An Investigation into the Application of used Lube-Oil for Improvement of Engineering Foundations

Paul Christopher Kimali Kioko , Dr. (Eng.) Geoffrey N. Mang'uriu , Prof. (Eng.) Walter Oyawa
Department of Civil Engineering, School of Civil , Environmental and Geospatial Engineering
Jomo Kenyatta University Of Agriculture and Technology,Nairobi-Kenya.

Abstract - Lube Oil is used to mean Lubricating Oil as used in automobile engines for lubrication of moving parts, cooling, cleaning, corrosion control. It is used as such in subsequent chapters save insofar as otherwise stated.

Lube-Oil is produced in fractional distillation in refinery processes and is mainly used in the automotive industry and has least caught the attention of civil engineers within the purview of research with a view to subsequent application upon use and for infrastructure development.

Soil improvement is the alteration of any property of a soil to improve its engineering performance through for instance; increased shear strength, reduced permeability, and reduced compressibility. It results in improved durability of soil by increasing its strength and resistance to water.

The improvement of black cotton soil is the basis of study by the application of Used Lube Oil in varying quantities and percentages. These soils are highly sensitive to seasonal moisture content variations and are responsible for substantial distress to foundations and the structures that are built over them. These soils when subjected static and dynamic forces heave and crack due to swelling and shrinkage. Hence, the soils are to be stabilized before construction in order to have efficient and long lasting foundations. The experimental study involves classification and evaluation of the main index properties of the soil, compaction and California bearing ratio. The attempt is to investigate the limits within which it can be used to improve black cotton soil for engineering foundations and to examine the effect of used lube oil on various geotechnical and engineering properties.

Test results have subsequently shown how Used Lube Oil alters the soil performance in terms of strength parameters. Results include those of Atterberg Limits and Plasticity Index, Maximum Dry Density and Optimum Moisture Content as well as California Bearing Ratio results with varying quantities of used lube oil.

Used Lube Oil has to some extent been used in Kakuma refugee camp during preparation of foundations and the possibility of using it as an improvement material inspired this research proposal. It is therefore hoped that this thesis will provide the impetus necessary to operationalise the findings in our construction industry.

Key Words: Used Lube Oil, Maximum Dry Density (MDD) , Optimum Moisture Content (OMC), California Bearing Ratio (CBR), Dynamic Viscosity (η)

CHAPTER ONE

1.0 INTRODUCTION:

1.1 General

Soil is generally a very important material in civil engineering where it provides the foundation for all civil engineering structures. Soils exist in many different forms such as clay soils, sandy soils, gravel, organic soils and murram all of which behave differently with regard to strength, susceptibility to cracking, permeability and erosion.

These properties can be improved using admixtures such as bitumen, cement, lime, pozollana and used lube oil. As a result of this there is need to improve these weaknesses using an admixture.

Black cotton soils, which form the basis of this thesis, are highly sensitive to seasonal moisture content variations and are responsible for substantial distress to foundations and the structures that are built over them on these soils. Civil Engineering Structures especially foundations in these areas suffer from premature failures attributed to the rich proportions of montimorillonite and kaolinite found in the soil. Stabilizing black cotton soil with chemicals, industrial wastes, geotextiles and so on have been found to be effective in improving their engineering properties, strength characteristics and CBR value.

Black cotton soils are problematic for Civil Engineers, because of their unconventional behaviour. These soils show large volume changes with respect to variation of seasonal moisture content. These soils when subjected static and dynamic forces heave and crack due to swelling and shrinkage. Hence, the soils are to be stabilized before construction in order to have efficient and long lasting foundations. Considerable research has taken place using different stabilizing materials such as lime, flyash,cement, rice husk ash, industrial wastes and geosynthetics and proved to be useful improvement of black cotton soils.

Foundation cracks resulting from alternate heave and settlement lead to ultimate failure.

Black cotton soil swells during rainy season and cracks in summer due to shrinkage. These shrinkage cracks are 100 mm to 150 mm wide and 0.5 m to 2 m deep. Swelling creates upwards pressure on the structure and shrinkage creates downward pull. It results into cracks in foundations,walls,and,roof.

Hence foundation in black cotton soil needs special care.

Used Oil has been a challenge over a long time and efforts to sustainable handling started way back in the 1970s in Pennsylvania. Due to this, interest has been developed into the suitability of Used Oil for soil improvement for engineering foundations.

Soil stabilization is the alteration of any property of a soil to improve its engineering performance through for instance; increased shear strength, reduced permeability, and reduced compressibility. It results in improved durability of soil by increasing its strength and resistance to water.

Soil improvement in foundation construction has become very expensive in recent times due to the increased costs on the materials that go into their construction. This research seeks to come up with an appropriate technology that is suitable, sustainable and economically adaptable. Used Lube Oil is thereby investigated to establish its suitability as an improvement material for foundations in Kenya and beyond. Lube-Oil is produced in fractional distillation in refinery processes and used for automobile engine lubrication and subsequently discharged in petrol stations as waste.

1.2 PROBLEM STATEMENT

Good infrastructure has been and still is the desire of many nations especially in the developing world and indeed even in the developed world. This has been a daunting task to many governments though it has been declared a millennium development goal to be achieved in this century. The Kenyan government has also outlined this to achieve its vision for the year 2030 which is the country's new development blue print covering the years 2008 to 2030.This goal cannot be achieved if expensive construction methods and approaches are still used as is the case today. With the high levels of poverty and uncertainty of the world's economy, there is need for cheaper and locally available construction materials.

First and foremost, Portland cement, fly ash and ordinary bitumen which are widely used in stabilization of road sub-bases albeit being readily available in most countries are significantly more expensive in contrast with the used lube oil being investigated in this research. The monthly waste is estimated at 1.5 Million Litres and the figure is always escalating and this will soon be exacerbated by the recent discoveries of Oil in Turkana, North Eastern Kenya and the Coast region compounded with the overall accelerated development towards vision 2030.

Secondly, it is surprising to discover that no attempt has been made to research on used lube oil from automobile engines mainly because it is employed in the province of Mechanical engineering and its manufacture falls within the purview of Analytical and Industrial Chemistry.

Used lube oil is a generic of fractional distillation just like bitumen and is discharged or drained as waste in numerous waste generators including petrol stations and mechanics' garages with the discharge rate now creating inter-alia; unprecedented public health concerns, detrimental impacts on the flora and fauna, soil degradation, compromising on the quality and the standard of living and image and rating at a global scale.

This research seeks to come up with an appropriate technology that is suitable, sustainable and economically adaptable and to provide enhanced soil improvement technique.

The research is aimed at obviating the costs associated with the use of alternative foundation types like piles or at worst the cost of hiring mechanical plant to scoop vast quantities of black cotton soil and associated municipal disposal costs compounded with National Management Authority(Nema)regulations.

1.3. RESEARCH HYPOTHESIS:

It is conjectured that there is a significant impact in the alteration of engineering properties of black cotton soil with the application for engineering foundations.

1.4. OBJECTIVES

1.4.1 Main Objective

To determine the suitability of used lube oil for improvement on black-cotton soil and red coffee soil for engineering foundations within the ranges of replacement of 0%,5%,10%,15% and 20%.

1.4.2 Specific objectives

(i) To determine the fundamental properties of used engine oil such as dynamic viscosity and density.

(ii) To assess the suitability or otherwise of used lube oil on the strength and engineering properties of the soils such as liquid limit, plastic limit, plasticity index, optimum moisture content, California bearing ratio.

(iii) To determine the permeability of the soil before and after the application of used lube oil.

1.4.3 Limitations of the Research

- Financial constraint was a major factor in determining the extent of the research. The data collection and the research scope were limited by finances.
- Time factor limited data collection and analysis for the research
- Some Equipment for carrying out certain tests were not available. This also limited the scope of the research.
- Literature for past research in this area was not readily available because access to such information was limited.

1.5 JUSTIFICATION OF THE STUDY

A study of this nature is very useful and it has far-reaching benefits.

It is imperative to note that to date there is no policy on used oil management and micro-managing the same by limited entrepreneurs has not born any fruits hitherto.
This comes hot on the heels of vast quantities of used lube oil discharge into the liquid and solid waste stream currently estimated at 1.5 Million Litres Monthly and this figure is conservative.
Any legislation based on this research on used lube oil will be to assign common points for generating and collecting used lube oil for purposes of ensuring safe disposal and ultimate use for stabilization.
It will be useful to the National and County Governments (for the rehabilitation of the Class A road to Juba in Sudan) as well as professional bodies in an endeavour to address economy in construction, the ever glaring eco-challenges of waste management and disposal , enhancement of small & medium size industries for used oil storage, handling and disposal. Professionally it will help set precedent in defining other frontiers within this research context for our universities.
This research is an integrated effort towards sustainable development as defined in AGENDA21 of the United Nations Conference on Environment & Development held at Rio de Janeiro,Brazil,3rd to 14th June,1992 and as well the provisions of Environmental Management and Co-Ordination Act(EMCA) 1999-Laws of Kenya.
Specifically, it will facilitate in policy making if not drafting a piece of legislation for this cause.
The research is aimed at obviating the costs associated with the use of alternative foundation types like piles or at worst the cost of hiring mechanical plant to scoop vast quantities of black cotton soil and associated municipal disposal costs and further Nema regulations regarding the same.

Used Lube Oil for black cotton soil improvement for foundations shall be extracted from lube bays of petrol stations, mechanics' garages or other disposal sites. In Kenya, used lube oil is predominantly treated as waste and is cheaply dispensed with to prospective buyers and is extremely cheap citing the example of far flung sites across the country like Kakuma where the retail prices of items is at least 3times the normal cost in towns like Nairobi. This makes used lube oil quite versatile for use in stabilization and is expected to cut down the cost of stabilization significantly.

Acute shortage of water and very low ground water table in for instance, Kakuma, low or negligible cost of used lube oil and plenty of mechanical plant and equipment are cited in this choice of stabilization.

CHAPTER TWO
2.0 LITERATURE REVIEW
2.1Background: Pennsylvania

This below five acre property in Pennsylvania was formerly the location of a fuel oil recycling and solvent recovery facility between the late 1970s and early 1990s.

During this time period, used oils were re-refined into fu el oil for sale to residual fuel users and lubricating oil was manufactured from the used oils. This process generated a clay filter cake waste that was stockpiled on the property. The property came to the attention of the Pennsylvania Department of Environmental Protection (PADEP) due to community complaints and non-compliance issues on the solid waste mess. In 1988, they conducted a site inspection of the property and identified volatile organic compounds (VOCs). Analytical results, for samples collected by the United States Environmental Protection Agency (USEPA) Region III, from staged waste materials (sludge, clay filter cake) onsite recommended remedial measures.

Remedial Investigation for the property was transferred to the Potentially Responsible Parties (PRPs) group in the late 1990s. Following preparation, submittal and approval of the Remedial Investigation Work Plan (2000), investigative activities were conducted from 2000 to 2004 and included collection and analysis of surface soils, subsurface soils, groundwater, sediment, surface water and light non-aqueous phase liquid (LNAPL).

Results from the five phases of the remedial investigation reported no site contaminants were detected in surface water samples and the results of the stream sediment data did not indicate that the site contaminants had impacted sediments.

A human health risk assessment was conducted that evaluated both industrial and residential receptors based on current and projected future use of the property. Site-specific remedial objectives were identified and included in the Feasibility Study.

The Remedial Investigation Report (including the human health risk assessment) and Feasibility Study Report were approved by USEPA Region III in 2005 and 2006. EPA issued the Record of Decision (ROD) for the site in the spring of 2007. A remedial design investigation is anticipated for late 2010 or 2011.

Evaluated human health exposure pathways included vapour intrusion into future commercial buildings, direct contact risks to future construction workers, and direct contact risks to future residents on offsite, down gradient properties.

Plate 2.0.(a) *Adopted from* http://www.applied geology.net/index

CHAPTER THREE

3.0 METHODOLOGY

3.1 TEST PROCEDURES:

The research method to be used in this study will be experimental. I, the researcher will gather information through laboratory experiments & tabulation. The information that was gathered from the analysis was analysed to aid in making sound conclusions and inferences within the purview of this research.

The study involved samples collection and laboratory tests. Each test was done several times, varying the quantities of lube oil and averages of results considered; all based on a work schedule.

The research samples and data were processed in the following ways:

- Visiting the site to collect black cotton soil and visit to petrol station to buy used lube oil and packing the same ready for laboratory testing.
- Laboratory tests to ascertain the engineering properties of this soil under investigation.
- Laboratory tests on improved black cotton soil with used lube oil.
- Inference made from the results

The results attained of the stabilized black cotton soil have been compared with data available from virgin black cotton soil tests including reference to standard road design manual requirements for material being used foundation material.

After obtaining the soils and the lube oil tests have been done on used lube oil dynamic and kinematic viscosity and subsequently the soil tests.

The tests have been done according to BS 1377-2, 1990. First moisture content determination, particle size distribution, plasticity index, liquid limit and linear shrinkage were done and then compaction and CBR test including viscosity tests.

Both lube oil and the soil have been mixed in percentages from 0% to 20% with varying moisture contents.

CHAPTER 4

4.0 RESULTS PRESENTATIONS, ANALYSIS AND DISCUSSION

4.1 VISCOSITY TEST:

RED WOOD EFFLUX VISCOMETER TEST (ISO 9000) ASTM- D445-06

VISCOSITY TEST: Red Wood Viscometer No. 1- Universal (For less than 2000seconds)

Viscosity is recorded as Red Wood seconds.

The conversion constants for Red Wood time units are;

Constant A=0.26

Constant B=172

Kinematic Viscosity $\upsilon = A.t - B/t$ (c-st or mm2/s)

Dynamic Viscosity from Kinematic Viscosity is obtained by:

$\eta = \upsilon.\ \rho.10^{-3}$

Where;

η= dynamic viscosity, mPa.s

υ= kinematic viscosity, mm^2/s

ρ= density,kg/m^3 at the same temperature(50^0C) used for the determination of the kinematic viscosity

Computation:

Mass Of Lube Oil In 50ml Beaker = Mass With Oil – Mass When Empty=75grammes-35grammes=**40grammes = 0.04KG**

Volume=50Ml= 0.00005M^3

Therefore Density=Mass/Volume = 0.04/0.00005 = 800KG/M^3

And Dynamic Viscosity is given by: $\eta = \upsilon.\ 800.10^{-3}$

Table 4.1

TEST	RED WOOD SECONDS	KINEMATIC VISCOSITY	KINEMATIC VISCOSITY
NO.1	268	69	55.2
NO.2	262	67.5	54
NO.3	264	68	54.4
	AVERAGE VISCOSITY	**68.17 ≈ $68\ mm^2/s$**	**54.53 ≈ 55 mPa.s**

4.2 TEST RESULTS FOR BLACK COTTON SOIL

4.2.1 Particle size distribution for the soil

This wet sieve test has been done to determine the percentage particle size distribution of a given sample of the black cotton soil. The analysis shall be done according to BS1377 part 2 (1990). The results obtained are graphically illustrated as in fig. 4.1 below

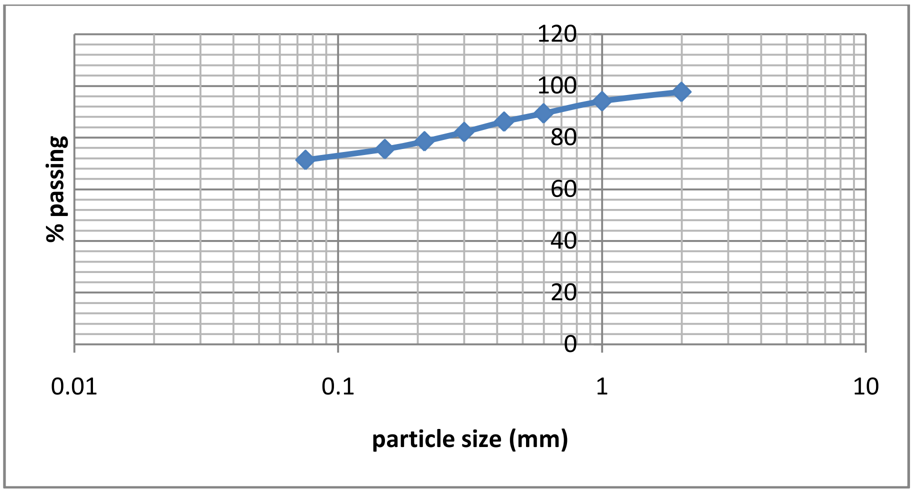

Figure 4.1 typical grading (wet sieve) curve for black cotton soil (neat): Soil Description (Silty Clay)

4.2.2 Moisture content determination

This test has been done to establish the field moisture content of the sample and the present moisture contents (PMC) for compaction tests

Table 4.2 field moisture content

A(WET+TIN)	B(DRY+TIN)	C(Tin wt)	(A-B)	(B-C)	(A-B)/(B-C)%
68.2	54.8	31	13.4	23.8	56.30252
69.2	54.8	30	14.4	24.8	58.06452
73.2	56.4	28.6	16.8	27.8	60.43165
77.4	61	34.6	16.4	26.4	62.12121
A V E R A G E Liquid Limit(L.L)					60

4.2.3 ATTERGBERGS LIMITS

4.2.3.1 Plastic limit

This is the moisture content at which the soil becomes dry to be plastic. The test shall be carried on a disturbed soil sample dried at room temperature and the gravel passed through 0.425mm sieve

Table 4.3 plastic limit test- black cotton

A(WET+TIN)	B(DRY+TIN)	C(Tin wt)	(A-B)	(B-C)	(A-B)/(B-C)%
35.4	34.4	30.8	1	3.6	27.77778
37	35.8	31.8	1.2	4	30
A V E R A G E Plastic Limit					29

4.2.3.2 Liquid limit

The sample shall be prepared in the same manner as plastic limit test and the liquid limit of the sample determined using Cone Penetrometer method. The data was recorded and the graph as shown in fig 2 drawn

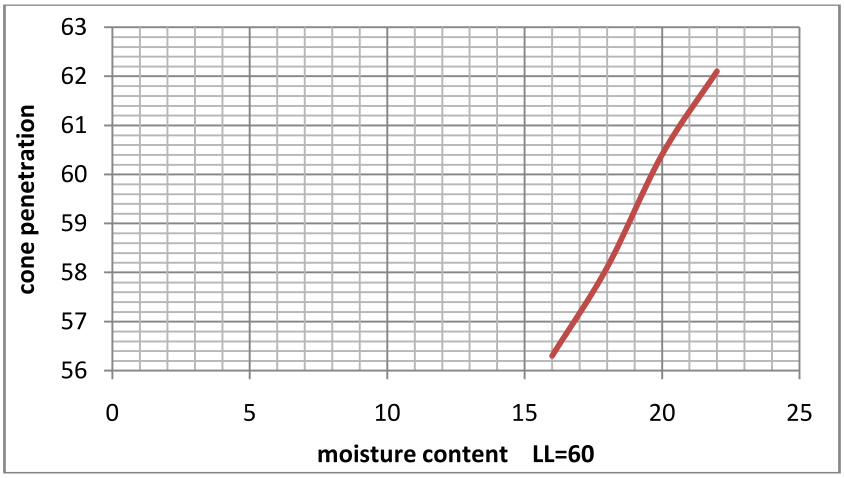

Figure 4.2 liquid limit for neat black cotton soil

4.2.3.3 Plasticity index

Plasticity index is calculated from the equation,

Plasticity index (PI) **PI = LL – PL =60-30=31%**

4.2.3.4 Linear shrinkage (LS)

It shall be calculated from the equation,

LS= (1 – Ld/Lo)*100% OR Half of P.I. = 31/2 =15.5%

Shrinkage =(20mm/140)*100=14.3%

Where; Lo- length of sample before oven drying=length of shrinkage mould

Ld-length of sample after oven drying

4.2.3.5. COMPACTION TEST

4.2.3.5.1 proctor compaction test

Proctor was carried out to establish the maximum dry density (MDD) and optimum moisture content (OMC) of the material by graphical data analysis and representation. The results obtained are to be recorded and illustrated in a typical graph similar to fig 4.4 below

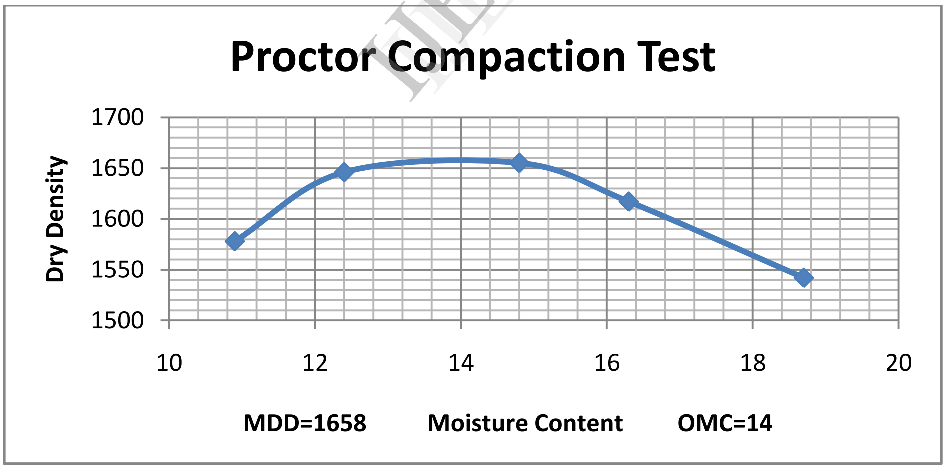

Figure 4.4 proctor analysis for black cotton soil at 10% Lube Oil

PERMEABILITY TEST:FALLING HEAD
Black Cotton Soil-
Table: 4.4

Percentage Lube Oil Replacement	Average Coefficient of Permeability(k)
0%	0.048×10^{-7}
5%	1.57×10^{-7}
10%	1.97×10^{-7}
15%	2.93×10^{-7}
20%	3.73×10^{-7}

CURVES SUMMARISED:

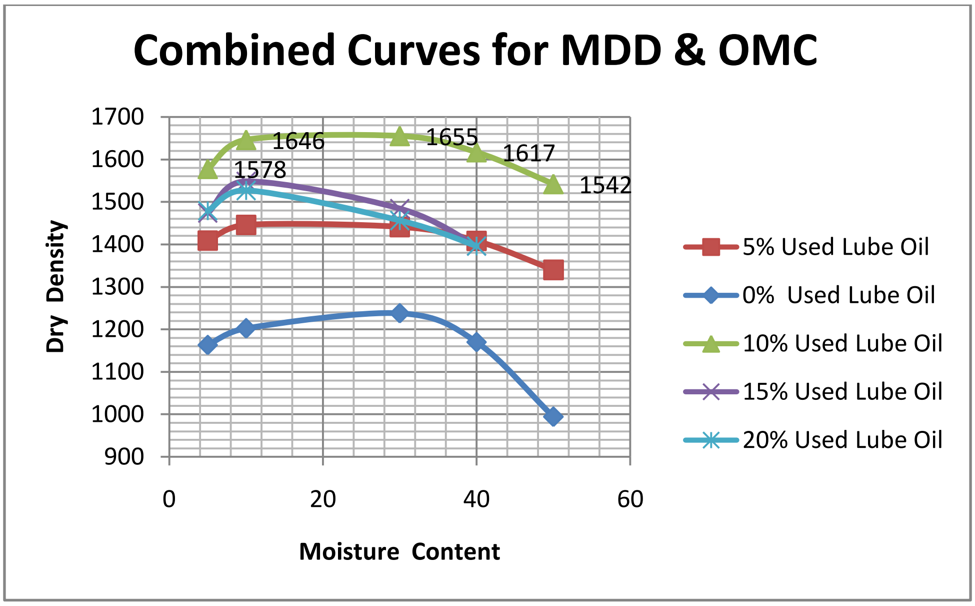

Figure 4.5) combined results for proctor analysis for black cotton soil

4.2.3.5.2 DYNAMIC CBR TEST

It has been done to determine the strength of black cotton material of maximum particle size of 20mm. This shall be determined by getting the relationship between force and penetration when cylindrical plunger of cross section area $1935mm^2$ was made to penetrate the soil at a given rate.

The results obtained are recorded and a typical graphical analysis is shown on figure 5 below.

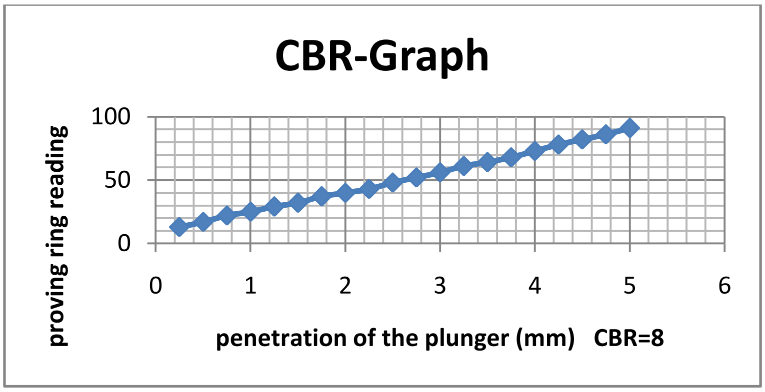

Figure 4.6 CBR analysis for black cotton soil at 10% Lube Oil

COMPARISON OF PROPERTIES OF VIRGIN BLACK COTTON SOIL WITH BLACK COTTON SOIL TREATED WITH USED LUBE-OIL

Table 4.4

Properties of neat Soil	Properties of improved soil at 10%
• LL = 60% • PL = 29% • PI = 31% • LS = 14.3% • MDD=1255Kg/m^3 • OMC=26.5% • CBR= 1	• LL = 40.6% • PL = 21.1% • PI = 19.5% • LS = 13.8% • MDD=1655Kg/m^3 • OMC=13.8% CBR= 8

From the Atterberg Limits it is possible to determine KARL PEARSON'S COEFFICIENT OF CORRELATION between neat soil and 10% treated soil :-

Where r between two variables x and y is defined by the relation,

$r = \frac{\sum XY}{[(\sum X^2)(\sum Y^2)]^{1/2}}$ where $X=x-\bar{x}$, $Y=\bar{y}-y$ that is, X and Y are the deviations measured from their respective means.

Table 4.6 Mean of Atterbergs: at 0%=33.6 $\longrightarrow x$, at 10%=30.5 $\longrightarrow y$

x	y	X=x-33.6	Y=y-30.5	X^2	Y^2	XY
60	44	26.4	13.5	696.96	182.25	356.4
29	22	-4.6	-8.5	21.16	72.25	39.1
31	22	-2.6	-8.5	6.76	72.25	22.1
14.3	11	-19.3	-19.5	372.49	380.25	376.35
134.3	99	-0.1	-23	1,097.37	707	793.95

Here $\sum X^2 = 1{,}097$, $\sum X^2 = 707$, $\sum XY = 793.95$

$$r = \frac{\sum XY}{[(\sum X^2)(\sum Y^2)]^{1/2}} = \frac{793.95}{(1097.37 \times 707)^{1/2}} = \frac{793.95}{880.82} = \mathbf{0.9}$$ ***perfect correlation!***

Therefore, r= 0.9 confirms a very high (perfect)correlation between change of soil parameters upon application of used lube oil at 10% replacement.

At 10% Used Lube Oil treatment

Results of liquid limit test shall be recorded but graphically analysed as shown below in fig 4.7

Liquid limit

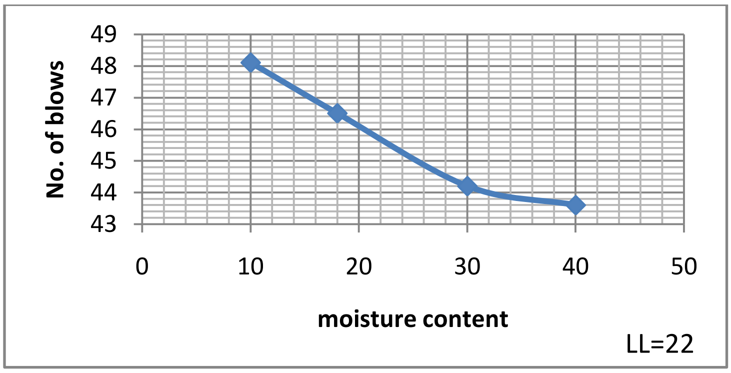

Figure 4.7 liquid limit - 10% Used Lube Oil

DISCUSSION

The liquid limit, linear shrinkage and plastic limit exhibit variations with increase in used lube oil contents as shown below:-

The variations shall be shown on a typical graph as shown below in figures below

The variations have been shown on graphs as shown in figure below

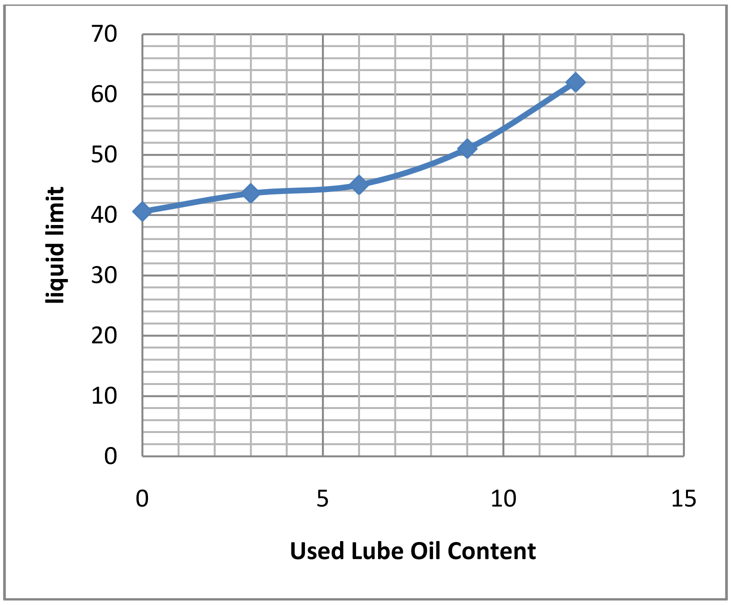

Figure 4.8 variation of liquid limit with Used Lube Oil content

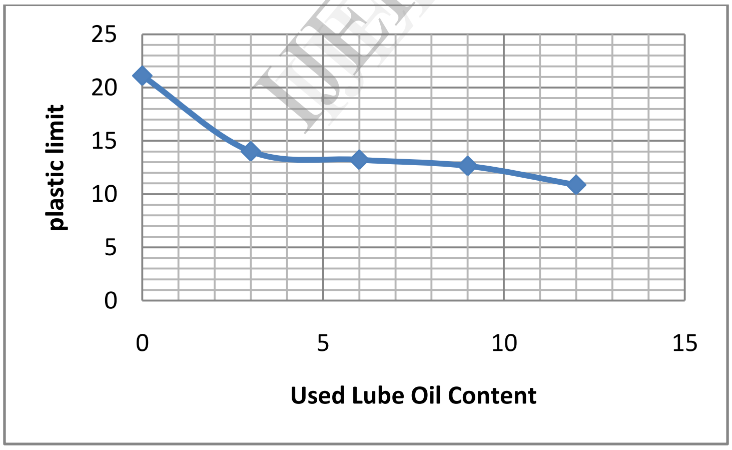

Figure 1 variation of plastic limit with Used Lube Oil

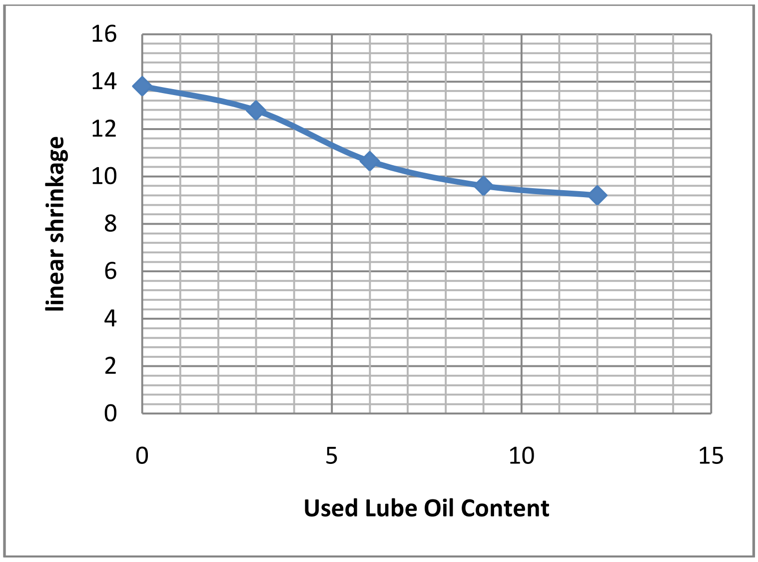

Figure 20 variation of linear shrinkage with Used Lube Oil

4.3.2 Effect of Used Lube Oil on maximum dry density (MDD) and optimum moisture content (OMC) of black cotton soil

The change in maximum dry density and optimum moisture content is noted in every change in Used Lube Oil content. Graphical analysis shall be done for every combination to illustrate the comparative effect of Used Lube Oil on black cotton.

DISCUSSION

The results show the variation of OMC and MDD with increasing contents of Used Lube Oil.

The variations shall be attributed to the replacement of soil by Used Lube Oil in the mixture which has relatively different physical properties including the specific gravity compared to that of the soil which is approximately.

It may also be attributed to the coating of the soil by the Used Lube Oil which results to large particles with larger voids and hence variation in density.

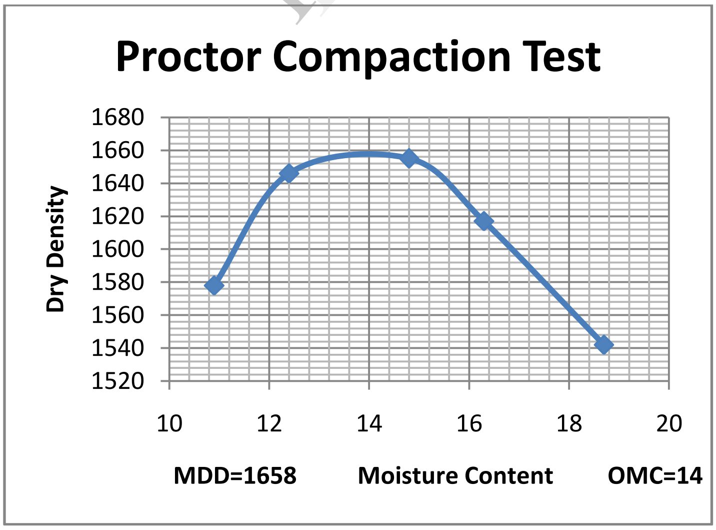

Figure 3 variation of maximum dry density with Used Lube Oil

The OMC varies within a certain range and this trend may be attributed to the addition of Used Lube Oil which alters the quantity of free silt and clay fraction and forming coarser materials with larger surface areas (these processes need water to take place).

This also suggests that water or more of it is needed in order to compact the soil-Used Lube Oil mixtures.

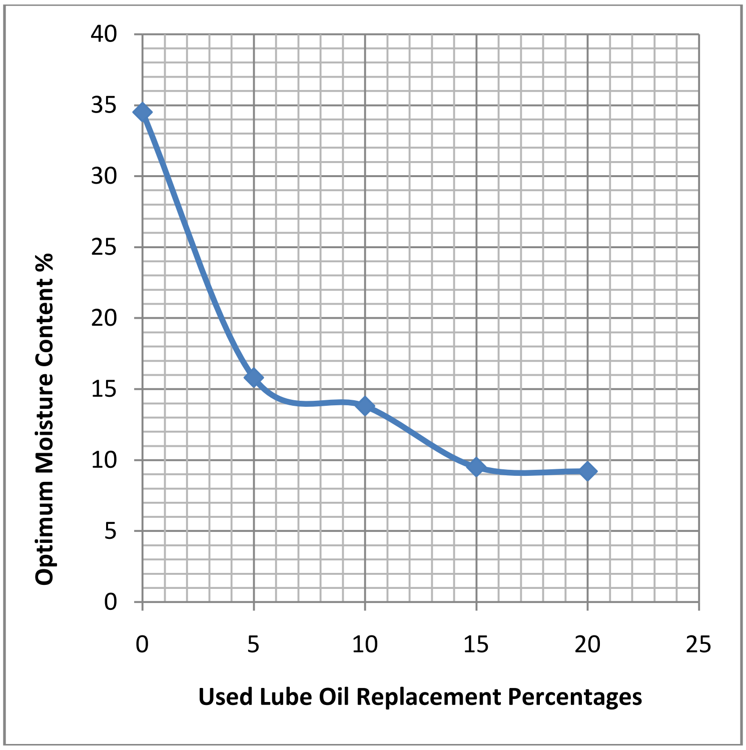

Figure 4.12 variation of OMC with Used Lube Oil

DISCUSSION

The results show that the CBR value of the black cotton soil varies with increased Used Lube Oil content.The reason for variation in CBR may be because of the gradual formation of bond in the soil by Used Lube Oil.

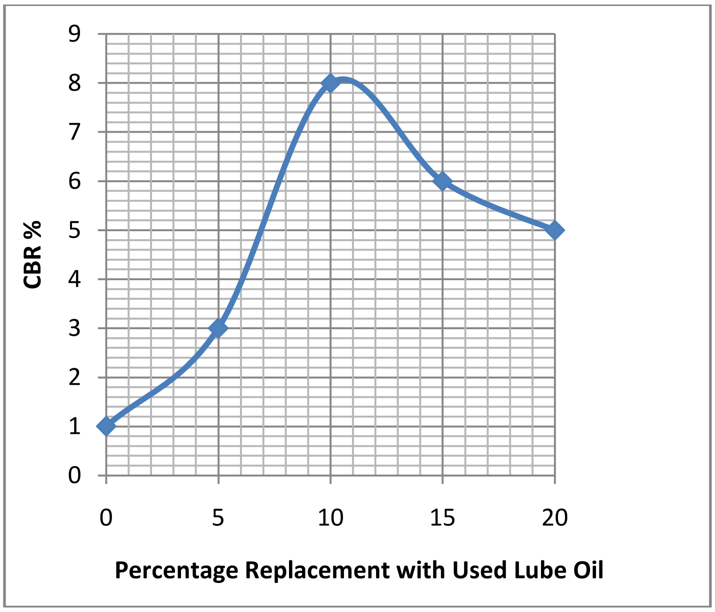

Figure 4.13 variation of CBR with Used Lube Oil

5.0 CONCLUSIONS

The following is the conclusion based on the results and discussion found in this in comparison with the virgin soil and the standard test results.;

- The Dynamic Viscosity determined at 500^C was 55MPa.S and density $800Kg/M^3$.
- The black cotton soil is unsuitable for foundations and hence the need for improvement.
- Attergbergs limits; the liquid and plastic limitsimproved favourably at an average of 30% with increase in Used Lube Oil content at 10%.This quite significant.
- MDD and OMC; the MDD for black cotton soil and red coffee soil increased up to $1655KG/M^3$ and $1523KG/M^3$ respectively at 10% Used Lube Oil while OMC decreased with increased Used Lube Oil content at 32% and 48% respectively. A similar trend is noted with red coffee soil.
- CBR value; the results showed that the CBR value of black cotton soil increased from 1 to 8 with increased Used Lube Oil contentof 10% while that of red coffee soil increased to 14 for the same percentage replacement with Used Lube Oil. This is due to the improved properties that cause improvement of the ***load bearing*** capacity of the black cotton soil.
- That 10% Used Lube Oil gives optimal values for both black cotton and red coffee soils.Bitumen is usually 4%.
- Black cotton and red cofee soil strength and engineering properties are greatly enhanced by treatment with used lube oil and so would any other commonly improved soils.
- Addition of Used Lube Oil increases the permeability of both black cotton soil and red coffee soil to 3.73 and 5.93 respectively as evidenced by the test results so that for black cotton soils
- Karl Pearson's statistical coefficient of correlation r= 0.9 confirms a very high (perfect)correlation between change of soil parameters upon application of used lube oil at 10% replacement.

5.1 RECOMMENDATIONS

a) Collaborative research work should be done to corroborate the findings in this research.

b) Need, if at all, to incorporate additional admixtures.

c) Need for incentives to enhance this nature of research through interventions.

REFERENCES:

1. **Engineering Treatment Of Soils :F.G.Bell-3rd Edn. 2009.**
2. **Modern Geotechnical Engineering:Alam Singh-4th Edn.2010.**
3. **Geotechnical Engineering:C.Venkatramalah-3rdEdn.2010.**
4. **Soil Mechanics And Foundation Engineering:Dhar & Gupta Ist Edn 1993**
5. **Kakuma Site Photos ,August ,2012.**
6. **Road design manual part 3 "standard specification for road and bridge construction"**
7. **British standard institution(1990) " method of test for soils for civil engineering purposes**
8. **Part 1. General requirements and sample preparation" BS 1377: part 1, 1990**
9. **British standard institution(1990) " method of test for soils for civil engineering purposes**
10. **Part 2. Classification tests" BS 1377: part 2, 1990**
11. **British standard institution(1990) " method of test for soils for civil engineering purposes**
    Part 4 .compaction related tests" BS 1377: part 4, 1990
12. **Lambe T William "Soil testing for the engineers", first edition**
13. **"International Journal of Research and Reviews in Applied Sciences" Volume 1, Issue 3(December 2009)**
14. **12."Leonardo Electronic Journal of Practices and Technologies " ISSN 1583-1078 Issue 11, July-December 2007 pg. 47- 58 http://lejpt.academicdirect.org**
15. **Ijimdiya, T.S. and Igboro, T. (2012) Effect of used oil on the strength and compressibility behaviour of lateritic soil.**
16. **Ijimdiya, T. S. (2011). "Effect of oil contamination on particle size distribution and plasticity**
    characteristics of lateritic soils." Advanced Materials Research, Vol. 367, pp. 19.
    http://www.scientific.net Trans Tech Publications. Switzerland.
17. **Osinubi, K.J. and Ijimdiya, T.S. (2009). Effect of Compactive Efforts on the Plasticity and Strength Properties of Reconstituted laterite. Nigerian Society of Engineers, Technical Transactions. Oct. – Dec. Vol. 44, No. 4. Pp. 1 – 14.**
18. **Little,D. and S.Nair,"Background for Development of Standard Practice for Modification and stabilization of Subgrade Soils and base Courses." NCHRP 20-07,(2008)**
19. **Texas Department of Transportation ,"Guidelines for modification and Stabilization of Soils and base for Use in Pavement Structures." ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/tech/stabilization.pdf(March 2008)**
20. **United Facilities Criteria(3-250-11). Soil Stabilization for Pavements,TM 5-822-14/AFJMAN 32/1019." (2004). http://www.wbdg.org/ccb/DOD/UFC/ufc_3_250_11.pdf(Jul.16,2006).**