Characteristics

CKD consists primarily of calcium carbonate and silicon dioxide which is similar to the cement kiln raw feed, but he amount .of alkalis, chloride and sulphate is usually considerably higher in the dust (Miller 1980). There are three types of cement kiln dust processes: long-wet, long-dry and alkali by-pass with precalciner were characterized for chemical and physical traits by Klemm (1980). CKD generated from long-wet and long-dry kilns is composed of partially calcined kiln feed fines enriched with alkali sulphates and chlorides. The dust collected from alkali by-pass of precalciner kilns tend to be coarser, more calcined and also concentrated with alkali volatiles. However, the alkali by-pass process contains the highest amount by weight of calcium oxide and lowest loss of ignition (LOI), both of which are key components in many beneficial applications of CKD. CKD contains insignificant amounts of trace metals and therefore metal concentrations are not usually a concern for most applications. A comprehensive study evaluated the presence of trace metals in CKD from 79 plants in the United States and Canada plants using both conventional and waste derived fuels (Miller, 1980) each CKD was tested for the eight metals: arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver. The samples were also analysed for antimony, beryllium, thallium and nickel, which are regulated under the Boiler and Industrial Furnace rule for hazardous solid wastes. Results show that the average level of trace metals found in the CKD was significantly below the regulation limits (Corish A. And Caleman, 1995).The particle size of CKD is dependent upon type of kiln operation. (Miller 1980) showed that the dusts collected from dry kilns were finer than those from wet and *semi-wet/semi-dry* kilns this was true for both the returned dust and discarded dusts. Studies conducted by McCoy and Allentown (1971) showed that for modern cement plants equipped with alkali by-pass, the dust is relatively coarse compared o the CKD from both the wet and dry kilns.

The oxide composition of cement kiln dust collected from Benue Cement Factory, Gboko, Benue State, Nigeria is presented in Table 2.3.

Table 2.3: Oxide Composition of Cement Kiln Dust (CKD)

Oxide	Percentage composition
Ab03	3.10
Si02	11.50
S03	0.78
K20	1.14
CaO	67.72
Ti02	0.35
V20S	0.02
MnO	0.12
Fe203	3.55
Y203	0.30
Ag20	1.55
Ln20S	0.96
BaO	0.20
LU203	0.05
Loi	8.70

Source: Benue Cement Factory, Gboko, Benue State - Nigeria

2.4 Research Review on CKD Usage for Soil Stabilization

In the field of geotechnical engineering in general and soil stabilization in particular, the parent soils are practically categorized under either cohesionless soils (i.e. sandy and larger particle-sized soils) or cohesive soils (i.e. clay and silt). Since the soil stabilization mechanism of fine-grained soils requires calcium as the major stabilizing agent, it is possible that some CKDs, especially those high in free lime, would similarly be useful in stabilizing clay soils. In the case of sandy soils which are commonly selected in the pavement layers, the usage of CKD may provide cementitious materials when it is mixed with water in a way similar to the mechanism by which Portland cements provide their binding characteristics (Al-Amoudi and Rahman, 2011).

Any potential application of CKD, including sand and clay stabilization, is governed by the physical and chemical composition of the dust. In practical terms, the dust vary markedly from plant to plant in chemical, mineralogical, and physical composition, depending upon the feed raw materials, type of kiln operation, dust collection facility and the fuel used (Klemm, 1980).

Collins presented a number of patents (1997, 1982) quite number of investigations on CKD and fly ash mixtures, for producing sub-base materials with different aggregates. CKD was used up to 16% by weight of the mixture, producing a durable mass by reacting with water at ambient temperatures. Collins and Emery (1983) demonstrated the effectiveness of substituting CKD for lime in a number of lime-fly ash-sandy aggregate systems for sub-base construction. The results indicated that the majority of the CKD-treated fly ash and aggregate mixtures resulted in materials which were comparable in strength, durability, dimensional stability and other engineering properties to those of the conventional lime fly ash-aggregate mixtures. Miller, et al. (1980) have also reported the use of CKD and fly ash as the cementitious ingredients in developing pozzolanic bases that demonstrated comparable properties to those of a stabilized base.

Kriner and McCoy (1983) examined the possibility of using CKD in stabilizing sandy soils for pavement sub-grade applications, It was reported that an addition of 15% CKD having 5.9% free CaO and MgO, and 0.9% total alkali ($K_2O + Na_2O$) ensured a compressive strength of 2.5 Mpa, which is a standard practice in Poland for the sub-grade within 14 days of the treatment. Baghdadi and Rahman (1990) studied the effects of CKD on stabilizing siliceous dune sand in highway construction. It was deduced that a mix proportion of 30% CKD and 70% sand gave peak performance for application as a base materials.

A number or'CKDs and clay- type soils were used by McCoy and Kriner (1971) to study the soii stabilization. Soil CKD mixes containing 3, 8 and 10% of CKD were tested for various engineering properties, such as the unconfined compressive strength, moisture-density relationship, liquid limits (LL), plastic limit (PL), plasticity index (PI) and shrinkage limit. The study found that the use of CKD was potentially promising in stabilizing soils for sub-base applications. Bhatty et al. (1996) reported that CKD with high free lime (26.6%) and moderate alkali produced mixtures with compressive strengths compared to those obtained with cement and lime. CKD having lower free lime (0.5%) and low alkali (2.2% Na_2O equivalent) gave lower strengths. In general, CKDs with high free lime and moderate alkali gave enhanced stabilization in terms of improved compressive strengths and reduced plasticity. It might also be pointed out that the higher alkali in CKDs can counter the stabilization reactions because of the ionic interference.

Azad (2000) found that an increase in the unconfined compressive strength (UCS) of soil occurred with the addition of CKD. Furthermore, the increase in UCS was inversely proportional to the plasticity index (PI) of the untreated soil. Significant PI reductions occurred with CKD treatment, particularly for high PI soils. Mohamed (2000) evaluated the potential use of cement-kiln dust (CKD) foe enhancing the mechanical as well as the hydraulic properties of soils in arid lands. Various tests were conducted to determine the different physical properties of the stabilized matrix and the optimum mixture that produces maximum integral energy and minimum hydraulic conductivity was selected. The analysis showed that 6% by weight of CKD is the optimum mix design, which increases the shear strength and decreases the hydraulic conductivity to less than 10-9 mls. Therefore. The treated soil could be used as a soil-based barrier for containment of hazardous waste. [Halidu, 2006].

2.5 Quarry Fines

There is no standard definition of Quarry Fines in the quarrying sector or construction industry. This leaves room for arbitrariness in description of the material. The terms quarry fines, dusts and wastes are used interchangeably, and are used to refer to materials which are of different particle size distribution; some of which are produced intentionally, and is thus not a waste (Eze-Uzomaka and Osondu, 2010). According to the Sridhana and Soosan (2005), if materials are not useable, does not meet the technical specifications required for its use or no specified market for it, then it remains a waste until a useful output has been identified. Finding uses of Quarry Fines will solve the problem of its disposal and resultant environmental pollution. It also yields some revenue.

The utilization of Quarry Fines which can be called manufactured sand has been accepted as a building material in the industrially developed nations for the past three decades. As a result of sustained research and development work undertaken with respect to increasing application of this industrial waste, the level of utilization in the industrialized nations like Australia, France, Germany and United Kingdom has reached more than 60% of its total production.

Due to high demand of aggregates for construction purposes, rubble quarry and aggregates are common. Out of the different quarry wastes, quarry fines is one of which is produced in abundance. Bulk utilization of this waste material is possible through geotechnical applications like embankments, backfill material, sub-base material and alike. It becomes a useful additive to the natural soil to improve its shear strength characteristics (Sridharan and Soosan, 2005). According to Mir and Shubnada (2009) the geotechnical and mineralogical characteristics of quarry fines and its interaction behaviour with soils can lead to viable solutions for its large-scale utilization and disposal. The effect of addition of quarry fines on properties of expansive clay was studied in detail. The percentage increase of 10, 20, 30, 40 and 50 in quarry fines content increased the ues values considerably.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Soil

The soil used in this study is greyish black in colour and is Black Cotton soil (BCS). It was obtained at Worujulbe village, km 46 along Numan - Yola road in Damsa Local Government Area of Adamawa State. The top soil was removed to a depth of O.Sm before the soil sample was taken by disturbed sampling, sealed in plastic bags and put in sack to avoid loss of moisture during transportation.

3.1.2 Cement Kiln Dust (CKD)

The Cement Kiln Dust (CKD) used was obtained from freshly deposited heaps of the waste at the Benue Cement Factory located in Gboko Local Government Area of Benue State, Nigeria. The CKD was sieved through BS sieve No. 40 (0.42Smm) and was stored in -air tight bags.

3.1.3 Quarry Fines

The quarry fine was obtained at Arab Contractor Quarry site, Mpape, one of the satellite towns in Abuja- FCT. It was also sieved through BS sieve No. 40 (0.42Smm).

3.1.4 Water

The water used for conducting the laboratory tests was bore-hole water obtained at Civil Engineering laboratory, Federal University of Technology, Minna. This was used in the absence of distilled water in the laboratory.

3.2 Methods

J.:':.1 Laboratory Tes s

This involves "theprocedures in 'which the different Laboratory investigations were arried out. They were conducted in accordance and in compliance with the specifications contained in BS 1377 (1990).

3.2.1.1 In-Situ Moisture Content

The moisture content ofa soil sample is defined as the ratio (usually expressed in percentage) of the weight of water to the weight of dry soil grain in the mass

i.e.

$$\text{Moisture content, } w = \frac{\text{Mass of water}}{\text{Dry Mass of soil}} * 100\% \quad \text{----------------equation (3.1)}$$

M_2-M_3

Where M_1 = mass of empty container

M_2 = mass of container with wet soil

M_3 = mass of container with dry soil

The apparatus used for this test include; electric weighing balance, thermostatically controlled oven and moisture content weighing cans.

Two cans were weighed empty as M_1 and filled with little quantity of soil specimen and weighed again as M_2. The specimen was then placed in an oven with the lids removed for 24 hours. The specimen is reweighed as M_3. The result is presented in Table 3.1

Table 3.1: Result of In-Situ Moisture Content Moisture Test

Can Number	H4	CS
Mass of empty can m, (g)	25.20	25.00
Mass of can + wet soil m2(g)	82.50	82.80
Mass of can + dry soil m, (g)	70.50	71.00
Mass of moisture (g)	12.00	11.80
Mass of dry soil (g)	45.30	46.00
Moisture content (%)	26.49	25.65
Mean moisture content (%)	26.05	

3.2.1.2 Specific Gravity Test

Two density bottles were cleaned and weighed. Air dried soil sample passing through BS sieve No. 40 (0.425mm) of approximately equal parts was placed in the density bottles and weighed. Water was added to each of the bottles, so that it just covers the soil and shaken gently. Water was added again up to the 250m! mark and weighed. The result is presented in Table 3.2.The specific gravity of the sample was calculated from the relation:

Gs = m2- ml ________________ equation (3.2)

(II14-ml)- (m--m-)

Where Gs = Specific gravity

MJ = mass of density bottle

M2= mass of density bottle with soil

M3= mass of density bottle with soil and water

Ma = mass of density bottle with water only

Table 3.1,: Re sult of Specific Gravity Test

Density Bottle	A	B
Mass of density bottle, m, (g)	114.30	97.50
Mass of density bottle + soil, In2 (g)	129.30	121.30
Mass of density bottle + soil + water, m, (g)	371.10	359.70
Mass of density bottle + water, m, (g)	362.80	346.30
Mean Specific Gravity, Gs	2.26	

3.2.1.3 Grain Size (Sieve) Analysis

The apparatus used include: British standard sieves, electronic weighing balance, thermostatically controlled drying oven, large pan, scoop and a brush.

About 300g of soil sample was washed thoroughly through BS sieves No. 10 (2rnm) and No. 200 (0.075mm). The material retained on the sieves was allowed to drain and carefully transferred to a pan and oven dried. The dried soil was passed through a nest of the complete range of sieves to cover the sizes. The portion retained on each sieve was weighed and percentage passing each sieve was calculated and the grading curve plotted as presented in Fig 4.1.

Table 3.3 Sieve Analysis Test

Sieve Size, mm	5.00	3.35	2.00	1.18	0.850	0.600	0.425	0.300	0.150	0.075
% Passing	99.2	98.8	98.2	97.9	97.7	97.6	97.5	97.4	95.6	94.8

3.2.1.4. Liquid Limit Test, LL (Cone Penetrometer Method)

About 200g of air dried soil sample passing through BS sieve No. 40 (0.425mm) was mixed with water in a plastic tray to a putty-like consistency. The sample was then systematically placed in a brass cup using a spatula with care taken to ensure that no entrapped air in the process. After filling the cup, it was centrally placed beneath the cup lip. The knob was adjusted until there is a slight contact between the tip of the penetrometer and the surface of the soil sample in the brass cup. The button on the penetrometer is pressed and allowed to fall freely and penetrate in to the soil paste, and then penetration was then recorded. Soil sample from the brass can was then placed in moisture content can in an oven for 24 hours for moisture content determination. The test was repeated four times but with increase in moisture content at varied proportion. The test was carried out on both the unstabliized and the stabilized BCS.

A graph of penetration against moisture content was plotted, and the moisture content at 200mm penetration gives the liquid limit in percentage as presented in Figs. 4.2 (AI) - (AS) in Appendix A.

Table 3.4: Liquid Limit (LL), % Test Results of *QF/CKD* Stabilized Soil

CKD, %	0	4	8	12	16
	72.S0	70.S0	67.00	6S.00	62.S0

3.2.1.5 Plastic Limit Test, PL

About ISOg of the soil sample passing BS sieve No. 40 (0.42Smm) prepared in the manner as in liquid limit was used it was thoroughly mixed with water in plastic tray until it was plastic enough to be rolled into a ball. It was then rolled with the finger tip with a constant applied pressure. The rolling continues until a thread of about 3mm in diameter was obtained. When the thread breaks, the crumbled soil sample is put in a can and placed in oven for 24 hours for moisture content determination. The test was carried out for both untreated and stabilized soil.

Table 3.5 (a): Plastic Limit (PLh i'~ Test Results of QF/CKD Stabilized Soil

CKD,%	0			12	16
	38.09	36.10	34.02	33.85	31.70

Table 3.5(b): Plasticity Index (PI), % Test Results of QF/CKD Stabilized Soil

CKD,%	0	4	8	12	16
	35.41	34.30	32.82	31.15	30.80

3.1.2.6 Compaction Test

The British Standard Light (BSL) method of compaction was adopted.

The apparatus used were compaction mould, 2.5kg Rammer, brush, mallet, measuring cylinder and weighing balance.

The mould with its base attached was weighed. 3.0kg of air dried soil was placed on a tray and pulverized. About 5% of water was added to the sample and thoroughly and the mould was placed on the concrete floor. The moist soil was then compacted in three layers of approximately equal mass, each layer been given 25 blows from the rammer dropping from a height of 300mm above the surface. The blows were uniformly distributed over the surface of each layer. After compacting the third layer, the collar was removed and the soil trimmed off the top of the mould. The mould and the compacted soil were weighed and a representative sample was obtained from the top and bottom of the compacted soil. The compacted sample was then demoulded, broken up and mixed with the remaining sample and water content was increased. The compaction process was repeated each time varying the water content until there was a drop in the weight of mould plus soil (BS 1377).

Cnlculation:

P_b = wJ/m ---------------- equation (3.6a)

Where Ph = Bulk Density (Mg/rrr')

W_3 = Weight of compacted soil (g)

And Dry Density (td) = Pb/l +w ---------------equation (3.6b)

The test was equally repeated for the stabilized soil. A graph of dry density against moisture content was plotted as presented in Figs.4.3 (Cl) - (C5) in Appendix B. The MDD and OMC were then obtained.

Table 3.6 (a): OMC, % Test Results of QFI CKD Stabilized Soil

CKD,%	0	4	8	12	16
	32.40	30.60	29.50	27.80	25.60

Table 3.6 (b): MDD, Mg/M3 Test Results of QFI CKD Stabilized Soil

CKD,%	0	4	8	12	16
	1.36	1.38	1.40	1.44	1.49

3.2.1.7 Unconfined Compressive Strength Test

Unconfmed compressive strength test was carried out using the Triaxial test machine without applying the cell pressure.

The apparatus used for this test are triaxial machine, compaction mould, rammer, tiaxial mould and knife.

The soil sample was mixed with water at optimum moisture content before compaction takes place. The optimum moisture content was obtained from the previous compaction test carried out.

The sample was extruded from the mould and then prepared for testing by cutting and ievelii.ng the specimen to the r quired shape and size of the triaxial mould. The specimen was then sealed in nylon sheets and cured in a humid condition for 0,7, 14,21 and 28 days before testing.

The sample was placed in the triaxial machine and tightened and the handle was rotated until the specimens just made contact with the top platen. The strain dial gauge was adjusted to read zero before the machine was switched on. The handle was plugged in and electrically rotated at a steady rate until the sample fails. The final strain and load at failure was obtained and recorded. The result is presented in Table 3.7.

The formula below was used to obtain the strength.

Qu = P/A -----.:_--------- equation (3.7a)

A = A° --------------------equation (3.7b)

1-~

Where

Qu = Compressive strength

A = Area after comprJssion

A_0 = Initial area before compression

"~ = Strain

The proving ring factor for the machine is 7.14

Tabl.e 3.7: Strength Development, kNfM2 Test Results ofQF/CKD ~tabilized Soil

CKD,%	0	4	8	12	16
Curing Time, Days					
0	96.11	117.56	147.21	181.99	222.20
7	137.71	184.46	229.76	298.77	315.87
14	194.81	281.03	298.86	414.20	417.94
21	219.29	349.84	472.86	490.88	530.26
28	257.17	515.96	635.81	755.65	602.22

CHAPTER FOUR

TEST RESUL 1'8 AND DISCUSSION

4.1 Index Properties of the Natural Soil

The results of the index properties on the natural soil are summarised in Table 4.1. The soil belongs to the A-7-6 of AASHTO Soil Classification System. Its particle size distribution shows that it is a fine-grained and highly compressible soil. The soil has high natural moisture content value and highly plastic (AASHTO).

The test also revealed that the soil has low amount of sand content (about 5.2%), high amount of silt content and highly clayed (94.8%).

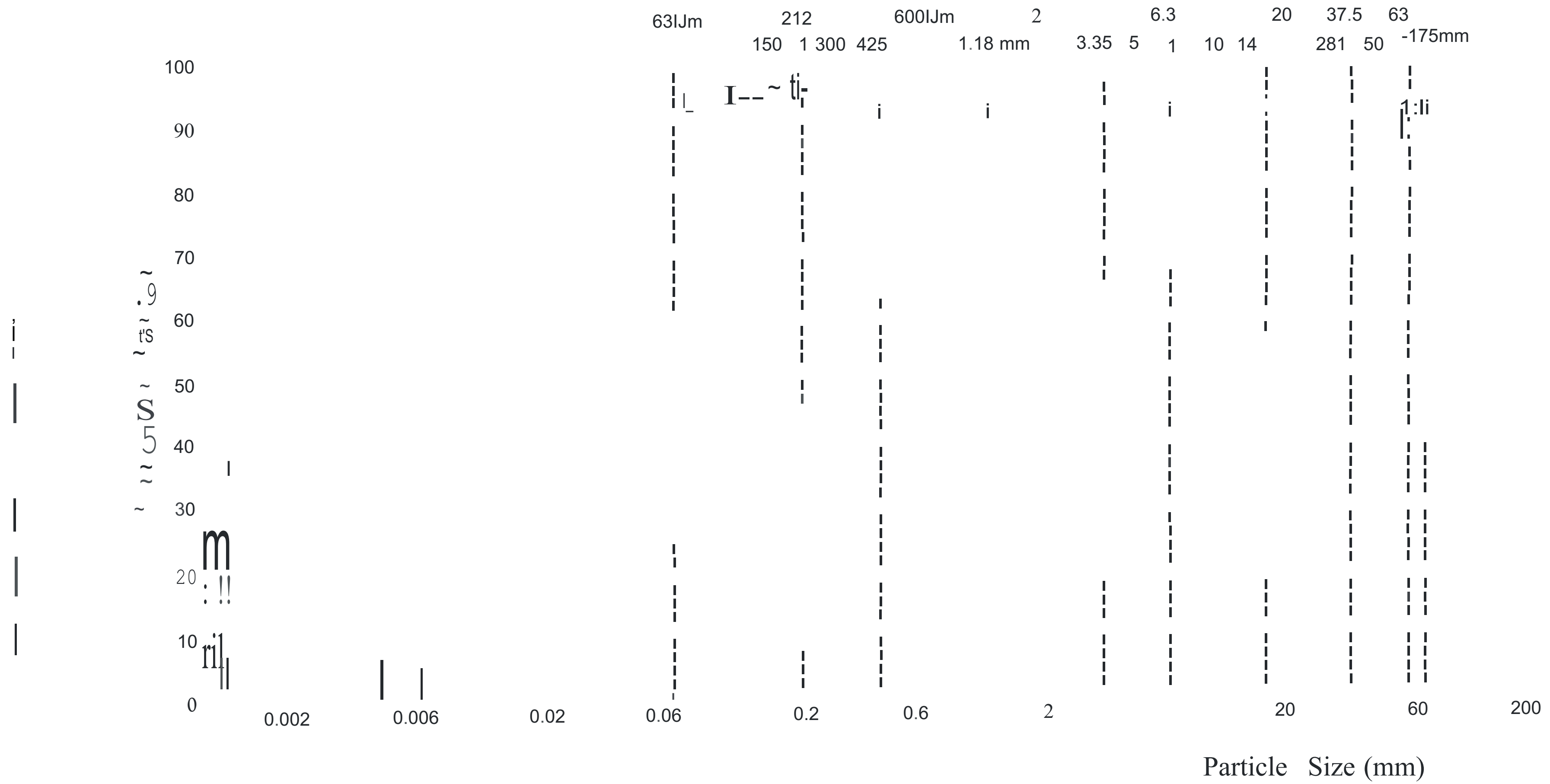

Fig. 4.1: Particle size distribution curve of the naairal soil

Table 4.1: Test Results for the Geotechnical Properties of the Natural Soil

Property	Quantity
Percentage passing BS No. 200 sieve, % .	94.81
Natural Moisture Content, %	26.05
Liquid Limit, %	72.50
Plastic Limit, %	38.09
Plasticity Index, %	35.41
Specific Gravity	2.26
AASHTO Classification	A-7-6
Maximum Dry Density, Mg/nr'	1.36
Optimum Moisture Content, %	32.40
Unconfined Compressive Strength, kN/m^2	96.11
Colour	Greyish black

4.2 Atterberg's Limits

The Liquid Limit (LL) decreased with increase in CKD content as presented in Fig 4.2. This may be as a result of water of hydration being used in accelerating pozzolanic reaction with the mineral content of the soil. Thus the minimum value in LL was recorded at 16% CKD.

Similarly, the Plastic Limit (PL) and Plasticity Index (PI) also decreased with addition of CKD content as shown in Fig. 4.2.

~

0 4 8 12 16

CKD.%

Fig. 4.2: Variation of Atterberg's Limits with CKD Contents

4.3 Compaction Characteristics

The variation of Dry Density (MDD) with Moisture Contents is presented in Fig. 4.3 (a). The MDD of the natural soil was established as 1.36Mg/m^3 and increased with addition of CKD contents indicating that the treated soil improves in density .The Peak value of MDD of *1.49*Mg/m^3 was recorded for soil treated with 16% CKD.

The Optimum Moisture Content (OMC) of the natural soil was 32.40% and decreased with addition of CKD contents. This may be attributed to replacement of soil particles in a given volume by particles *ofQF/CKD* thereby reducing the water absorbing ability of the natura} soil. The minimum value in OMC was recorded at 16% CKD as shown in Fig. 4.3 (b).

"

0 4 8 12 16

CKO.%

Fig. 4.3 (a): Variation ofMDD with CKD contents

I~OMCI

0 4 8 12 16

CKO.%

Fig. 4.3 (b): Variation of OMC with CKD Contents

~

4.4 Strength Characteristics

The result of the Unconfined Compressive Strength at different days of curing is presented in Fig.4.4.

Generally, strength of the black Cotton Soil increased with higher CKD contents. The increase can be attributed primarily to the formation of various compound such as calcium silicate hydrates (CSH) and calcium aluminates hydrates (CAH) which are responsible for strength development. Although, the UCS value of 16% CKD for 28 days curing decreased, probably because of insufficient water needed to bring pozzolanic reaction to completion (Eberemu, Osinubi and Oyelakin, 2011). The longer the curing time, the higher the strength development of the stabilized soil. The highest compressive strength was recorded at 28 days curing for 12% CKD as presented in Fig. 4.4, thus indicating that the blend has potential for time-dependent increase in strength.

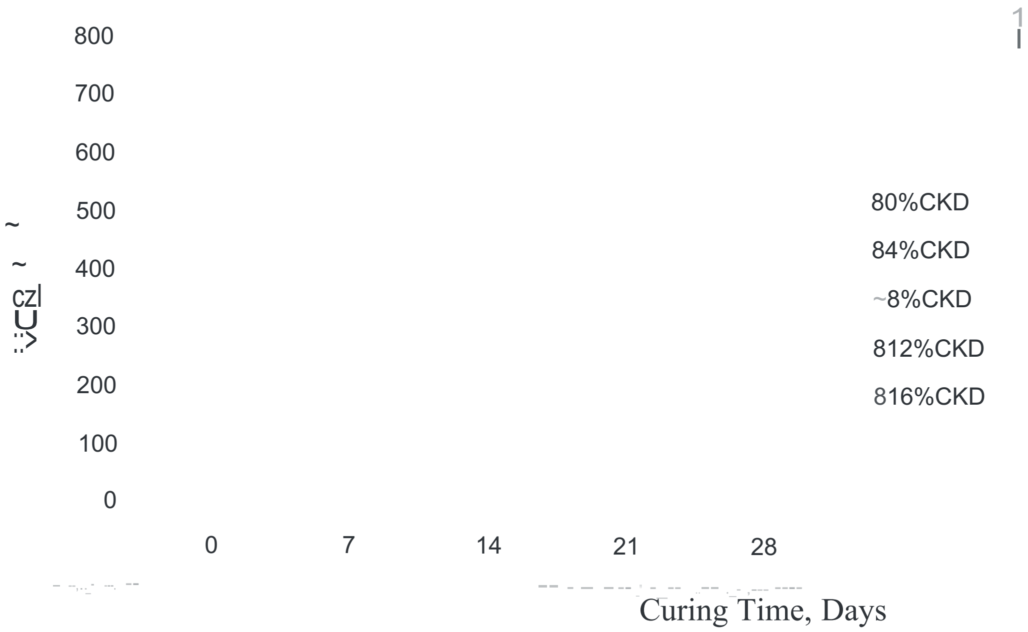

Fig. 4.4: Variation of UCS with Curing Time

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Within the limits of experimental error: temperature, loading, weighing, mixing conditions and parallax in measurements considered in this study, the investigation concluded that CKD is potentially useful in stabilizing soils and the following inferences were drawn;

1. The soil was identified to belong to A-7-6 group according to the AASHTO Soil Classification system.

2. Preliminary tests carried out on the soil showed that there was reduction in LL, PL, PI, OMC and increase in MDD.

3. There was a general increase in the UCS values with increase in CKD content and curing time, thus indicating that the blend has potential for time-dependent increase in strength. The soil treated with 12% CKD recorded the peak UCS value of 755.65kN/m^2 from 257.*17KN/m2,* for the natural soil, representing 193.83% when cured for 28 days.

5.2 Recommendations

The author wish to recommend that:

1. Based on the UCS results, it is recommended that 12-16% CKD should be used for stabilization and curing for about 28 days or more will be the most appropriate.

2. The use of CKDs should be encouraged for various applications such as soil stabilization, pavements etc, so that its disposal does not pose threat to the environment.

3. Finally, it is the opinion of the author that further studies should be carried out with higher percentage of QF*ICKD* and longer period of curing.

''

REFERENCES

AASHTO (1986). Standards Specifications for Transport Materials and methods of Sampling and Testing: 14thEdition, American Association of State Highway and Transport Officials (AASHTO), Washington D.C.

Al-moudi and Rahman (2011). Identification of non hazardous secondary materials that are solid waste Cement Kiln Dust: Journal of Environmental Quality, Vol. 4, pp.267-273.

Arora, K.R. (2009). Soil Mechanics and Foundation Engineering: Published by AK Jain 1705-B, Nai Sarak, Delhi - 110006. Seventh edition.

Azad, S. (2000): Influence of soil type on stabilization with CKD: Construction and Building materials vol. 3.

Baghadi, Z.A, and Rahman (1990): Engineering studies of Kiln Dust-Kaolinite Mixtures: Proceedings Southeast Asian geotechnical Conference, Taipei, republic of China, April, vol. 1, pp. 17 -21

Bhatty, M.S.y' (1984c): Use of Cements Kiln Dust in Blended Cements: Alkali-Aggregate Reaction Expansion, World Cement Technology, London.UK, vol. 16 No. 10 December, 1984.

BS 1377 (1990). Methods of testing soil for civil engineering purposes: British Standards Institute, London.

Caleman, T. And Corish, A (1995). Cement kiln Dust-Concrete: (London) 29 (5), pp. 40-42.

Collins, R.1. and Emery 1.1. (1983). Kiln Dust and Fly Ash in pozzolanic concrete base courses, in Emulsion Mix Design, stabilization and Compaction: TRB, Transportation Research Record No 754, National Academy of Science Washington, DC, USA, PP. 36 -41

Eberemu, AO., Osinubi, K.j. and Oyelakin M.A (2011). Improvement of Black Cotton Soil with Ordinary Portland Cement - Locust Bean Waste Ash Blend: EJG~, vol. 16 pp. 619 -627.

Collins, RJ. and Emery J.1. (1983). Kiln Dust -Fly Ash systems for highway bases and sub-bases: Federal highway administration, Report No. FHWA/RD - *82/167,* Washington, DC, September, 1983.

Eze-Uzomaka, Osondu John (2010). Suitability of Quarry Dust as Improvement to Cement Stabilized-Laterite for Road Bases: EJGE l. 15 pp 1053 - 1054.

Halidu, A. (2006). Improvement of Problem Laterite with Cement using Saw Dust Ash and Sodium Chloride as Admixtures: Unpublished B.Eng Thesis, Department of Civil Engineering, Abubakar Tafawa Balewa University, Bauchi.

Ijindiya,T.S., Nmadu and Osinubi K.1. (2009). Lime Stabilization of Black Cotton Soil using Baggasse Ash as Admixture: Advance Materials Research Vols.62-64, pp 3-10.

Iyere, E. O. (2008). Effect of Curing on the Strength Properties of Lateritic Soil treated with Bentonite: Unpublished B.Eng Thesis.

Klemm, W.A (1980). Kiln Dust Utilization: Martin Marietta Laboratories Report MML TR 80-12, Baltimore, Maryland, U.S.A

APPENDIX

APPENDIX A

,

Moisture Content (%)

Fig. 4.2(Al): Variation of Penetration with Moisture Content for O%CKD

10 20 30 40 S0 60 70 80 90 100

Moisture Content (%)

Fig. 4.2(A2): Variation of Penetration with Moisture Content for 4% CKD

T-'--

-I.

Moisture Content (%)

Fig. 4.2(A3): Variation of Penetration with Moisture Content for 8% CKD

Moisture Content (0/0)

Fig. 4.2(A4): Variation of Penetration with Moisture Content for 12% CKD

..

APPENDIXB.

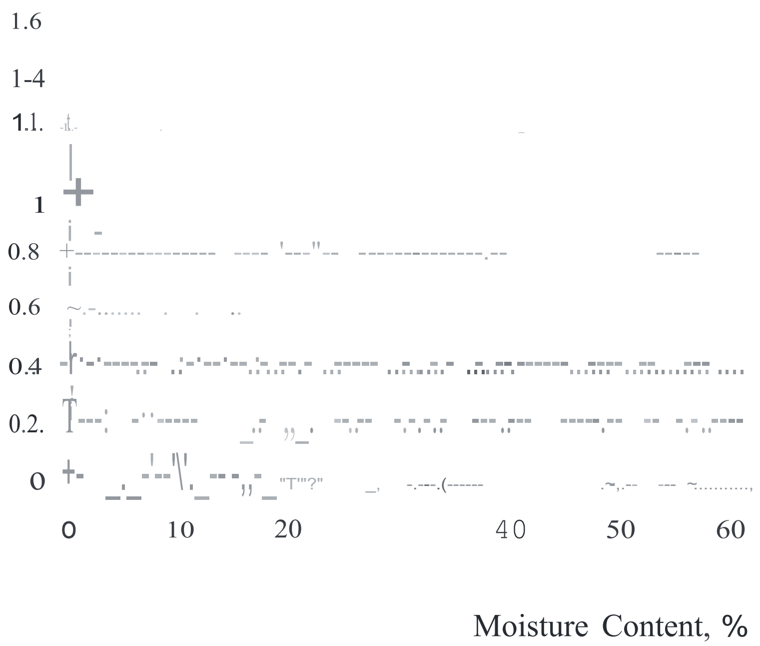

Fig. 4.3 (Bl): Variation of Dry Density with Moisture Content for 0% CKD

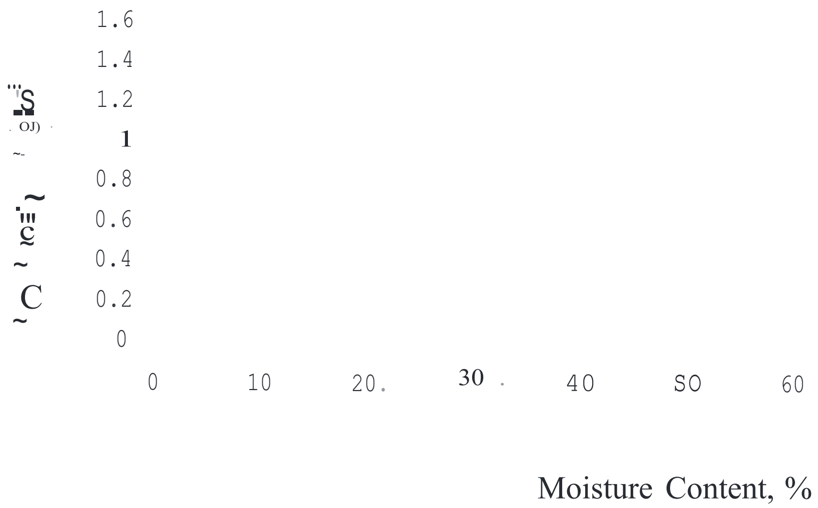

Fig. 4.3 (B2): Variation of Dry Density with Moisture Content for 4% CKD

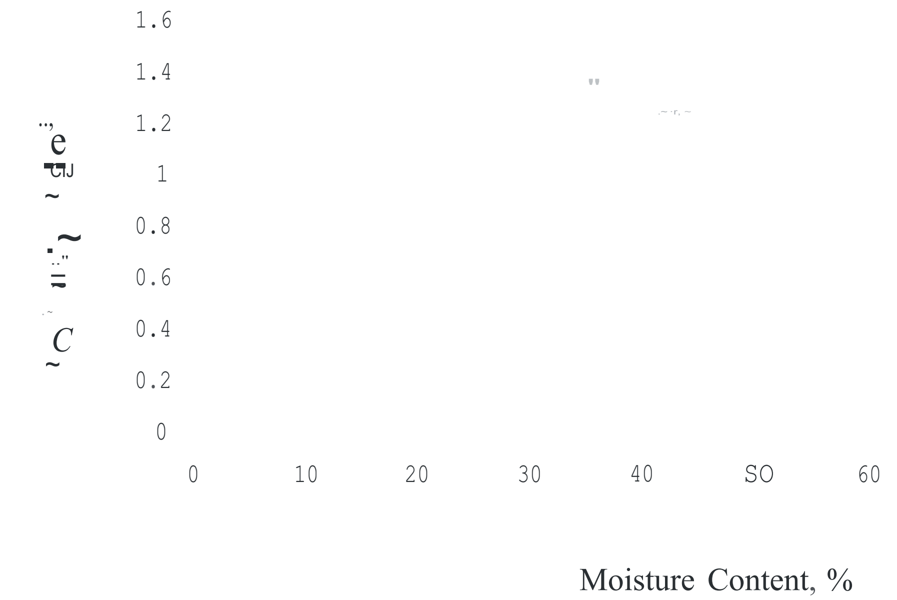

Fig. 4.3 (B3): Variation of Dry Density with Moisture Content for 8% CKD

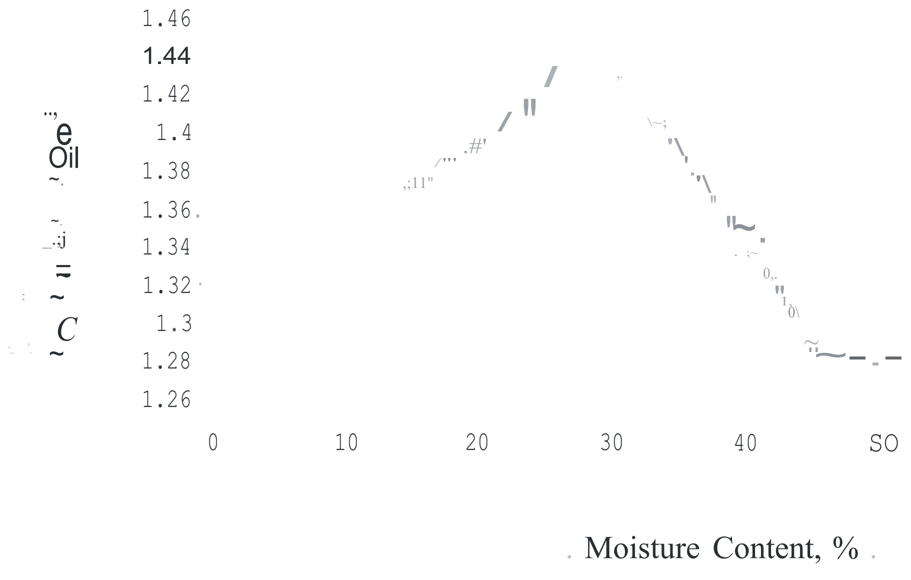

Fig. 4.3 (B4): Variation of Dry Density with Moisture Content for 12% CKD

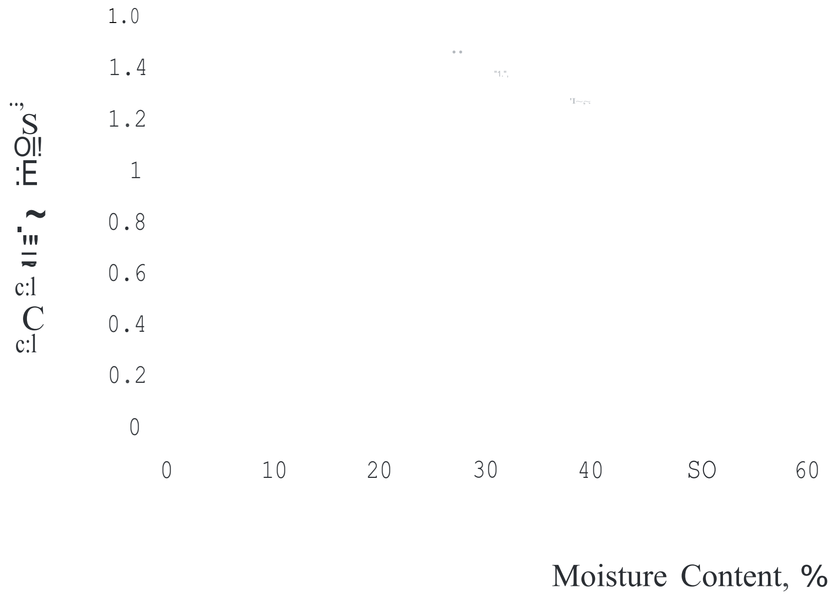

Fig. 4.3 (BS): Variation of Dry Density with Moisture Content for 16% CKp

Moisture Content (%)

Fig. 4.2(A5): Variation of Penetration with Moisture Content for 16% CKD

Curing Period (Days)

Fig. 4.4(Cl): Variation ofUCS with Curing Period for 0% CKD

Curing Period (Days)

Fig. 4.4(C2): Variation ofUCS with Curing Period for 4% CKD

Curing Period (Days)

Fig. 4.4(C5): Variation ofVCS with Curing Period for 16% CKD