Global Scientific JOURNALS

GSJ: Volume 7, Issue 9, September 2019, Online: ISSN 2320-9186
www.globalscientificjournal.com

AN INVESTIGATION INTO FIELD FACTORS THAT AFFECT THE STRENGTH OF COMPACTED LIME STABILISED CLAY FOR SUBGRADE CONSTRUCTION

SAJJAD ZAMIN

ABSTRACT

Field factors can affect the strength gain of compacted lime stabilized clay that affects the subgrade force. The main objective of this study was to investigate the effect of the field. Factors on the resistance of clay soils stabilized with compacted lime for subgrade construction.

Laboratory tests were performed and included in the tissue; Slope, calving ability, compaction test and CBR. Laboratory results showed a 4% increase in lime content and a 4% decrease in CBR (6%). The 4% decrease in CBR is due to unnecessary lime excess in the mix for an initial increase in strength. It has been found that 4% of the lime content is the best to stabilize the clay. Laboratory results showed higher CBR values for dry lime / clay mixtures than for the slurry (wet) mixture. Therefore, in all experiments with lime and CBR clay, the dry mix was used to achieve the highest test yield. In all percentages of lime addition, compression delays had an impact on the CBR. With an increasing time delay, the CBR value decreased. However, the rate of decrease in the CBR value decreased with the increase in lime content. CBR value improved at cure temperatures.

Due to the larger correlation coefficient (0.601), it was found that temperature is the most important factor affecting RBC. The SPSS software has developed a model to predict peak and minimum CBR based on lime content, compaction delay and temperature. Possible suggestions are made to improve the accuracy of this study. Further studies are recommended on the long-term results of clay and limestone stabilization, the effects of carbonation and sulfur attack on calcified clays. Minor temperature differences should be considered when conducting experiments to improve the accuracy of the regression model.

1 CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

The substrate is the foundation of the pavement and its strength, along with other factors such as compaction level and workmanship, is one of the most important factors in road construction that determines the structural integrity of the pavement. Weak surfaces often lead to failure and are caused by poor compaction or poor materials. MOWHC (2005) recommends subgrades with a strength of less than 2 percent CBR, which must be treated according to the specific situation. Some of the possible approaches include: in-situ treatment with lime (for clay-containing materials), removal and replacement with higher quality materials, use of geo-materials and construction of a pioneer layer (for highly expansive material and marshy areas) or rock fill. These conditions often occur in low-lying, wet and swampy areas, and the treatment should ideally be based on past proven practice for similar conditions

Lime stabilization is a technique that improves the stability of clay soils to successfully maintain the load on the pavement. In situ lime stabilization saves a lot of time and millions of dollars compared to the method of cutting out and replacing the unstable soil (Negi et al., 2013). Lime has been used on motorways for years to improve the technical characteristics of subsoil.

There is limited information on the long-term performance of lime-treated soils. Soil lime's reaction is pozzolanic and sensitive to the following factors: soil components such as sulfates, phosphates and organic matter, lime composition, temperature changes and dosage of the stabilizer. Since the strength of the lime-stabilized soil depends on the speed of the pozzolanic reactions, i-e slower pozzolanic reactions give lower strength than faster pozzolanic reactions, field conditions and technology affect the process of lime stabilization. A delay between mixing the lime with the soil and compacting the soil-lime mixture results in a decrease in both density and strength for a fixed compaction effort. A compaction delay may be unavoidable due to sudden rainfall and a sudden failure of the compaction equipment. These delay the compression process. Delays in compaction have a significant impact on the strength of stabilized soils. Makusa (2012) explains that delaying the compaction may result in hardening of the stabilized soil mass and therefore may require additional compaction to achieve the same effect. This can lead to serious bond breaks and thus loss of strength.

In the field, the temperature fluctuates continuously during the day. The pozzolanic reactions between the lime and clay particles slow down at low temperature and lead to a lower resistance of the stabilized mass. Prusinki and Bhattacharja (1999) explain that the purpose of the field mixing process is to obtain an intimate mixture of lime and earth to achieve the desired changes in properties. The mixture in the field can be dry or wet. The wet mixture increases the Ca + flow at the surface of the clay molecules due to an increase in moisture, hence a greater pozzolanic reaction and greater strength than the dry mix. Lime mud can also be used in dry soils where water may be needed for effective compaction (Hicks, 2002). Fine grain granules are the easiest to stabilize because of their large specific surface area relative to the particle diameter. The clay soil has a large surface compared to the others due to its flat and elongated particle shapes. On the other hand, the muddy material can be sensitive to slight changes in moisture and can therefore be difficult during stabilization. The resistance of the stabilized soil depends

1.2 PROBLEM STATEMENT

Field factors such as the compaction delay, temperature changes, the distribution of lime in the soil (measurement) and mixing processes can influence the increased resistance of the stabilized clay with compacted lime, which affects the resistance of the substrates.

1.3 AIM AND OBJECTIVES

1.3.1 AIM

The study aims to investigate the effect of field factors on the strength of compacted lime stabilized clay soils for subgrade construction

1.3.2 OBJECTIVES

Determination of the physical properties of clay and the stabilization suitability of lime.
To determine the effects of dosing, compaction delay, temperature and mixing methods on the CBR of lime-stabilized clay soils.
Establish statistical relationships between lime dosages that delay compaction, temperature and mixing methods with the strength of the lime-stabilized clay.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 STABILIZATION

With an adequate intake of lime and water, the soil pH rises rapidly above 10.5, degrading the clay particles. Determining the amount of lime required is part of the design process and is handled using tests such as the Eades and Grim tests. Silica and alumina are released and react with calcium from lime to form calcium silicate hydrates (CSH) and calcium aluminate hydrates (CAH). CSH and CAH are similar to cement-based products such as Portland cement. They form the matrix that contributes to the resistance of the soil layers stabilized with lime. During the formation of this matrix, the soil, sandy and granular, turns into a hard layer, relatively impervious and of a considerable bearing capacity. The process starts in a few hours and can be continued for years in a well thought out system. According to the National Lime Association (2003), lime reacts well with medium, medium and fine grain soils, reducing the plasticity and swelling potential of expansive soils and improving their processing and resistance properties. Lime is a suitable stabilizer for most cohesive soils, but the degree of reactivity depends on the type and amount of clay minerals in the soil. Benedetto (2010) has shown that higher levels of added lime (typically 3-8%) cause chemical reactions: alumina silicates precipitate as cement hydrate and soil resistance properties change considerably. In this case, the soil chemically modifies its own properties and the process is rightly called stabilization.

2.2 CHEMICAL REACTIONS IN LIME TREATED SOILS

Many reactions occur when the clay is mixed with lime in the presence of water. The reactions are: cat ion exchange, flocculation agglomeration, carbonation and pozzolic acid. Cat ion exchange and flocculation agglomeration reactions occur immediately after mixing and cause immediate changes in strength, plasticity index and dirt. Carbonic acid is a reaction of carbon dioxide in fresh air or lime in the soil with lime, which reduces cementing capacity. Cementation caused by carbonation on the clay surface results in a rapid initial increase in resistance. A pozzolanic reaction occurs between lime and silica and the aluminum ore of clay ore and produces a cementitious material comprising calcium and silicate hydrates and calcium and aluminum oxide hydrates. The long-term result of the pozzolanic reactions (equations 1 and 2) is the solidification of the soil. The speed of pozzolanic reactions depends on time and temperature. Scale stabilization can refer to a pozzolanic reaction in which pozzolanic materials react with lime in the presence of water to form cementitious compounds (EuroSoilStab, 2002). The effect can be caused by quicklime, CaO or hydrated lime, Ca (OH) 2.

$$Ca(OH)_2 + SiO_2 \longrightarrow CaO\text{-}SiO_2\text{-}H_2O \quad \text{...(1)}$$

$$Ca(OH)_2 + Al_2O_3 \longrightarrow CaO\text{-}Al_2O_3\text{-}H_2O \quad \text{………………………………………………...(2)}$$

2.2.1 DRYING

Quick lime is immediately hydrated (i.e. chemically combined with water) and releases heat. The soil is dry because the groundwater contributes to this reaction and the released heat allows evaporation of extra moisture. The hydrated lime produced by these initial reactions reacts with the clay particles. These successive reactions will result in extra drying because they reduce the moisture retention capacity of the soil. If hydrated lime or hydrated slurry is used instead of quick lime, drying only occurs through chemical changes in the soil that reduce water retention and increase stability.

2.2.2 MODIFICATION

After initial mixing, the calcium ions (Ca +) of the hydrated lime migrate to the surface of the clay particles and displace water and other ions. The soil becomes brittle and grainy, which facilitates its work and compaction. At that time, the plasticity index of the earth is in free fall, as is the tendency to swell and contract. The process called "categorization and agglomeration" usually takes place in a few hours.

2.3 FACTORS AFFECTING THE STRENGTH OF STABILIZED SOIL

2.3.1 STABILIZER DOSAGE

The amount of stabilizer required depends on the final objectives of the stabilization process. The resistance of the stabilized soil depends on the lime content. The higher the content, the greater the force.

2.3.2 ORGANIC MATTER

In many cases, the upper layers of most soil make up a large amount of organic matter. However, in well-drained soils, organic matter can spread to a depth of 1.5 meters (Sherwood, 1993). The organic substance in the soil reacts with the hydration product, e.g. Calcium hydroxide (Ca (OH) 2) results in a low ph. The resulting low pH can delay the hydration process and affect the hardening of stabilized soils, making compacting difficult or impossible.

2.3.3 COMPACTION

In practice, the influence of binder addition on soil density is of considerable importance. The stabilized mixture has a maximum dry density which, at a certain degree of compaction, is lower than that of the unstabilized soil. The optimum moisture content increases with increasing binder (Sherwood, 1993). Any delay in compaction may result in hardening of the stabilized soil mass, and therefore additional compaction force may be required to achieve the same effect. This can lead to severe fractures and thus to loss of strength.

2.3.4 TEMPERATURE

The reaction of pozzolan is sensitive to changes in temperature. In the field, the temperature fluctuates continuously during the day. Pozzolanic reactions between binders and soil particles slow down at low temperatures and cause a decrease in the resistance of the stabilized mass. In cold climates, it may be advisable to stabilize the soil during the hot season (Sherwood, 1993).

PAVEMENT TEMPERATURE PREDICTION MODEL

Matic et al. (2013) developed a model with the aim of predicting the road surface temperature at different depths from the road surface. Regression equations have been formed to predict the maximum and minimum road surface temperatures as a function of the maximum and minimum road surface temperature and depth

.

2.3.5 FIELD MIXING METHOD

Prusinki and Bhattacharja (1999) explain that the goal of the field mixing process is to obtain an intimate mixture of lime and soil to produce the desired changes in properties. The field mix may be dry or wet and affect gradation and spraying. The interaction between a stabilizer and the soil is influenced by the available surface area and by sufficient spraying. The wet mix increases the Ca + flow at the surface of the clay molecules due to an increase in moisture, resulting in a faster pozzolanic reaction and higher strength than the dry mix. Quicklime can also be used in dry soils where water may be needed for effective compaction (Hicks, 2002).

2.4 ASSESSING THE PROJECT FOR LIME STABILIZATION

If a project is to be assessed for lime stabilization, several aspects need to be considered to ensure lime stabilization is feasible for the project. Soil conditions are an important factor in deciding whether lime stabilization is appropriate. However, there may be conditions in which the soils are well suited for lime stabilization, but cost and design problems can make the use of lime impossible. Since it is recognized that lime has some potential health and safety problems, it is important that appropriate action be taken to ensure that these concerns are taken into account during construction, especially if the project is located in an urban area.

2.5 TREATMENT WITH LIME

According to MOWT (2010), the addition of lime has proven to be very effective in many high IP materials, usually greater than 10, that do not respond so well to cement treatment. It can be used to reduce the IP of the materials in the pretreatment (for the same purpose) of materials that can then be treated with a cement or bitumen emulsion to produce a suitable road construction material. In some areas, lime is produced on a small scale in local batch ovens, while in others it may be commercially available on a large scale. As the quality control of the products can also vary considerably, the engineer must first confirm that the production rate and quality are satisfactory for the identified need. Two main types of lime can be produced: hydrated and non-hydrated (quick) lime. The use of quicklime is discouraged due to health risks and its use for road construction is already prohibited in several countries. Compared to cement, the strength and stiffness gains are less pronounced and the reaction to the cement is slower, so that (depending on the base material) measurable changes can occur over several years. Similarly, the initial effect of the addition of lime, especially in wet soils, is rapid and the chemical reaction leads to an increase in the resistance and ease of circulation of said materials. The lime treatment can be used for the construction of the base and base.

3 CHAPTER THREE: MATERIALS AND METHODS

3.1 INTRODUCTION

This chapter discusses the materials, standard laboratory tests and procedures that were used in the study. The tests were carried out on the materials and included; Atterberg tests, gradation, suitability of lime, compaction test and CBR.

3.2 MATERIALS

The materials used for this study were hydrated lime, clay soil and water.

3.2.1 LIME

The lime used for this study was commercial hydrated lime ($Ca\ (OH)_2$). The lime was stored in an airtight bag to avoid carbonation with carbon dioxide in the air, which would affect its stabilizing power. Lime has not undergone any chemical analysis.

3.2.3 CLAY SOIL

The clay soil was obtained from Kohat Road. It was collected at a depth of 0.5 to 1 meter below the natural ground level by open pit excavations. The clay bottom was suitable because it had a PI greater than 37. The sample was carefully dried, weighed and stored in bags at room temperature. The general characteristics of the container have been thoroughly examined in the laboratory, namely. H. Liquidity limit, plastic index and optimal moisture content and maximum density in the dry state

SAMPLE PREPARATION

3.2.4 EFFECT OF DOSAGE ON THE STRENGTH OF STABILIZED CLAY

To determine the effect of lime content / lime capacity on the resistance of lime stabilized clay, clay was mixed with 2%, 4% and 6% lime in the dry state. These properties were chosen on the basis of ICL, because the optimal lime content should be close to the ICL so that the clay does not fire too much. A small amount of water was added to obtain the optimum moisture content for the mixture.

This was determined from

$$V = \frac{Q(P + C)}{100} - (M - P)$$

where

V = volume of water (ml)
Q = optimum moisture content
P = mass of material (oven-dry) to be used (g)
C = mass of stabilizer to be added (g)
M = mass of material (air-dry) (g)

Immediately (after 0 hours) the samples were compressed (BS Heavy) and their CBR was tested after hardening for 4 days. Effect of the mixing method on the resistance of the stabilized clay. To find the effect of the mixing method on the strength properties of the clay, stabilized with compressed lime, the clay was mixed separately with the required percentage of lime in the dry state and in the form of a suspension. In both cases, a predetermined amount of water was added to the mixture to obtain the water content of the mixture that was equal to the optimum moisture content of the mixture. Immediately (after zero hours) the CBR of the lime-stabilized clay was determined for dry and suspended lime.

3.2.5 EFFECT OF DELAY IN COMPACTION ON STRENGTH OF STABILIZED CLAY

The impact of this compaction on the agricultural stabilization resistance properties of chocolates and the evidence and evidence, as well as the agrarian with the percentage of requirement in the dry. Their amount is predetermined in time and in the long term in the interest of a job and a balance between humidity and optimum humidity. This wet mixture was then suspended for 0 hours (no delay), 2 heirs, 4 hours and 6 hours. During the delay time, the value of evaporation is determined by means of evidence. Read the preparation and testing OKs.

3.2.6 EFFECT OF CURING TEMPERATURE ON STRENGTH OF STABILIZED CLAY

To determine the effect of a continuous temperature change on the resistance of compacted calcified clay, the clay was mixed with the required percentage of lime in the dry state. A predetermined amount of water was added to the mixture to obtain a water content of the mixture corresponding to the optimum moisture content of the mixture. This mixture was then covered with polyethylene bags and immersed in water baths maintained at temperatures of 25 ° C, 30 ° C, 35 ° C and 40 ° C for 4 days. Provision has been made to avoid leakage of water in the mixed sample. For each temperature, the sample was prepared and tested for CBR.

3.3 LABORATORY TESTS

Laboratory tests were performed on clay samples to investigate their physical properties and determined whether the clay was sufficient to stabilize lime. Soil testing was performed in accordance with BS 1377. The following soil tests were performed on non-stabilized and stabilized clay samples. Using a 4.5 kg mortar coating (modified Proctor), heavy compaction was applied to increase the compressibility of the lime and soil mixture. The test was performed at the INU Soil Laboratory.

Table 3.1: Summary of laboratory tests and standards

No.	TESTS	MATERIAL TO BE TESTED	REFERENCE	GOAL
1	Atterberg limits; LL, PL, PI	Clay sample	BS 1377- 2: 1990	For classification of clay
2	CBR test	Lime stabilized clay	BS 1377-4: 1990	To determine the strength of lime stabilized clay
3	Compaction test	Clay sample	BS 1377-4: 1990	To determine OMC and MDD
4	Compaction test- lime Stabilized clay	Lime stabilized clay	BS 1924- 2: 1990	To determine the change in physical properties of lime stabilized clay

DATA ANALYSIS

The laboratory results obtained from the respective tests were analyzed with graphs and charts using Microsoft Excel software and Minitabs.

RELIABILITY OF MEASUREMENTS

Repeated analyses of CBR with dry and wet mixing on the same sample where checked to give relatively similar results and the random variation was found to be small.

Statistical measurements of accuracy and precision where used to reveal the reliability of the data from the CBR tests with variations in temperature, delay in compaction and lime content.

4 RESULTS AND DISCUSSION

4.1 NATURAL CLAY SOIL

The average water content in natural clay soils was 21.7%, with a high water content, indicating that clay soils have a high absorbency. It also provides information on volumetric stability issues related to clay absorption and water loss.

Properties	**Value**
Natural moisture content (%)	21.7
Liquid Limit (%)	50.4
Plastic Limit (%)	13.4
Plastic Index (%)	37.0
MDD (Mg/m^3)	1.635
OMC (%)	17.5
IS Classification	CH (High Plasticity Clay)
CBR (%)	2

4.2 ATTERBERG LIMIT TESTS

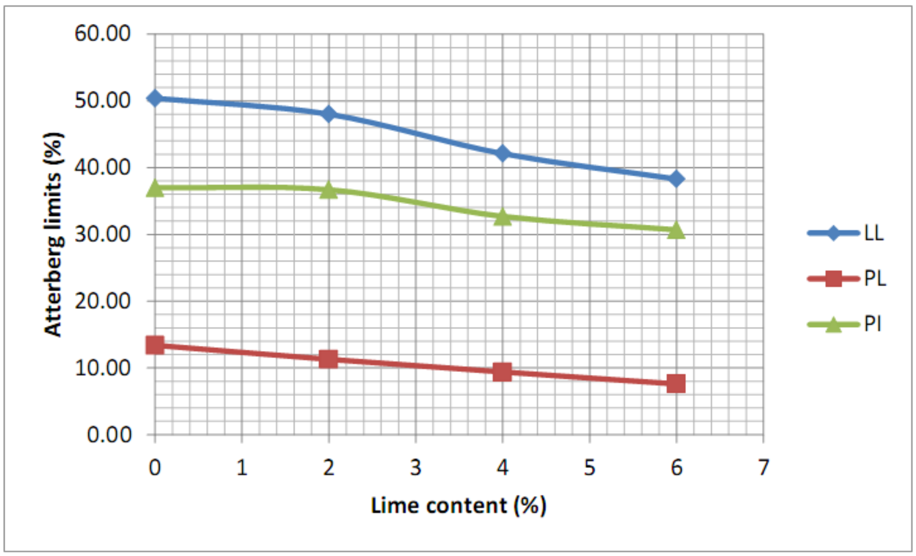

Figure 1 Atterberg limits against lime content

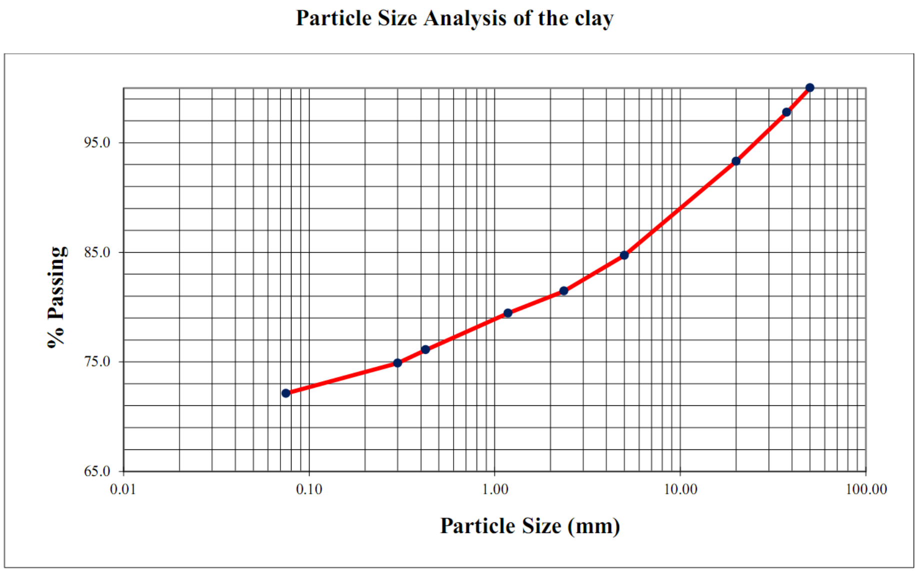

Figure 2 Gradation Curve (Natural clay)

CLASSIFICATION OF THE SOIL

Soil contains 78.5% fines. LL= 50.4 and PI= 37, plotting just above in the CH zone on the plasticity chart (Appendix). Thus the soil is classified as CH, that is, Clay of High Plasticity.

4.3 LIME TESTS

4.3.1 SUITABILITY OF LIME BS 1924: PART 2: 1990

The pH and temperature of the suspension were noted as 12.34 and 26°C respectively. The pH corrected to 25°C was calculated as 12.37. Hence the lime was suitable for stabilization based on

BS 1924: Part 2: 1990 which says that the pH corrected to 25°C must be between 12.35 and 12.4.

4.3.2 INITIAL CONSUMPTION OF LIME BS 1924: PART 2: 1990

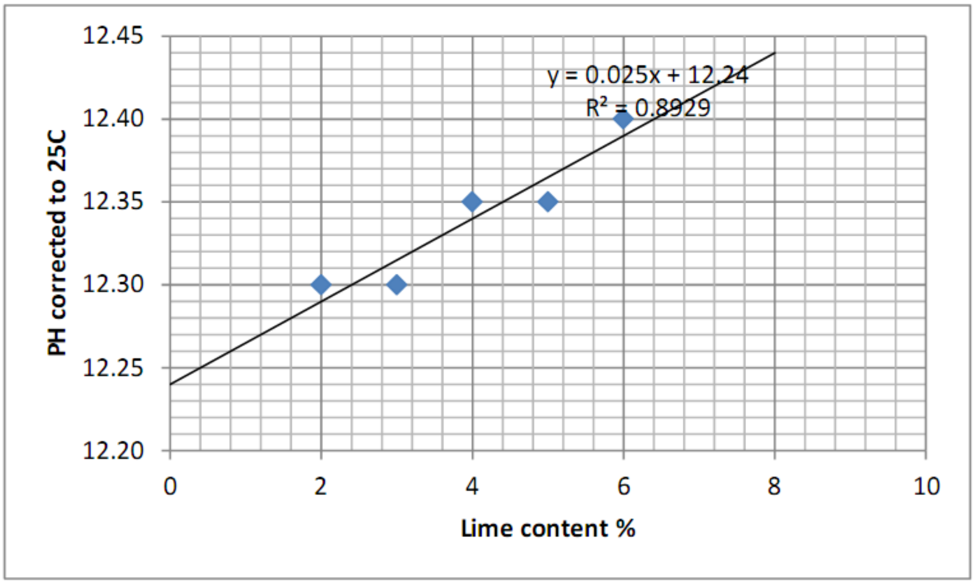

FIGURE 3 PH AGAINST LIME CONTENT ICL = 4.2%

4.4 COMPACTION TEST

Compression test results for natural clay and calcified clay showed maximum dry density (MDD) and optimal moisture content (see Figure 5). It was observed that the maximum dry density with the addition of a 4% lime content increased from 1635 to 1.6 mg / m3. The optimal water content increased from 17.5 to 18.5%. This is due to the drying effect caused by the heat generated during the hydration reaction.

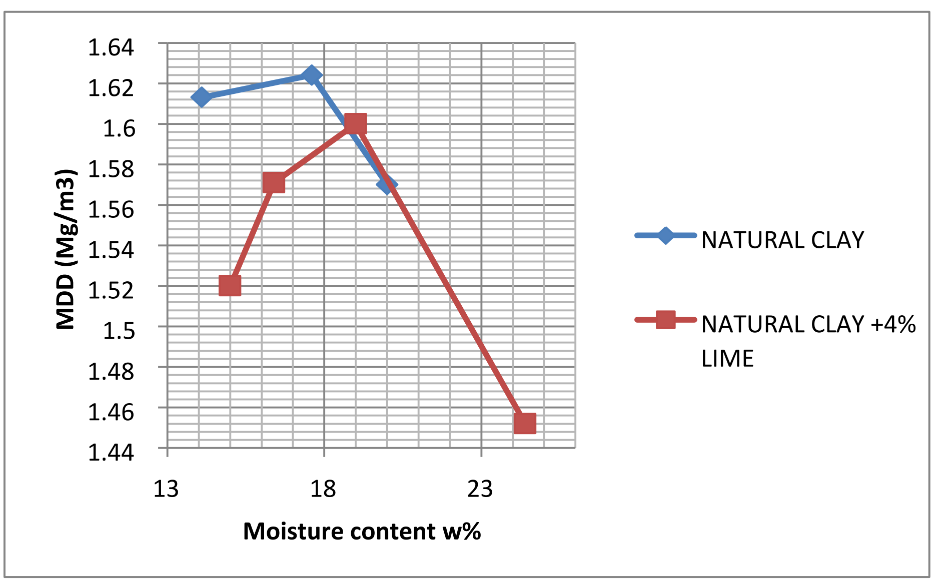

FIGURE 4 COMPACTION TEST RESULTS

4.5 CALIFORNIA BEARING RATIO (CBR) TESTS

The derivative CBR is intended for use in the formulation of Table 3 for 2%. This value is the minimum value in the general MOWHC specs (2005) for roads and bridges for bedding material given is. Therefore, clay was in a natural state

4.5.1 EFFECT OF DOSAGE/ LIME CONTENT

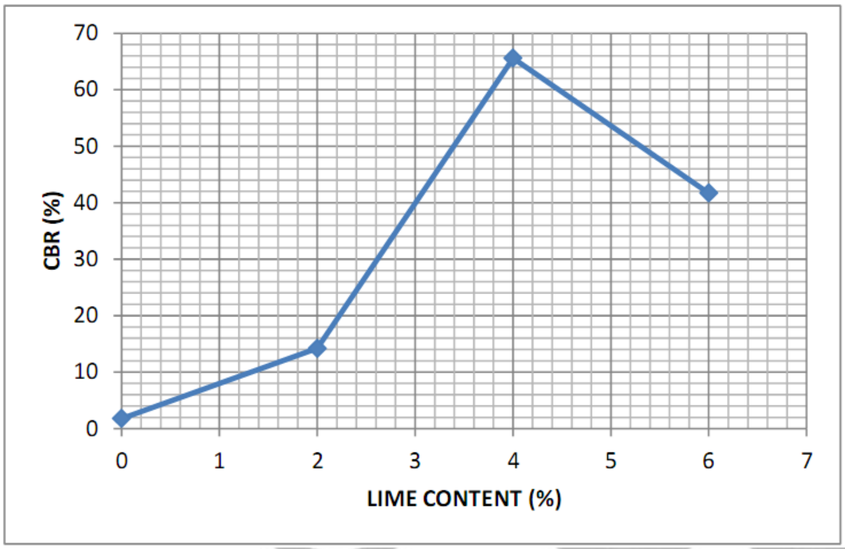

FIGURE 5 CBR VALUES WITH LIME CONTENT

It was observed that the resistance increased to 4% with increasing lime content, while the reduction in CBR was observed to be 4%, as shown in Figure 5. The reduction of CBR by 6% was attributed to the excess lime in the mixture, which was not required for the early increase in resistance due to flocculation. Therefore, it was concluded that the lime content of 4% is better for stabilizing the clay. It should be noted, however, that the long-term performance of the clay-soil-lime mixture has not been investigated. Excess lime is believed to be involved in the pozzolanic reaction, which in the long term can further enhance the strength of calcified clay.

4.5.2 EFFECT OF MIXING METHOD

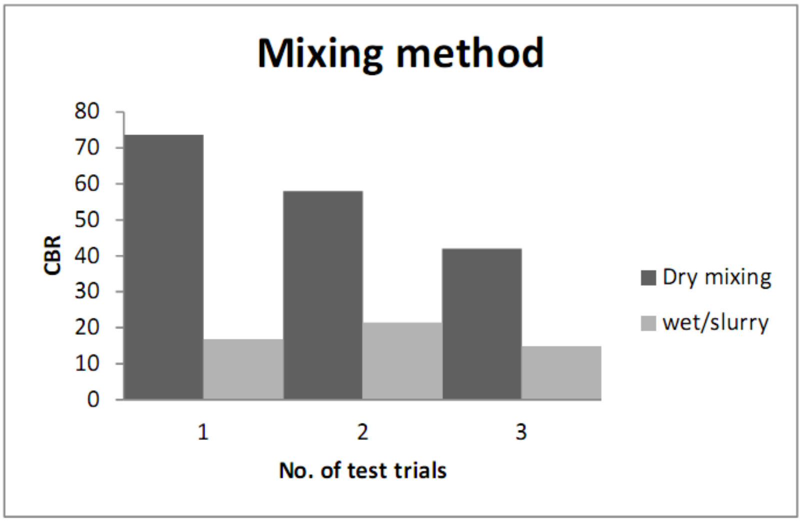

FIGURE 6 CBR RESULTS FOR MIXING METHOD

The laboratory results in Figures 6 show that dry mix yielded higher CBR values for all three experiments than slurry mix. This is due to the interaction between lime and smoke which is affected by the available surface and the sufficient powder. Wet mixing increases the Ca + current to the clay molecule surface and reduces the interaction surface due to flocculation. Flocculation takes place on the clay surface, changes the structure of the clay and prevents interaction with lime. Dry mixing between the clay and lime molecules has a greater range of interaction and therefore greater strength than when the mixture is suspended. Therefore, the dry mixture was used for all CBR tests of lime and clay.

4.5.3 EFFECT OF DELAY COMPACTION

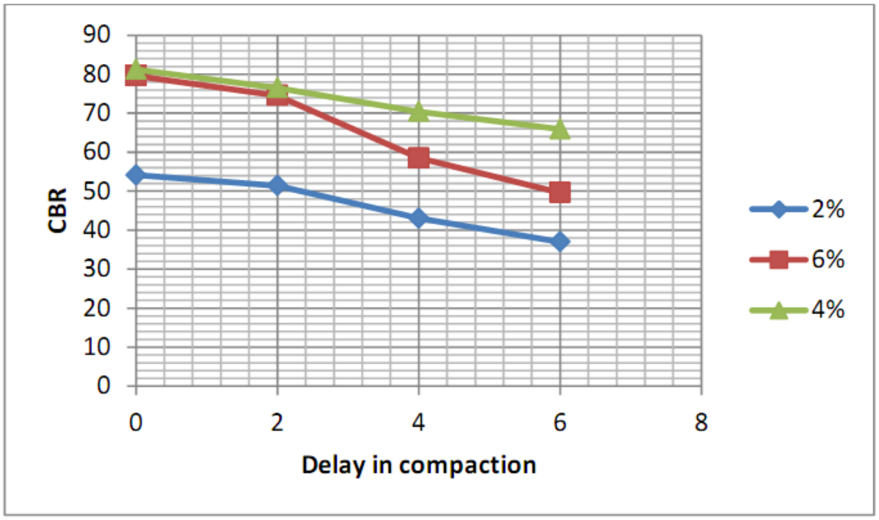

FIGURE 7 CBR VALUES FOR DELAY IN COMPACTION WITH VARYING LIME CONTENT

The period considered was chosen to repeat the practical situation. As shown in FIGS. 7, the delay between the mixing of the clay and limestone with water and the compression of the wet mixture resulted in a decrease in the CBR at different lime levels with a fixed compaction cost. This has been attributed to the modification of the structure of the disperse clay into a flocculated structure, which offers greater resistance to compact energy and, consequently, a reduction in CBR. The CBR value decreases as the delay time increases. Compression delay affects CBR values for all lime addition percentage.

GSJ: Volume 7, Issue 9, September 2019
ISSN 2320-9186

4.5.4 EFFECT OF TEMPERATURE

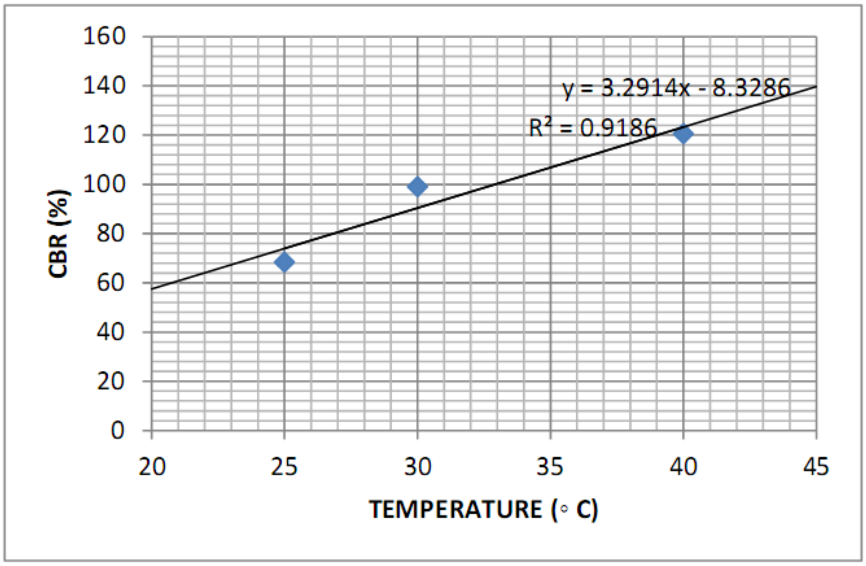

FIGURE 8 CBR VALUES WITH CURING TEMPERATURE

As can be seen in the laboratory results in Figure 8, it was observed that the increase in cure temperatures increased the CBR value. Therefore, the temperature affected the durability of calcified clay stabilized with lime. In fact, pozzolans react chemically with hydrated lime (calcium hydroxide) at room temperature to form compounds with cementitious properties (ASTM 595).

Table 4.2 CBR TEST MATRIX

Mixing method	Lime Content (%)	Delay in compaction (hrs.)	Curing Temp. /^oC	Strength (CBR)	No. of tests
Dry	0	0	25	1.8	4
	2			14.2	
	4			65.6	
	6			41.7	
	4	0	25	73.6	3
				58	
				42	
	4	0	25	68.5	4
			30	98.9	
			35	102.5	
			40	120.5	
	2	0	25	54.1	4
		2		51.4	
		4		43.03	
		6		36.97	
	4	0	25	79.6	4
		2		74.5	
		4		58.5	
		6		49.6	
	6	0	25	81.2	4
		2		76.5	
		4		70.4	
		6		65.9	
Wet/Slurry	4	0	25	16.8	3
				21.5	
				14.9	
Total no. of Tests					26

4.6 REGRESSION ANALYSIS

All the parameters i.e. lime content, delay in compaction and curing temperature were explanatory variables in the analysis. Mixing method (wet/ dry) was considered as a string variable because only dry mixing was found to give significant values with the variables.

Descriptive Statistics

	Mean	Std. Deviation	N
CBR	57.00769	29.025754	26
L.C	3.85	1.488	26
D.I.C	1.38	2.174	26
C.T	26.154	3.5518	26

The table of descriptive statistics above indicates that for a sample size of 26 (N=26 for each field factor) the mean of the CBR Values was 58.485 having a standard deviation of 28.4829. The mean of the Delay in Compaction (DIC) was 1.8hrs with a standard deviation of 2.331hrs while the mean of the Lime content (L.C) and curing temperature (C.T) were 3.8% and 26^{o}C having standard deviations of 1.7% and 3.479^{o}C respectively.

4.6.1 CORRELATION AND MEASURE OF RELATIONSHIPS BETWEEN FIELD FACTORS

Correlations

		CBR	L.C	D.I.C	C.T
Pearson Correlation	CBR	1.000	.456	-.028	.627
	L.C	.456	1.000	.068	.035
	D.I.C	-.028	.068	1.000	-.215
	C.T	.627	.035	-.215	1.000
Sig. (1-tailed)	CBR	.	.010	.445	.000
	L.C	.010	.	.370	.433
	D.I.C	.445	.370	.	.146
	C.T	.000	.433	.146	.
N	CBR	26	26	26	26
	L.C	26	26	26	26
	D.I.C	26	26	26	26
	C.T	26	26	26	26

As shown in correlation table above, there is a negative relationship between delay in compaction and CBR (r= -0.028) with a statistical significance of 0.744 at p< 1 level. The coefficient of determination (r^2)

is low because of the large variations in delays of 2hrs which in turn cause variations in CBR values. Smaller variations in compaction delays would increase the correlation and the coefficient of determination (r^2) of the CBR values. Lime content gives a relatively strong positive relationship with the CBR (r=+0.456) with a statistical significance of 0.010 at p<0.05 level whereas curing temperature gives a strong positive relationship with the CBR (r=+0.627) with a statistical significance of 0.000 at p<0.01.

4.6.2 REGRESSION MODEL

Table 4.3 Summary of the regression model

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.767[a]	.588	.532	19.857567	.588	10.471	3	22	.000

a. Predictors: (Constant), C.T, L.C, D.I.C

b. Dependent Variable: CBR

Table 4.3 above presents the summary of the Regression Model with curing temperature, lime content and delay in compaction as the predictors and CBR as the dependent variable.

Table 4.4 Analysis of variance (ANOVA)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12387.255	3	4129.085	10.471	.000[b]
	Residual	8675.106	22	394.323		
	Total	21062.360	25			

a. Dependent Variable: CBR

b. Predictors: (Constant), C.T, L.C, D.I.C

Table 4.4 above shows that the regression model can describe a significant proportion of variance (r= +0.795) and statistical significance of 0.01. Hence the model is statistically significant at p<0.1 level.

GSJ: Volume 7, Issue 9, September 2019
ISSN 2320-9186

Table 4.5 Regression coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-111.039	32.023		-3.468	.002		
	L.C	8.367	2.678	.429	3.124	.005	.993	1.007
	D.I.C	1.035	1.876	.077	.551	.587	.948	1.055
	C.T	5.140	1.146	.629	4.483	.000	.951	1.051

a. Dependent Variable: CBR

Table 4.5 above shows the coefficient for the regression model (line). The constant in the column labeled B gives the Intercept where the lime content, delay in compaction and curing temperature are zero. The next rows under column B provide the gradients of the regression line which implies that for every 1% increase in lime content, 1hr increase in compaction delay and 1^{o}C increase in the temperature, the model predicts CBR values; 8.367, 1.035 and 5.14. The Regression Model therefore takes the form:

$$\boldsymbol{Y = -111.039 + 8.367A + 1.035B + 5.14C}$$

Where Y= CBR, A= Lime Content (%), B= Delay in compaction (hr.), C= Temperature

Standard model deviation is 0.15% Correlation coefficient is 0.767

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	17.46528	128.03389	57.00769	22.259609	26
Std. Predicted Value	-1.776	3.191	.000	1.000	26
Standard Error of Predicted Value	4.211	15.987	7.303	2.760	26
Adjusted Predicted Value	24.79602	141.91211	57.94496	23.834486	26
Residual	-36.031387	28.668612	.000000	18.628049	26
Std. Residual	-1.814	1.444	.000	.938	26
Stud. Residual	-1.876	1.493	-.019	.991	26
Deleted Residual	-38.528614	30.655544	-.937265	20.998414	26
Stud. Deleted Residual	-2.000	1.539	-.028	1.016	26
Mahal. Distance	.163	15.242	2.885	3.271	26
Cook's Distance	.000	.188	.033	.042	26
Centered Leverage Value	.007	.610	.115	.131	26

a. Dependent Variable: CBR

4.6.2.1 MODEL VALIDATION

The formulated model for predicting CBR was validated by comparing measured and predicted CBR values. Table 4.9 summarizes the nature of the residuals (errors in prediction) and the values predicted in the regression model. The model has a correlation coefficient (r) of 0.767 and a coefficient of determination (r^2) of 0.632.The higher the correlation, the smaller the residuals and the more accurate the predictions are likely to be. For the sample size of 20 the model predicts the minimum and maximum CBR values as 20.5301 and 127.0756 with an error in prediction of 0.01. Hence the model predicts CBR values with adequate accuracy.

However we recommend that he model be validated with independent set of data other than the data used in the development of it.

5 CONCLUSIONS AND RECCOMMENDATIONS

5.1 CONCLUSIONS

As discussed in chapter one the specific objectives of this study were;

To determine the physical characteristics of clay and the suitability of lime for stabilization

To determine the effects of dosage, delay in compaction, temperature and mixing methods on CBR of lime stabilized clay soils.

To establish statistical relationships between lime dosages, delay in compaction, temperature and mixing methods with the strength of lime stabilized clay.

CLASSIFICATION OF THE SOIL AND LIME SUITABILITY

The soil was classified as CH i.e. clay of high plasticity with poor strength and high water absorption capability thus suitable for lime stabilization.

The lime was suitable for stabilization based on BS 1924: Part 2: 1990 which says that the pH corrected to 25^{o}C must be between 12.35 and 12.4.

EFFECT OF DOSAGE ON CBR

The properties of the clay could be improved by adding lime. The CBR increased with increasing lime content up to 4% with a reduction after 4%. The reduction in the CBR after 4% was attributed to the excess lime in the mixture not required for the early strength gain. The best suitable lime content for stabilization of the clay was found to be 4% lime content.

EFFECT OF DELAY IN COMPACTION ON CBR

Compaction delay affected the CBR for all the percentages of lime addition. The CBR value reduced with increase in time delay. The rate of reduction in CBR value decreased as the lime content increases.

EFFECT OF MIXING METHODS ON CBR

Laboratory results indicated higher CBR values for dry mixing of lime and clay than for slurry (wet) mixing for all the trials. Hence dry mixing was used for all CBR tests of lime and clay.

EFFECT OF TEMPERATURE ON CBR

Increase in the curing temperatures increased the CBR.

STATISTICAL RELATIONSHIPS BETWEEN FIELD FACTORS AND THE CBR

Temperature had the highest correlation coefficient (0.627) hence it was the strongest factor affecting the CBR

A regression model for predicting the maximum and minimum CBR's depending on the lime content, delay in compaction and temperature was formulated. Based on the correlation coefficient, standard model deviation and residuals the model can be utilized with the adequate accuracy for predicting maximal and minimal CBR value.

5.2 RECOMMENDATIONS

Smaller variations of temperature should be considered when carrying out the tests for better accuracy of the regression model. Temperature is the strongest factor affecting CBR. This will increase the correlation and the coefficient of determination (r^2) of the CBR values.

We recommend that further research be carried out on the effect of carbonation and sulphur attack on the lime stabilized clays and also; research study on the effect of cold temperatures on the strength of lime stabilized clay.

We recommend extensive research in long term performance of the clay soil-lime because of the pozzolanic reaction that may further improve the strength of the lime-stabilized clay.

6 REFERENCES

Benedetto, A. (2010). *Externalities of Soil Stabilization in the Construction of Main Transportation Infrastructures. The Case of the High Speed Railway in North Italy: Economic and Environmental Benefits*. The Open Environmental Engineering Journal 3(1)

CML, (2000) Laboratory Testing Manual, The Republic Of Tanzania

Dallas, N. L., Eric H. M., Jan, R., Prusinski, B. S. (2002) Cementitious Stabilization, TRL

DFID-TRL, Literature Review Stabilised Sub-Bases for Heavily Trafficked Roads, Project Report Origin PR/INT/202/00

EuroSoilStab. (2002*). Development of Design and Construction Methods to Stabilize Soft Organic Soils: Design Guide for soft soil stabilization.* CT97-0351, European Commission, Industrial and Materials Technologies Programme (Rite-EuRam III) Bryssel.

Hicks, R. (2002). *Alaska Soil Stabilization Design Guide*

Makusa, G.P (2012) Soil Stabilization Methods and Materials; *State Of The Art Review*

Matić, B., Matić, D., Ćosić, Đ., Sremac, S., Tepić, G., Ranitović, P. (2013) *A Model for the Pavement Temperature Prediction at Specified Depth*

MoWT (2010) Road Design Manual, *Volume 3: Pavement Design Part 1: Flexible Pavements*

Negi Ankit Singh, Faizan Mohammed, Siddharth Devashish Pandey, Singh Rehanjot, (2013) *Soil Stabilization Using Lime* International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 2

NLA, (2004) Lime-Treated Soil Construction Manual

Prusinki, J.R. and Bhattacharja, S. (1999) Effectiveness of Portland Cement and Lime in Stabilizing Clay Soils

Sherwood, P. (1993). *Soil stabilization with cement and lime. State of the Art Review.* London: Transport Research Laboratory, HMSO.

Sweeney, D.A., Wong, D.K.H. and Fredlund, D.G. (1988) TRL 1190; *Effect of Lime on Highly Plastic Clay with Special Emphasis on Aging*

Vincy, S.S., Muttharam, M. (2009) Delayed Compaction Effects on The Behaviour Of Stabilized Soils