A LABORATORY STUDY ON THE STABILIZATION OF MARINE CLAY USING SAW DUST AND LIME

Koteswara Rao. D[1], M.Anusha[2], P.R.T. Pranav[3], G.Venkatesh[4]

[1]*Professor, Dept. of Civil Engineering, JNTU Kakinada, Andhra Pradesh, India,* ***dr.dkrjntuk@rediffmail.com***
[2]*Graduate Student, Dept. of Civil Engineering, JNTU Kakinada, Andhra Pradesh, India,* ***anushamusunuru@gmail.com***
[3]*Graduate Student, Dept. of Civil Engineering, JNTU Kakinada, Andhra Pradesh, India,* ***pranav1642@gmail.com***
[4]*Graduate Student, Dept. of Civil Engineering, JNTU Kakinada, Andhra Pradesh, India,* ***venkatesh.ganja@gmail.com***

Abstract

The technology of road construction is subjected to changes to cope up with changing vehicular pattern, construction materials and sub grade condition. Majority of the pavement failures could be attributed to the presence of poor sub grade conditions and expansive sub grade is one such problematic situation. Marine soils, because of the specific physico-chemical makeup are subjected to volume changes with changes in their ambient environment. The losses due to extensive damage to highways running over expansive sub grade are estimated to be in billions of dollars all over the world. In many countries like India, these soils are so aerially extensive that alteration of highways routes to avoid the materials is virtually impossible. Accumulation of various waste materials is now becoming a major concern to the environmentalists. Saw dust is one such by-product from Timber industries and Wood cutting factories. Saw dust by itself has little cementitious value but in the presence of moisture it reacts chemically and forms cementitious compounds and attributes to the improvement of strength and compressibility characteristics of soils. So in order to achieve both the need of improving the properties of marine clays and also to make use of the industrial wastes, the present experimental study has been taken up. In this paper the effect of Saw Dust and Lime on strength properties of marine clay has been studied.

Index Terms: *Marine Clay, OMC, CBR, Sawdust, Lime (CaO)*

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1. INTRODUCTION

Maintenance and replacement of pavement consumes a large portion of the budgets of transportation departments in every country. Methods for reducing the cost of constructing and maintaining pavements and lengthening pavement life can help transportation departments better maintain the road network on limited budgets. Modern pavements are expected to provide a high level of safety and comfort for their users. Pavements are commonly designed using a combination of mechanistic and empirical approaches. These methods involve selecting the appropriate soil and pavement parameters and then calculating layer thicknesses for the sub base, base and the concrete pavement as appropriate. With any method, a strength parameter is used to describe the sub grade or native material beneath the pavement layers. Variations in the sub grade, even over short distances, are inevitable and can occur abruptly or gradually, depending on the geologic history of the surface soils. A high variability in sub grade soil characteristics may dictate the use of conservative estimates that may lead to thicker pavements with higher construction costs or poor performance and higher maintenance costs. In order to alleviate these problems, methods have been developed to try and minimize the variability in sub grade characteristics.

The soil found in the ocean bed is classified as marine soil. It can even be located onshore as well. The properties of saturated marine soil differ significantly from moist soil and dry soil. Marine clay is microcrystalline in nature and clay minerals like chlorite, kaolinite and illite and non-clay minerals like quartz and feldspar are present in the soil. The soils have higher proportion of organic matters that acts as a cementing agent.

Marine soils in particular can present great problems in pavement design due to uncertainty associated with their performance. They are often unstable beneath a pavement and they are the most susceptible to problems from changes in moisture content. Marine soils tend to swell and become soft when wetted and may shrink and become stiff when dried. Marine clay deposits are found both in the coast and in several offshore areas spread over many parts of the world. India being peninsular country has a large area coming under coastal region and also it has been the habitat for considerable percentage of population. The marine clays are found in the states of West Bengal, Orissa, Andhra Pradesh, Tamilnadu, Kerala, Karnataka, Maharashtra and some parts of Gujarat. These soils are highly saturated, soft, sensitive and normally consolidated. These usually have low density and low shear strength and expansive in nature.

Expansive soils have the tendency to swell when they come in contact with moisture and to shrink if moisture is removed from them. These volume changes in swelling soils are the cause of many problems in structures that come into their contact or constructed out of them. The expansive soils in India have liquid limit values ranging from 50 to 100 %, plasticity index ranging from 20 to 65 % and shrinkage limit from 9 to 14 %.

A substantial literature has concluded the severity and extent of damage inflicted by soil deposits of selling nature, to various structures, throughout the world (Ganapathy, 1977; Jones and Jones, 1995; Abduljauwad, 1995; Osama and Ahmed, 2002; Zhan, 2007). The loss caused due to damaged structures proved the need for more reliable investigation, of such soils and necessary methods to eliminate or reduce the effect of soil volume change. Improving the strength of soil by stabilization technique was performed by SupakjiNontananandh et.al (2004) and Can BurakSisman and ErhanGezer(2011). The effect of electrolytes on soft soils were explained by Sivanna, G.S (1976);Anandakrishnan et.al (1966); Saha et.al (1991); Rao, M.S et.al(1992); Sivapullaiah, P.V. et al (1994); Bansal et.al(1996); S. NarasimhaRao et.al(1996); Appamma.P(1998); Chandrashekar et.al (1999);G. Rajasekaran et.al (2000); J. Chu et.al (2002);MatchalaSuneel et.al (2008). The effect of steel industrial wastes on soft soils were presented by Ashwani Kumar et.al (1998); Bhadra, T. K et.al (2002); Dr. D. D. Higgins (2005).

2. OBJECTIVE OF STUDY

The objectives of the present experimental study are

- To determine the properties of the Marine clay and Saw Dust.
- To evaluate the performance of Marine clay when stabilized with Saw Dust as an admixture and its suitability for the pavement sub grade.
- To evaluate the performance of stabilized Marine clay with an optimum of Sawdust, Lime and their suitability for the pavements.

3. STABILISATION OF MARINE CLAYS

Soil stabilization is a procedure where natural or manufactured additives or binders are used to improve the properties of soils. Chemical additives, such as lime, cement, Saw Dust and other chemical compounds have been used in marine clays stabilization for many years with various degrees of success.
The clay minerals have the property of absorbing certain anions and cations and retaining them in an exchangeable state. The exchangeable ions are held around the outside of the silica-alumina clay mineral structural unit.

Compositional variation through ionic or isomorphism substitution within the clay mineral crystal lattice can leave the structural unit with a net negative charge. Substitution also reduces the crystal size and alters its shape. Exposed hydroxyl groups and broken surface bonds can also lead to a net negative charge on the structural unit. The presence of this net negative charge means that soluble cations can be attracted or adsorbed on to the surface of the clay mineral structural units without altering the basic structure of the clay mineral. The ability of clay to hold cations is termed its cation exchange capacity. The most common soluble cations are Na^+, K^+, Ca^{2+}, Mg^{2+}, H^+, and NH_4^+.

Cation exchange capacity (C.E.C.) has major significance in determining clay mineral properties, particularly the facility with which they absorb water. Cation exchange capacity (C.E.C.) measures two of the fundamental properties of clays:
1. The surface area and the charge on this surface area.
2. The surface of clay can be of two sorts; external and internal.

The external exchange capacity measures nothing more than the average crystalline size. The surface capacity of adsorption is largely dependent upon broken bonds and surface growth defects.

The internal exchange capacity is much more interesting in that it reflects the overall charge imbalance on the layer structure and the absorption capacity of the clays. The exchange capacity is an estimate of both the number of ions adsorbed between the layers of a clay structure and of those adsorbed on the outer surfaces. C.E.C., measured in terms of milli equivalent of the atomic weight of solvent/100 gram of the dry solid, varies widely for various types of clay minerals
The exchange capacity is almost always measured as a function of the number of cations (positively charged) which can be measured on the clay surface once it is washed free of exchange salt solution. The operation is performed by immersing a quantity of clay in an aqueous solution containing a salt, usually chloride or ammonium hydroxide. The soluble

ions adsorbed with the water onto the interlayer structure can affect the adsorbed water arrangement in several ways. Principally, they act as a bond of varying strength holding the structural layer together and controlling the thickness of adsorbed water. Their effectiveness will depend on the size and charge. Thus Na^+, K^+ will tend to be weak and a clay-water system containing these ions will be capable of adsorbing large amounts of water. Ca^{2+}, Mg^{2+}, on the other hand, will have stronger links and a clay-water system containing them will possess substantially lower water content. Inclusion of Fe^{3+} or Al^{3+} would reduce the water content and plasticity and this is in fact the basis of the electro-chemical or electro-osmotic method of clay stabilization.

In this study, Saw Dust, Optimum Saw Dust and Lime will be utilized as cementitious materials while trying to stabilize the marine clay sample.

4. SAWDUST

Wood cutting factories, generates a by-product known as Saw dust. This surrounds the Forestry area. During cutting of trees about78% of weight is received from trees. Rest 22% of the weight of trees is received as dust. This dust is used as fuel in burning of bricks & generates steam for the parboiling process.

As transportation system expand, they are more likely to be supported by less desirable foundation soils, such as highly compressible deposits. The mass of the earthwork for such systems can cause unacceptable long –term settlement or even shear failure of these deposits. Ground improvement techniques may not be effective in stabilizing such soils. Although not a composite, geo-foam provides a very lightweight manufactured fill for embankments on such materials. The development of light weight fill has led to engineering of fills.

Fig 9: Saw Dust

Consisting of soil-like particulate materials that are lighter than soil, not prohibitively expensive and environmentally safe. Saw dust and Lime are excellent examples of such materials.

Table 1: Chemical composition of Sawdust

SiO_2	86 %
Al_2O_3	2.6%
Fe_2O_3	1.8%
CaO	3.6%
MgO	0.27%
Loss in ignition	4.2%

Table 2: Physical properties of Sawdust

Sl.	PROPERTY		VALUE
1	Grain size distribution (mm) (percent finer than)	4.75	100
		2.0	96
		0.6	80
		0.425	50
		0.21	29
		0.075	8
2	SPECIFIC GRAVITY		2.01

USES OF SAW DUST

As a stabilizer

The Saw Dust would appear to be an inert material with the silica in the crystalline form suggested by the structure of the particles, it is very unlikely that it would react with lime to form calcium silicates. It is also unlikely that it would be as reactive as fly ash, which is more finely divided. So saw dust would give great results when it used as a stabilizing material.

In lightweight fill

The ash would appear to be a very suitable light weight fill and should not present great difficulties in compaction, provided its initial moisture content is kept within reasonable limits (say less than 50%). The very high angle of internal friction of the material will mean that its stability will be high. However, its lack of cohesion may lead to problems in construction due to erosion and shearing under heavy rollers. To overcome these it will probably be desirable to place a 3 to 6 inch thick blanket layer of cohesive material every 2 to 3 ft.

Other uses

On an Industry, wide basis most saw dust is green. Green saw dust has limited uses, for examples, as fuel at the producing plant or pulping. Green hard wood saw dust is also used in fairly large amounts for meat smoking.

In some localities green soft wood saw dust furnace for domestic heating. Thus far it has seldom been considered economically feasible to dry saw dust artificially.

Brief information on various uses of sawdust and shavings is tabulated in tables 1 and 2 of this report.

Under four general classifications

1. Uses based on special physical qualities.
2. Fuel uses.
3. Fibre and wood base board uses.
4. Chemical Uses.

5. LIME

Lime, chemically known as, Calcium oxide (**CaO**), commonly known as **quicklime** or **burnt lime**, is a widely used chemical compound. It is a white, caustic, alkaline crystal solid at room temperature.

Fig 10: Lime

Properties of lime

- Lime is a white amorphous solid.
- It has a high melting point of 2600^{o}C.
- It is highly stable and even fusion cannot decompose it.

Chemical Properties

- On hydration, quick lime forms slaked lime or lime water. When water is added to lime it becomes hot and cracks to form a white powder. This is called slaking of lime.

$$CaO + H_2O \longrightarrow \underset{\text{slaked lime}}{Ca(OH)_2}$$

- Calcium oxide is a basic oxide. It can react with acids to give calcium salts.

$$CaO + \underset{\text{sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{calcium sulphat}}{CaSO_4}$$

- With acidic oxides like silicon dioxide and phosphorus pent oxide, it forms silicates and phosphates. This property makes lime useful as a flux in metallurgy to remove impurities.

$$CaO + SiO_2 \longrightarrow \underset{\text{calcium silicate}}{CaSiO_3}$$

$$3CaO + P_2O_5 \longrightarrow \underset{\text{calcium phosphate}}{Ca_3(PO_4)_2}$$

Lime is routinely used as a soil modification agent to improve the performance of sub grade soils with the primary goal of reducing volume change. Effective mixing of lime and soil is critical to ensuring that the expected improvements occur throughout the soil mass.

Lime also decreases the apparent amount of fines in a soil by causing flocculation and agglomeration of the clay particles (Little 1995). This results in an increase in the percentage of sand and silt size particles as measured by standard grain size distribution methods (Basma and Tuncer 1991.Lime also tends to reduce the swell potential of fine grained soils (Kennedy et al 1987).

Moisture content plays an important role in the swell potential of a lime treated soil; soils with moisture content below optimum show a much greater swell potential than soils with moisture content above optimum (Sweeney et al 1988).

It is found that soils with a significant amount of montmorillonite developed almost no increase in unconfined compressive strength. They concluded that most of the lime was used to break down the montmorillonite and the montmorillonite also had too great of a surface area for the cementitious compounds to significantly affect the strength.

MATERIAL USED

Marine Clay

The soil used in this study is Marine Clay soil, obtained from Kakinada Sea Ports Limited, Collected at a depth of 1.5m from ground level. The Index & Engineering properties of Marine Clay soil are determined as per IS code of practice and determined & presented in Table 4.

Saw Dust

Locally available Saw Dust was used in the present work. The physical properties are determined and presented in Table 5.

Lime

Lime stabilization is done by adding lime to a soil. It is useful for stabilization of clayey soils. When lime reacts with soil there is an exchange of cations in the adsorbed water layer and a decrease in plasticity of the soil occurs. The resulting material is more friable than the original clay, and is, therefore more suitable as sub grade. Lime is produced by burning of lime stones in kilns. The quality of lime obtained depends upon the parent material and the production process.

(1) High calcium, quick lime (CaO)
(2) Hydrated, high calcium lime ($Ca(OH)_2$)
(3) Dolomitic lime($CaO + MgO$)
(4) Normal, hydrated dolomitic lime ($Ca(OH)_2$)
(5) Pressure, hydrated dolomitic lime ($Ca(OH)_2 + MgO_2$)

DOUBLE LAYER THEORY

A **Double Layer** (**DL**, also called an **Electrical Double Layer**, **EDL**) is a structure that appears on the surface of an object when it is placed into a liquid. The object might be a solid particle, a gas bubble, a liquid droplet, or a porous body. The DL refers to two parallel layers of charge surrounding the object. The first layer, the surface charge (either positive or negative), comprises ions adsorbed directly onto the object due to a host of chemical interactions. The second layer is composed of ions attracted to the surface charge via the Coulomb force, electrically screening the first layer. This second layer is loosely associated with the object, because it is made of free ions which move in the fluid under the influence of electric attraction and thermal motion rather than being firmly anchored. It is thus called the **diffuse layer**. The quick lime is more effective as stabilizer than the hydrated lime, but the latter is safer and convenient to handle generally the hydrated lime is used. It is also known as slaked lime. The higher the magnesium content of the lime, the less is the affinity for the water and the less is the heat generated during mixing. Lime stabilization is not effective for sandy soils however these soils can be stabilized in combination with clay, fly ash and other pozzolanic materials.

6. LABORATORY STUDIES

The laboratory studies were carried out on the samples of Marine clay, Marine clay+ Saw Dust, Marine clay, Saw Dust and Lime mixes.

Liquid limit

Liquid limit test was conducted on Marine clay, Marine clay+15% Saw Dust, Marine clay+15% Saw Dust + 4% lime using Casagrande's liquid limit apparatus as per the procedures laid down in IS: 2720 part 4 (1970).

Plastic limit

Plastic limit test was conducted on Marine Clay, Marine Clay+15% Saw Dust, Marine clay+15% Saw Dust+ 4%lime as per the specifications laid down in IS: 2720 part 4 (1970).

Shrinkage limit

This test is also conducted on to Marine Clay, Marine Clay+15% Saw Dust, Marine clay+15% Saw Dust+ 4% lime as per IS: 2720 part 4 (1972).

Free swell index

This test is performed by pouring slowly 10 gm of dry soil, 10 gm of (soil+ Saw Dust) passing through 425 micron sieve, in two different 100 cc glass jar filled with distilled water. The swollen volume of Marine Clay, Marine Clay- Saw Dust, Marine clay, Saw Dust and lime mixes are recorded as per IS 2720 part 40 (1985).

$$\text{Free swell (\%)} = \frac{\text{Final volume} - \text{Initial volume}}{\text{Initial volume}} * 100$$

Proctor's standard compaction Test

Preparation of soil sample for proctor's compaction test was done as per IS: 2720 part-6 (1974).

Unconfined compressive strength

The unconfined compressive strength tests are conducted on Marine Clay, Marine Clay+ Saw Dust, Marine clay, Saw Dust, lime mixture as per IS 2720 part 10 (1973). All the samples are prepared by static compaction using split mould at Optimum moisture content and Maximum dry density to maintain same initial dry density and water content. The test was conducted under a constant strain rate of 1.5mm/min. The proving ring reading is noted for 50 divisions, and loading was continued until 3 (or) more reading are decreasing (or) constant (or) strain 20% has been reach. The samples of Marine Clay –additive mixes were cured4 days, 7days and 28days curing period and at the end of each curing period the samples were tested. Three samples for each mix were tested.

California bearing ratio Test

The California bearing ratio tests are conducted on Marine Clay, Marine Clay+ Saw Dust, Marine clay, Saw Dust, lime mixtures as per IS 2720 part 16 (1979). The test was conducted under a constant strain rate of 1.25mm/min. The proving ring reading is noted for 50 divisions, and loading was continued until 3 (or) more readings are decreasing (or) constant. The test was conducted at Optimum moisture content. The samples were tested in soaked condition. The tests were conducted at time interval of curing for 4 days, 7days and 14 days.

Differential Free Swell Test

Differential Free Swell (DFS) is a parameter used for the identification of the expansive soil.

For the determination of the differential free swell of a soil, 20g of dry soil passing through a 425µ size sieve is taken. One sample of 10g is poured into a 100c.c capacity graduated cylinder containing water, and the other sample of 10g is poured into a 100c.c capacity graduated cylinder containing kerosene oil.

Both the cylinders are kept undisturbed in a laboratory. After 24 hours, the settled volumes of both the samples are measured.

DFS= (Settled soil volume in water – settled soil volume in kerosene)*100

Settled soil volume in kerosene

Because kerosene is a non-polar liquid, it does not cause any swell of the soil IS: 2720 (Part III- 1980) gives degree of expansion of a soil depending upon its differential free swell as under.

Table 3: Differential Free Swell

S. No.	Degree of expansion	DFS
1	Low	< 20%
2	Moderate	20 - 35%
3	High	35 – 50%
4	Very High	>50%

PROPERTIES OF MARINE CLAY

Visual characteristics of soil

The following properties were observed from visual classification in dry condition.

Colour -- Black colour
Odour --Odour of decaying vegetation
Texture -- Fine grained

Table 4: Properties of Marine Clay

S. No	Property	Symbol	Value
1	Gravel		0%
2	Sand		14%
3	Fines	Silt	30%
		Clay	56%
4	Liquid Limit	W_L	74.5%
5	Plastic Limit	W_P	26.9%
6	Plasticity Index	I_P	47.6%
7	Shrinkage limit	W_s	10.678%
8	Soil Classification		CH
9	Specific Gravity	G	2.35
10	Differential Free Swell	DFS	70%
11	Optimum Moisture Content	O.M.C.	35%
12	Maximum Dry Density	M.D.D.	1.27 gm/cc
13	Cohesion	C	12 .20 t/m^2
14	Angle of Internal Friction	ϕ	2^0
15	CBR Value (soaked)		1.754 %

Table 5: Physical properties of sawdust

Sl. no	Properties	Saw dust
1	**Compaction properties** Optimum moisture content(%) Maximum dry density(g/cc)	 20.7 1.35
2	Un-soaked CBR(%) Soaked CBR(%)	5.5 3.15
3	Specific gravity	2.10
4	Free swell index	80
5	Cohesion C (KN/m^2) Angle of internal friction	8 31
6	Soil classification	ML

PROCTOR COMPACTION AND CBR TEST RESULTS FOR SOIL AND SAWDUST

(A) 100% MARINE CLAY

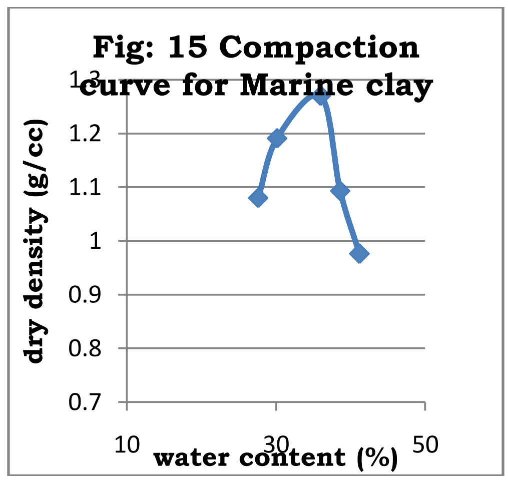

Fig: 15 Compaction curve for Marine clay

Optimum Moisture Content = 35.00%
Maximum Dry Density = 1.270gm/cc

Table 5.7 Variation of MDD with % of Saw Dust

Mix proportion	% OF SAWDUST	Dry Density (g/cc)
95%Soil+5%SD	5	1.169
90%Soil+10%SD	10	1.196
85%Soil+15%SD	15	1.295
80%Soil+20%SD	20	1.087
75%Soil+25%SD	25	1.038

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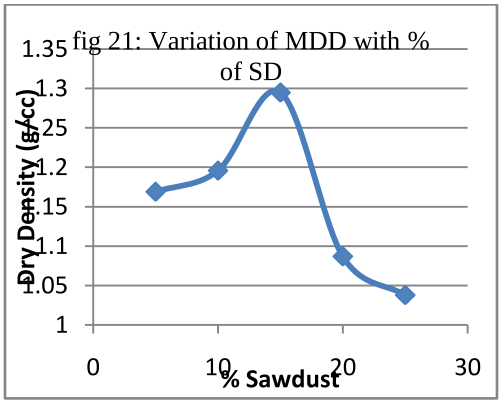


fig 21: Variation of MDD with % of SD

CBR TEST RESULTS FOR MARINE CLAY WITH SAWDUST:

The soaked and un soaked CBR values of various mixes of marine clay and Saw Dust using OMC obtained from compaction are determined. The soaked CBR after immersing in water for four days , that is when full saturation is likely to occur, is also determined. Variation of CBR with % variation in Saw Dust is presented.

(1) CBR Curve for 100% soil

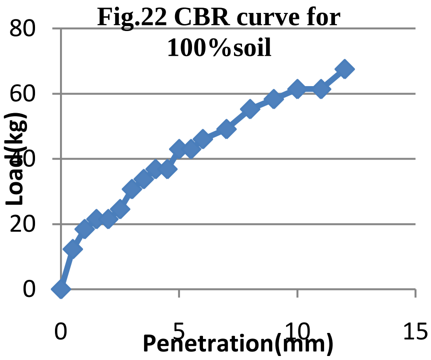


Fig.22 CBR curve for 100%soil

Soaked CBR value: 1.754%

(2)CBR Curve for 95% soil + 5% Sawdust

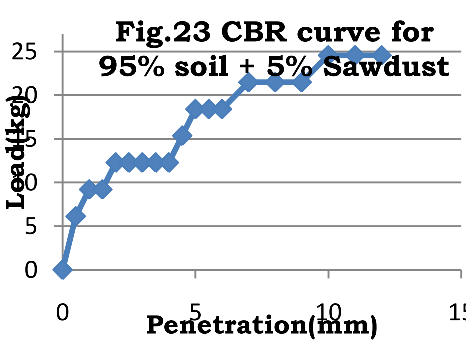


Fig.23 CBR curve for 95% soil + 5% Sawdust

Soaked CBR value: 0.896%

(3) CBR Curve for 90% soil + 10% Sawdust

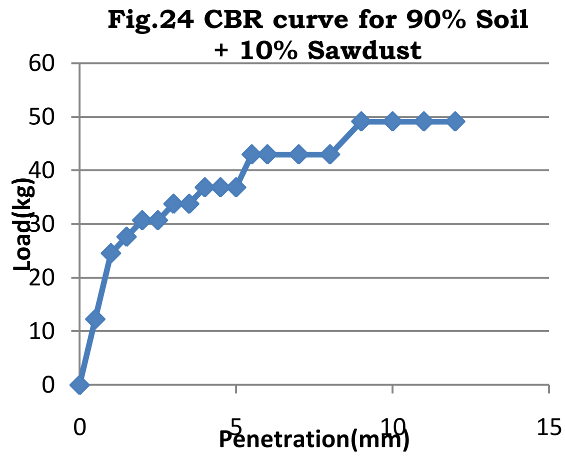


Fig.24 CBR curve for 90% Soil + 10% Sawdust

Soaked CBR value: 2.24%

(4) CBR Curve for 85% soil + 15% Sawdust

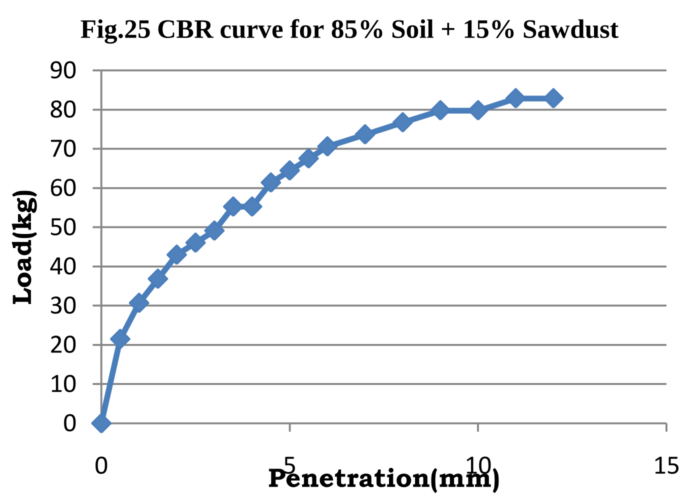
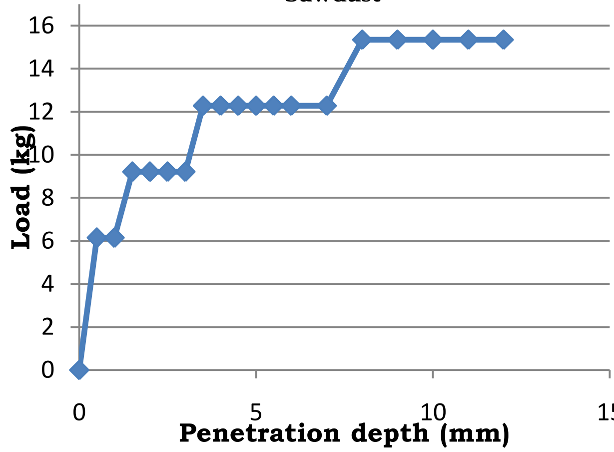


Fig.25 CBR curve for 85% Soil + 15% Sawdust

Soaked CBR value: 4.033%

(5) CBR Curve for 80% soil + 20% Sawdust

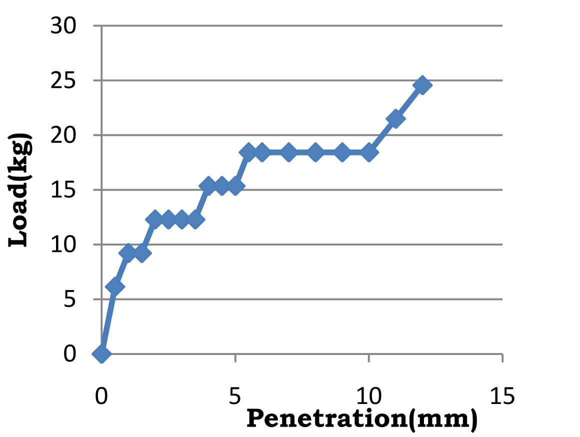
Fig.26 CBR curve for 80% Soil + 20% Sawdust



Soaked CBR value: 0.6722%

(6) CBR Curve for 75% soil + 25% Sawdust

Fig.27 CBR curve for 75% Soil + 25% Sawdust

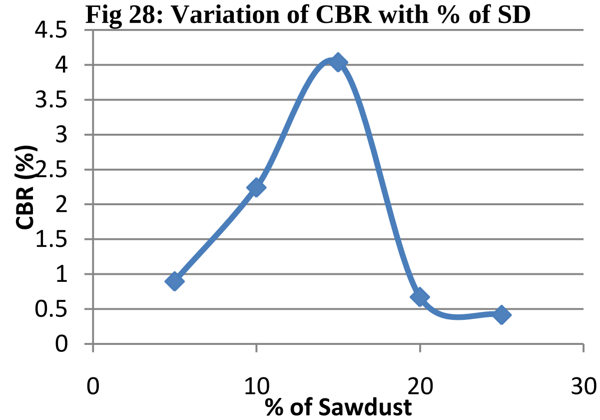


Soaked CBR value: 0.415 %

Table 5.8.variation of soaked CBR values with Sawdust

Mix proportion	% of SAWDUST	Soaked CBR
95%soil+5%SD	5	0.896
90%soil+10% SD	10	2.240
85%soil+15% SD	15	4.033
80%soil+20% SD	20	0.672
75%soil+25% SD	25	0.415

Fig 28: Variation of CBR with % of SD

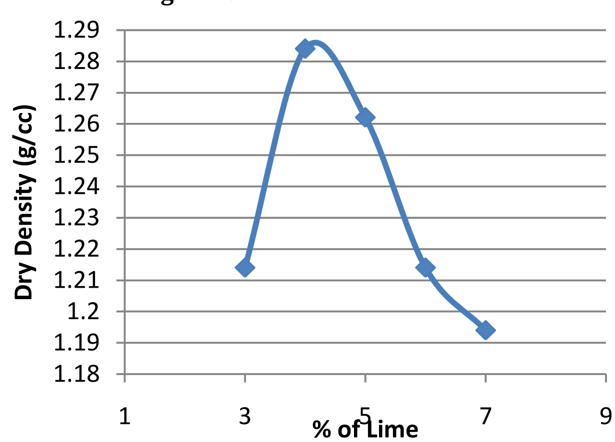


PROCTOR COMPACTION RESULTS FOR SAWDUST TREATED MARINE CLAY WITH VARIOUS PERCENTAGES OF LIME

TABLE 6.6 Variation of MDD of Sawdust treated marine clay with various percentages of Lime

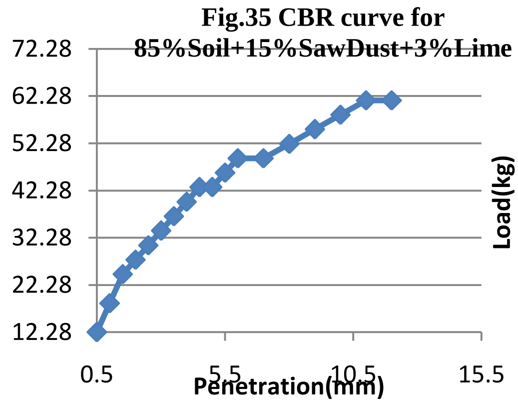
Mix proportion (85%MC+15%SD+)	% Lime	Dry Density(g/cc)
3%Lime	3	1.214
4%Lime	4	1.284
5%Lime	5	1.262
6%Lime	6	1.214
7%Lime	7	1.194

Fig 34: Variation of MDD with % Lime



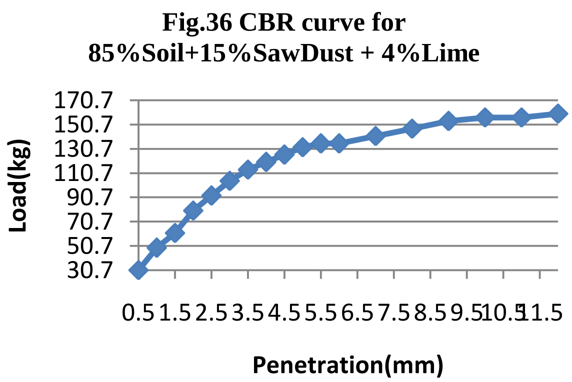
CBR RESULTS FOR SAWDUST TREATED MARINE CLAY WITH VARIOUS PERCENTAGES OF LIME

(1) CBR Curve for 85%Soil+15%SawDust+3%Lime



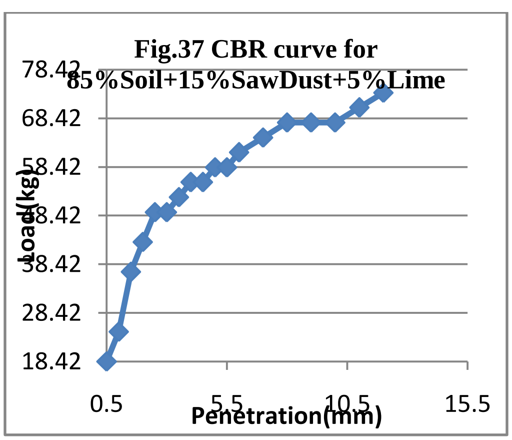
Soaked CBR: 2.240 %

(2) CBR Curve for 85%Soil+15%SawDust + 4%Lime



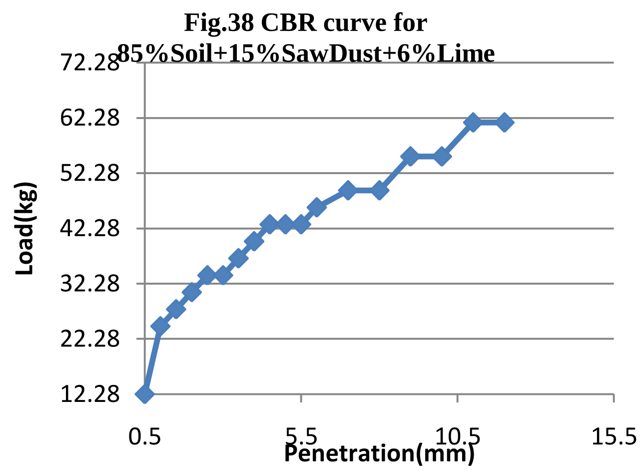
Soaked CBR: 6.720%

(3) CBR Curve for 85%Soil+15%SawDust+5%Lime



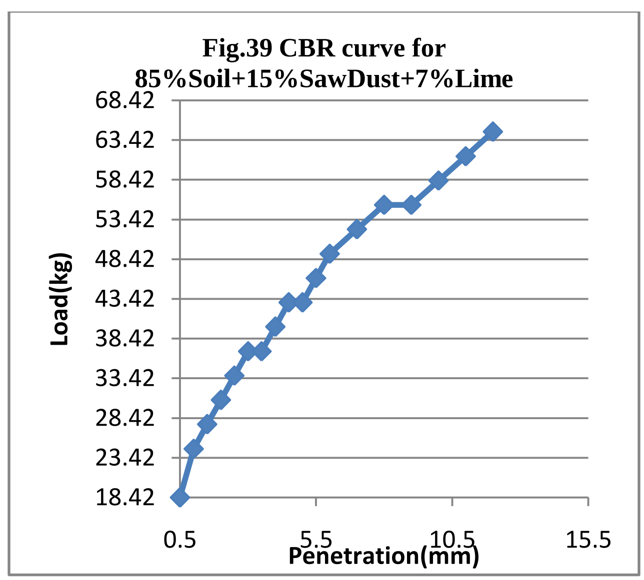
Soaked CBR: 3.580%

(4) CBR Curve for 85%Soil+15%SawDust+6%Lime



Soaked CBR: 2.460 %

(5) CBR Curve for 85%Soil+15%SawDust+7%Lime



Soaked CBR: 2.240 %

Table 6.7.variation of soaked CBR values of Sawdust treated marine clay with various percentages of lime

Mix proportion (85%MC+15%SD+)	% LIME	Soaked CBR
3%Lime	3	2.240
4%Lime	4	6.720
5%Lime	5	3.580
6%Lime	6	2.460
7%Lime	7	2.240

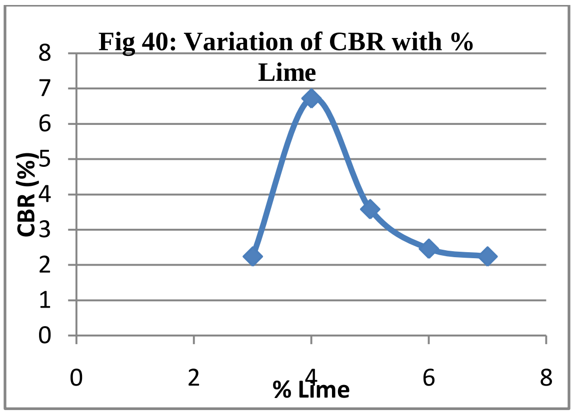


Fig 40: Variation of CBR with % Lime

Table 7: Properties of the Stabilized Marine clay with an optimum of 15 % Sawdust and 4 % Lime

S. No	Property	Symbol	Marine Clay	MC + 15%SD	85% MC + 15% SD+ 4%LIME
1	Liquid Limit (%)	W_L	74.5 %	63 %	54%
2	Plastic Limit (%)	W_P	26.9 %	28 %	30%
3	Plasticity Index (%)	I_P	47.6 %	35%	24%
4	Shrinkage Limit (%)	W_s	10.678	15.8	18.26
5	Soil Classification	--	CH	CH	CH
6	Specific Gravity	G	2.35	2.61	2.84
7	Optimum Moisture Content (%)	O.M.C	35 %	29.62%	28.73%
8	Maximum Dry Density (gm/cc)	M.D.D	1.27	1.295	1.284
9	Cohesion (t/m^2)	C	12.20	8.20	6.47
10	Angle of Internal Friction(^{0})	Ø	2^0	7.7^0	10^0
11	CBR value (%)	Soaked	1.754	4.033	6.720
12	Differential Free Swell	DFS	70 %	26%	19.5 %

CONCLUSIONS

- It is noticed that the liquid limit of the marine clay has been decreased by 15.43% on addition of 15% Saw Dust and it has been further decreased by 27.50% when 4% lime is added.
- It is observed that the plastic limit of the marine clay has been improved by 4.08% on addition of 15% Sawdust and it has been further improved by 11.50% when 4% lime is added.
- It is observed that the plasticity index of the marine clay has been decreased by 26.47% on addition of 15% Sawdust and it has been further decreased by 49.57% when 4%lime is added.
- It is found that the O.M.C of the marine clay has been decreased by 15.37% on addition of 15% Sawdust and it has been further decreased by 17.91% when 4% lime is added.
- It is found that the M.D.D of the marine clay has been improved by 1.96% on addition of15% Sawdust and it has been improved by 1.10% when 4% lime is added.
- It is observed that the C.B.R. value of the marine clay has been increased by 129.76% on addition of 15% Sawdust and it has been further improved by 283.12% when 4% lime is added.
- It is observed that the DFS value of the marine clay has been decreased by 62.85% on addition of 15% Sawdust and it has been further decreased by 72.14% when 4% Lime is added.

The soaked CBR of the soil on stabilizing is found to be 6.720% and is satisfying standard specifications. So finally it is concluded from the above results that saw dust can potentially stabilize the expansive soil solely (or) mixed with lime. The utilization of industrial wastes like saw dust is an alternative to reduce the construction cost of roads particularly in the rural areas of developing countries.

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BIOGRAPHIES

Dr. D. Koteswara Rao
Professor of Civil Engineering,
University College of
Engineering,
JNTUK KAKINADA,
East Godavari District,
Andhra Pradesh, India.

M. Anusha
Graduate student (Civil Engg.),
University College of Engineering,
JNTUK KAKINADA,
East Godavari District,
Andhra Pradesh, India

P.R.T. Pranav
Graduate student (Civil Engg.),
University College of Engineering,
JNTUK KAKINADA,
East Godavari District,
Andhra Pradesh, India

G. Venkatesh
Graduate student (Civil Engg.),
University College of Engineering,
JNTUK KAKINADA,
East Godavari District,
Andhra Pradesh, India