Evaluation of Clay Soil Stabilization with Cement Waste Through CBR Testing

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ABSTRACT

This research focused on the potential utilization of cement waste (CW) as a stabilizer to improve the compressive strength of clay soil. .A series of laboratory compaction and CBR tests were carried out. Soil specimens were compacted at maximum dry density with different percentages of cement waste 3%, 6%, 9%, 12% and 15% of weight of clay soil). Results indicate that an increasing of cement waste content decreases the maximum dry density and the optimum moisture content (OMC). Soil became non plastic when the addition of cement waste content was equal to or greater than 9% of weight of clay soil. An increasing of cement waste content increased the CBR values of clay soil and the highest value was 8.3 times the CBR of non treated soil and it was achieved at 9% of cement waste.

KEYWORDS: Clay soil, Cement kiln dust, stabilization, compaction and CBR

I. INTRODUCTION

A number of researchers have proposed alternative approaches to solve environmental problems due to the progressive rate of waste generation. Some acceptable waste disposal projects are outweighed by the disadvantages of the rising price of land, high operation costs and more stringent regulations

Heeralal and Praveen (2011) [1], had shown that the inclusion of fiber reinforcement within soil and cement kiln dust (CKD) soil mix caused an increase in the unconfined compressive strength (UCS), shear strength and axial strain at failure. They stated that increasing fiber content could increase the peak axial stress, decreases the stiffness and the loss of post-peak strength and weaken the brittle behavior of cemented soil. The increase in strength of combined fiber and CKD inclusions was much more than the sum of the increase caused by them individually. It could be concluded from their study that the combination of discrete fiber and CKD has the virtues of both fiber-reinforced soil and cements stabilized soil. Therefore the addition of fiber– CKD to soil can be considered as an efficient method for ground improvement.

Supakij and Naphol (2012),[2] focused in their research on the potential utilization of waste-based cement (WBC) as a stabilizer to improve the compressive strength of soft clay and also aimed to verify the hardening effects of WBC compared to ordinary Portland cement (OPC). The potential utilization of various types of industrial wastes as raw materials to produce WBC was studied based on newly developed concepts and techniques. As a stabilizer for soft clayey soil, the WBC had hydraulic properties to improve the strength of soft clay comparable to OPC. The newly developed cement provided hydration and subsequent reaction products such as calcium silicate hydrate and calcium aluminate hydrate, which contributed to the strength development of the stabilized soil.

Rahman et al (2011) [3] concluded that CKD is potentially useful in stabilizing a variety of soils (e.g. sandy and clayey). However, the stabilizing effect is primarily a function of the chemical composition, fineness, and addition level of the CKD as well as the type of parent soil. They stated that the following general conclusions can be made from the literature research and the experimental investigation carried out in their study: 1.CKD with high free lime and low alkalis resulted in compact soils of improved compressive strengths. Free lime is potentially reactive and quickly hydrates to promote the stabilization reactions. 2. CKDs with low free lime and high alkali adversely affect the unconfined compressive strength. Higher alkalis in CKD could counter the stabilization reactions because of the ionic interference, particularly with clayey soils. 3. CKDs with low loss on ignition (LOI) and moderate alkalis reduced the plasticity index (PI) and improved the unconfined compressive strength of clay soils. In some cases, the shrinkage limits increased to higher values than their respective optimum moisture contents.

Tarun R. Naik et al (2003) [4] stated that addition of CKD to soil can substantially improve the unconfined compressive strength, relative to untreated soil, CKD provides some protection from the adverse effects of saturation on strength, Addition of CKD rapidly increases unconfined compressive strength for 7-14 days after compaction, and thereafter more slowly, Then CKD-treated soil exhibits brittle behavior during unconfined compression. Significant increases in modulus and decreases in the strain at failure occur with the addition of CKD and The optimum moisture content and maximum dry unit weight, increase and decrease, respectively, with increasing amounts of CKD

Keerthi et al (2012) [5] concluded that CKD has been used as a soil additive to improve the texture, increase strength and reduce swell characteristics. Treatment with CKD was found to be an effective option for improvement of soil properties. Strength and stiffness were improved and plasticity and swell potential were substantially reduced, The percentage of cement added for clay soils was determined by the amount of cement needed to lower the PI below 10. For light applications, they expected that 12-30% CKD should be sufficient to upgrade dune sand;

however, forheavily loaded applications, it was expected to raise the CKD content to about 50%.Specimens of CKD revealed high compressive strength but failed the freeze-thaw durability requirement

Yooban pot *et al.* (2010) [6] and Nontananandh *et al.* (2011) [7] reported on attempts to produce clinker and cementing material using the combination of certain types of industrial wastes. The waste-based cement contained the essential Bougue's compounds such as C3S, C2S, C3A and C4AF and had a hardening effect similar to that of OPC. The results of analysis also revealed that the cement produced from wastes was an environmentally friendly product having a heavy metals content that conformed to the US Environmental Protection Authority's standard. However they stated that the quality of the so-called WBC, such as its hydraulic properties and enhancement on hydration, still need to be improved. Its potential utilization as a construction material in place of OPC also needs to be established.

II. OJECTIVE OF RESEARCH:

The main objective of this study is to investigate the strength development of stabilized soil using cement waste

The specific objectives are:

1. To determine the most effective waste – based stabilizers and dosage rates of stabilizers to increase the California bearing ratio clay soils.
2. To investigate the effect of addition of cement waste on clay soil properties such as liquid limit, plastic limit, optimum moisture content and maximum dry density

III. EXPERIMENTAL STUDY:

In order to achieve the stated objectives, this study was carried out in stages. In the initial stage, all the material and equipment's needed were be gathered and tested as follows:

a. Soil:

The soil that had been used in this research was collected from Alneil Street (National Club Project) located Khartoum, a state of Khartoum in fig (1). The soil passed through sieve No 4 and then was air-dried; quartering method was used to prepare the soil (see fig1 and fig 2). The properties of soil were determined by standard test procedures funished in table (1).

Fig 1: clay soil (National Club Project)

Fig 2: Qutering method

Table 1

Properties of Clay Soil

Properties	Standards	Value	Unit
Clay	-	58	%
Silt	-	22	
Sand	-	20	%
Liquid Limit	-ASTM: D4318-00	36.9	%
Plastic Limit	ASTM: D4318-00	27.85	%
Plasticity Index	ASTM: D4318-00	9.41	%
Shrinkage Limit -	ASTM: D4318-00	10	%
Specific gravity, Gs	ASTM: D854-02	2.43	-
Max. Dry Density	ASTM: D698	1.67	g/cm^3
Optimum Moisture Content	ASTM: D698	18	%
California Bearing Capacity	ASTM: D1883	2.9	%
Soil Classification (USCS)	ASTM: D2487-00	CL-ML	-

b. Cement waste:

In Sudan there are (7) factories for production of cement, All of these factories produce cement kiln dust (CKD). The CKD used in this research was collected from Atbara Cement Company. The chemical composition of the CKD is given in table 2. The properties of CKD are shown in table 3

Table (2) Chemical Composition of the cement kiln dust

S. No	Compound	Value %
1	SiO_2	17.84
2	Al_2O_3	4.57
3	Fe_2O_3	2.76
4	CaO	49.36
5	MgO	2.56
6	SO_3	9.65
7	K_2O	3.99
8	Na_2O	0.33
9	TiO_2	0.45
10	LOI	5.38

Table (3) Chemical of the cement kiln dust

Test	Test method	Value	unit
Specific gravity	ASTM: D 854	0.5	*mm*
Specific surface area	ASTM: C 204	25000	*Cm^2/g*
O.M.C	ASTM: D698	26	*%*
M.D.D	ASTM: D698	1.36	*g/cm^3*
Initial setting time	ASTM: C 403	10	*hr*

In the second stage the test program was as follows:
Various experiments were conduct to find the stabilization of clay soil using the wastes materials. The tests which were based on the ASTM procedure are listed below:

- Liquid Limit (ASTM D 4318 – 05)
- Plastic Limit (ASTM D 4318 – 10)
- Sieve Analysis (ASTM D 6913)
- Specific Gravity (ASTM D 6473)
- Standard Proctor Compaction Test (ASTM D 1557)
- California Bearing Capacity (ASTM D 1883)

Cement waste and soil mixes were prepared manually by hand mixing. Oven dried soil after passing through 4.75 mm sieve was taken and water added for clayey soil and mixed uniformly. Soil samples, with and without cement waste were tested to study the strength behavior of pure and treated clay soil.

IV. RESULTS OF EXPERIMENTAL TESTS:

The results of these laboratory tests were plotted, analyzed and interpreted. Fig (3) to fig (6) show the liquid and plastic limit results:

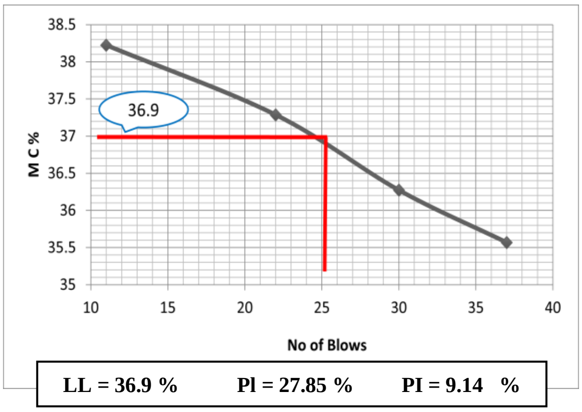

Fig (3)moisture content vs no of blows for clay soil

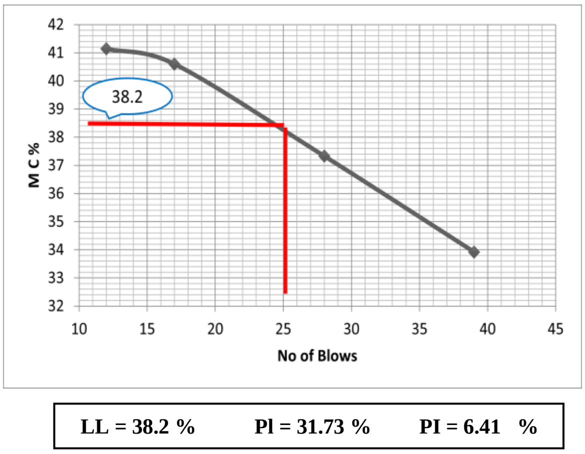

Fig (4)moisture content vs no of blows for clay soil + 3% cement waste

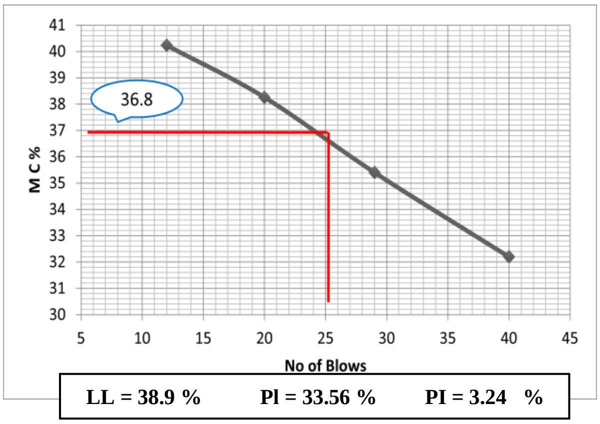

Fig (5)moisture content vs no of blows for clay soil +6% cement waste

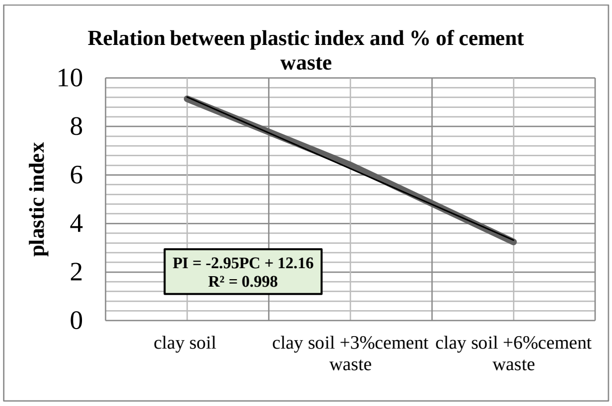

Fig (6)moisture content vs % cement waste

* Clay soil + (9 %, 12% and 15%) cement waste became non plastic soil

From fig (6) the prediction equation obtained by using Microsoft Excel (linear equation) for the relation between the plastic index and % of cement waste is:

$$PI = -2.95\,PC + 12.16 \qquad (1)$$

Where PI: plastic index. PC: percentages of cement waste

the results of compaction test are shown in figures(7) to (14)
From fig 14 the following equation was predicted by excel sheet to determine the maximum dry density in term of the percentage of cement waste

$$MDD = 1.385PC^{-0.03} \qquad (2)$$

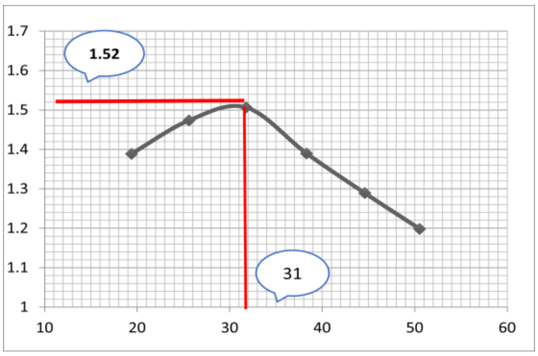

Fig 7Relation between DD and MC (Soil+3%CW)

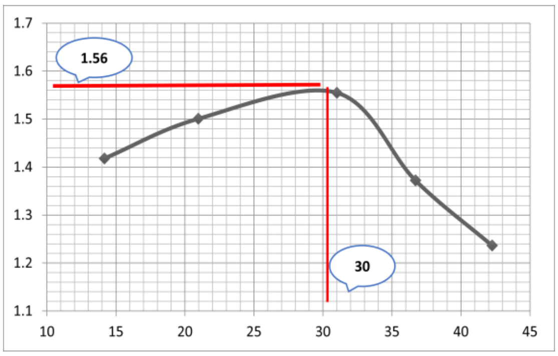

Fig 8 Relation between DD and MC (Soil+6%CW)

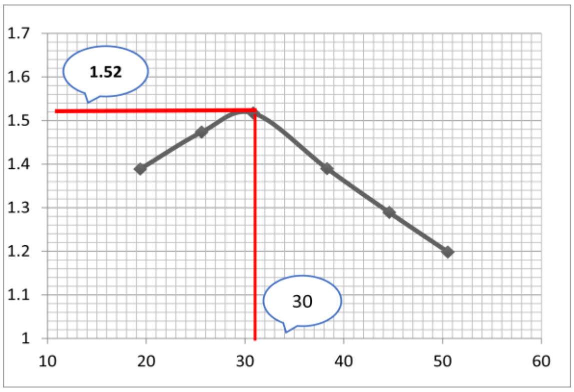

Fig 9Relation between DD and MC (Soil+9%CW)

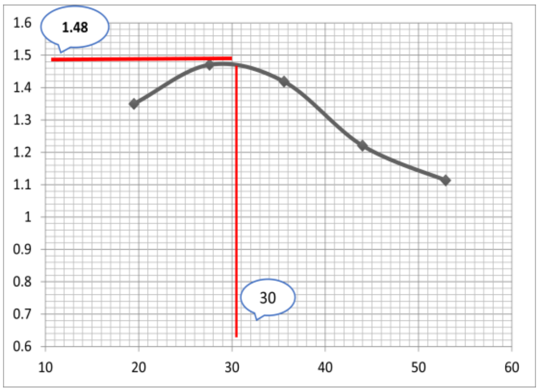

Fig 10 Relation between DD and MC (Soil+12%CW)

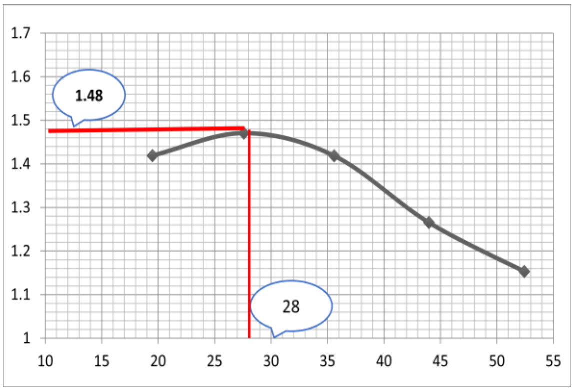

Fig 11 Relation between DD and MC (Soil+15%CW)

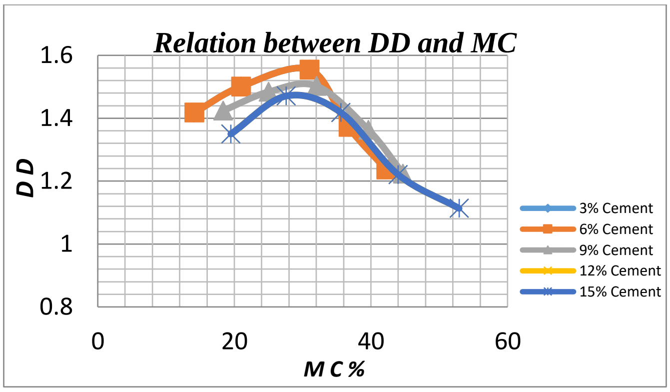

Fig 12 Relation between DD and MC for different % of cement waste

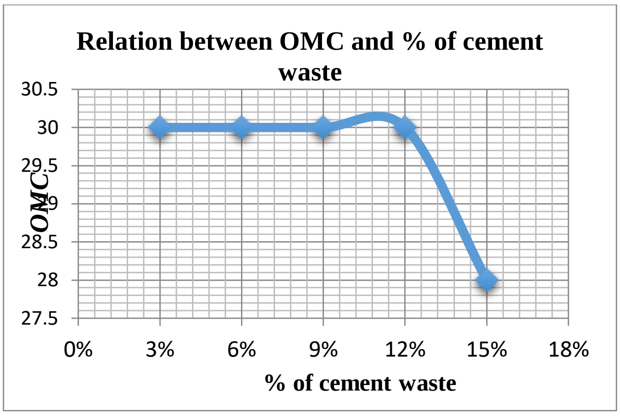

Fig 13 OMC vs % of cement waste

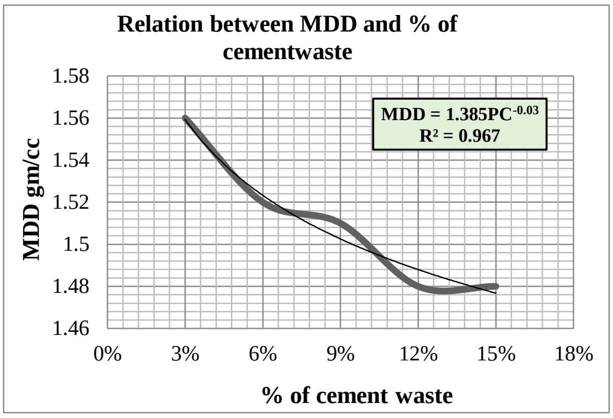

Fig 14 MDD vs % of cement waste

The results of CBR test are presented in figures (15) to (26).

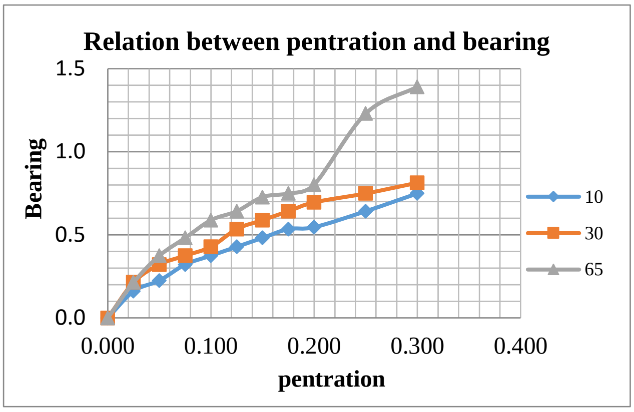

Fig 15 Relation between penetration and bearing (clay soil)

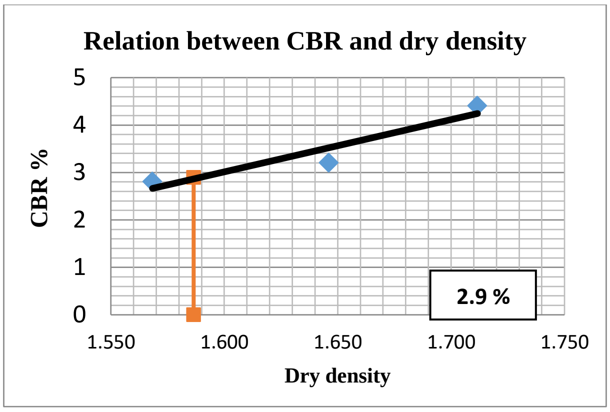

Fig 16 Relation between CBR and dry density (clay soil)

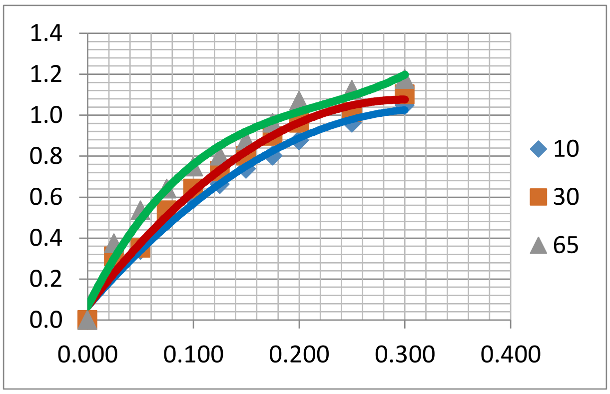

Fig 17 Relation between penetration and bearing (clay soil +3% CW)

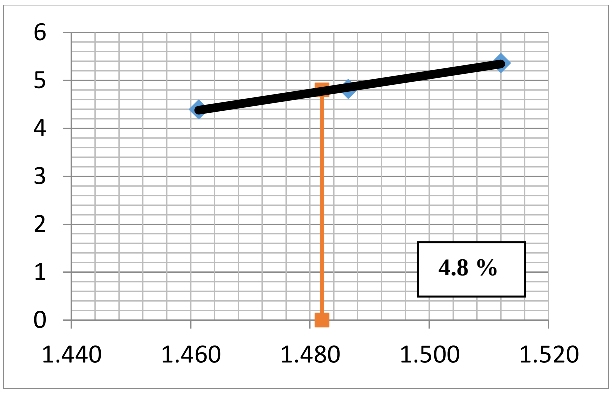

Fig 18 Relation between CBR and dry density (clay soil+3% CW)

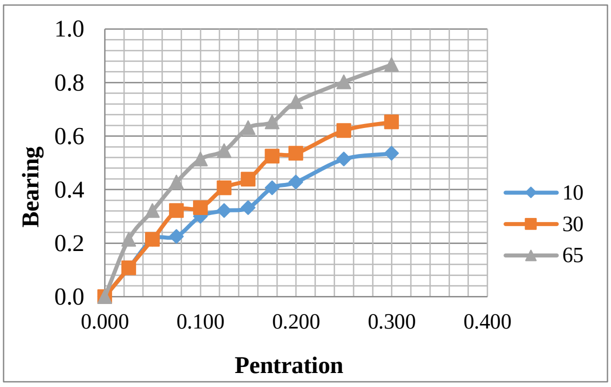

Fig 19 Relation between penetration and bearing (clay soil +6% CW)

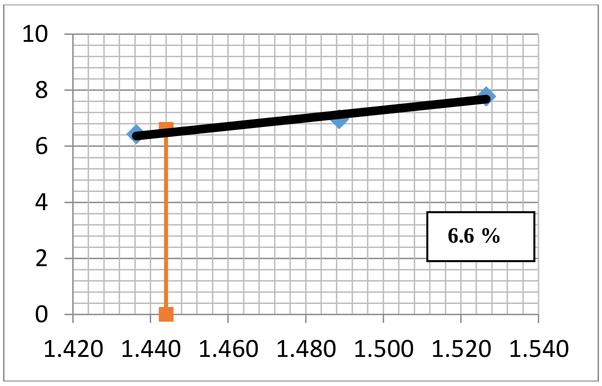

Fig 20 Relation between CBR and dry density (clay soil+6% CW)

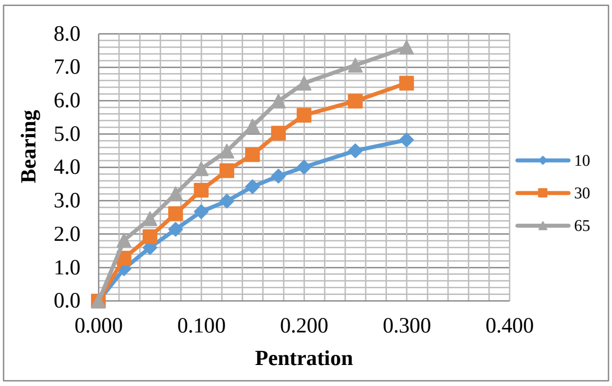

Fig 21 Relation between penetration and bearing (clay soil +9% CW)

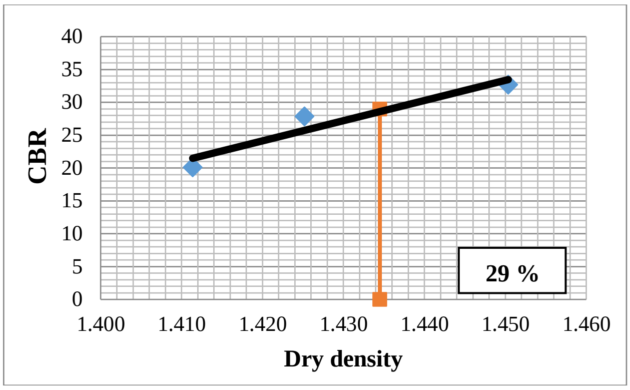

Fig 22Relation between CBR and dry density (clay soil+9% CW)

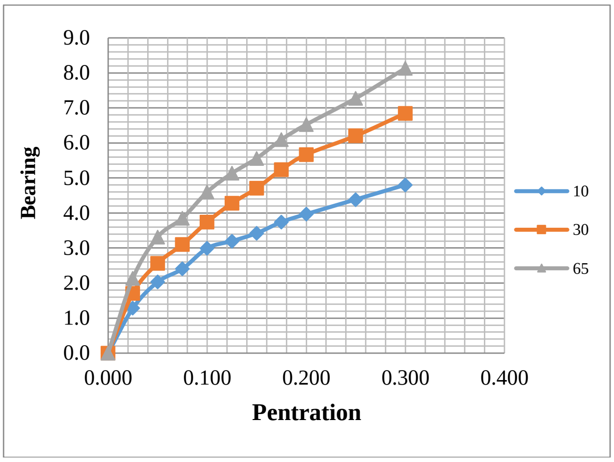

Fig 23 Relation between penetration and bearing (clay soil +12% CW)

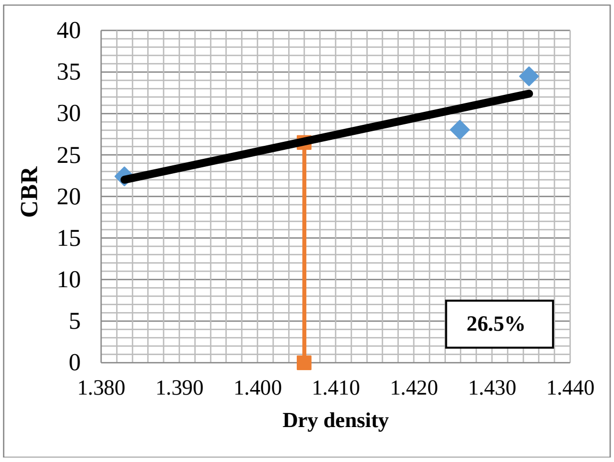

Fig 24Relation between CBR and dry density (clay soil+12% CW)

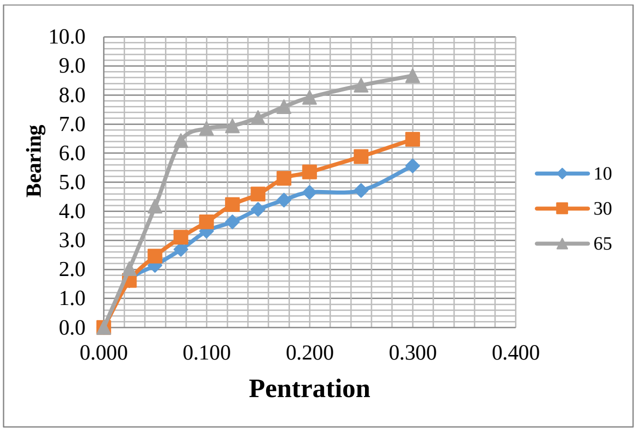

Fig 25 Relation between penetration and bearing (clay soil +15% CW)

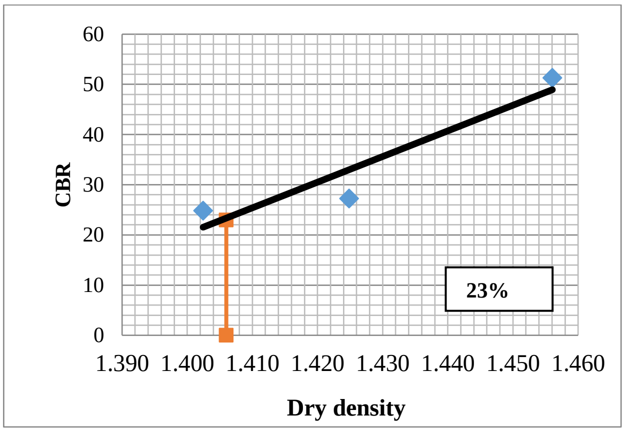

Fig 26Relation between CBR and dry density (clay soil+15% CW)

Table 4 shows the summary of the results of CBR test of soil treated by cement waste and fig 27 present variations of CBR values for various cement waste ratios. These indicate that the highest CBR was achieved when 9% of cement waste was added.

Table (4)Results of CBR test

% of cement waste	CBR %
00	2.9
3	4.8
6	6.6
9	29
12	26.5
15	23

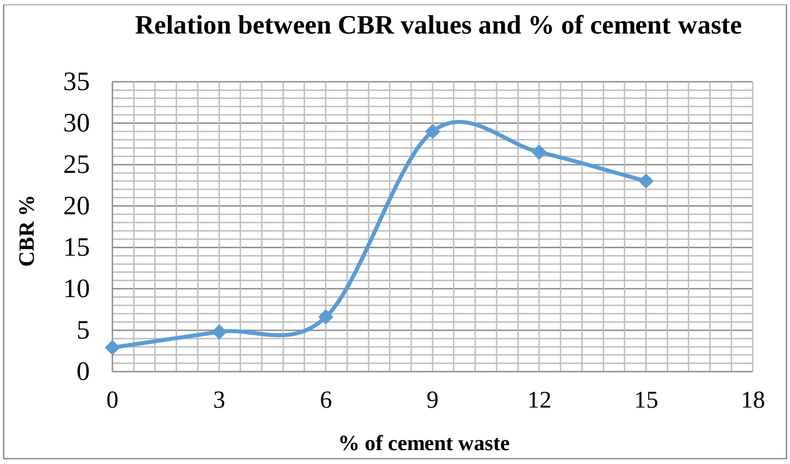

Fig27Relation between CBR values and % of cement waste

V. DISCUSSION OF RESULTS

The results obtained from the different tests are summarized and discussed as follows:

Liquid limit, Plastic limit and Plastic Index:

Fig (6) shows that an increasing of cement waste content increases the liquid and plastic limits and decreases the plastic index, After addition equal to or more than 9% of cement waste the clay soil became non plastic.

Standard Proctor Compaction Test Result

Fig (13)) indicate that an addition of 3% to 12% of cement waste content gave a constant value of OMC (OMC=30) which decreased with further increasing the cement waste content. Also an increasing of cement waste content decreased the maximum dry density

CBR Test Result

Fig (27) shows that an increasing of cement waste content increased the CBR up to a maximum value for 9% waste content. Addition of more than 9% decreased the CBR. The highest CBR value achieved is 8.3 times CBR of non treated soil

VI. CONCLUSION AND RECOMMENDATION

From the results of laboratory tests conducted to investigate the effect of using the various percentages of cement waste to improve the California bearing capacity of clay soil, the following conclusions are drown: Addition of cement waste increases the CBR up to a maximum value for 9% addition.When the percentage of addition of cement waste equal or greater than 9% soil becomes non plastic. The OMC decreases with an increasing of more than 12% of cement waste content. The dry density of the soil decreases with an increasing of cement waste content from 1.56 to 1.48 g/cm^3. `

As a result of this study it is recommended to use not more than 9% of cement waste as stabilizers to improve the California bearing capacity of clayey soil.

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