

Comparative Study of Soft Soils Characteristics with Cement Waste Dust, Lime Powder and Boiled Rice Water

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Abstract

Improvement of soft soil properties and effective pavement system performance of soft soils can be done only by stabilization process. It is an effective method. Jointly or individually, Chemical and/or Mechanical stabilization is done for various soils depending on the nature of that soil. As far as soft soils are concern, they are having reactive nature and so chemical stabilization is the best choice to improve such soil. Mainly, in Saurashtra, black cotton soil and red soil are the major problems for the highway's construction. Among the coastal strip, saline sea sand is the key weak factor to look for. Black cotton soil with full content of montmorillonite, according to mineralogical analysis, leads to severe to extreme severe cracks without warning. Deep cracks of one inch to twelve inches, in some cases, definitely damage the construction. Red soils unit ruddy in colour as a result of the presence of iron. Red soils area unit fashioned because of weathering of ancient crystalline and metamorphic rocks. Red soils are porous, friable in nature, loose and aerated, contains soluble salts in small quantities. In this paper, comparative study of three stabilizing agents (1) cement waste dust, (2) lime powder, and (3) boiled rice water is done. Cement waste dust, collected from the cement plant, found to be most effective agents for improvement of soft soils properties among three. Other two agents are also effective to improve the properties. They can be used individually when required. But as far as the comparison is there, descending order of stabilizing agents is cement waste dust, lime powder, and boiled rice water. Improvement in the soil properties varies from 10% to 30% at an edition of cement waste dust and lime powder in range 7%, 10% and 13% by weight and boiled rice water in range 10%, 20% and 30% by volume of sample of soil. This study provides satisfactory reason to use cement waste dust, lime powder and boiled rice water thereafter to get stabilized soil.

Keywords: Stabilization, black cotton soil, red soil, saline sand, cement waste dust, lime powder, boiled rice water

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INTRODUCTION

Black Cotton Soil

In Saurashtra region, BC Soil is spread over most of the part. Rich proportion of montmorillonite is found in BC Soil from mineralogical analysis. High percentage of montmorillonite renders high degree of expansiveness. These property results cracks in soil without any warning. These cracks have sometimes extent severe limit like ½" to 12" deep. Use of this type of land may suffer severe damage to the construction with the change in atmospheric conditions. Soil stabilization is the alteration of one

or more soil properties, by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. Soils may be stabilized to increase strength and durability or to relevant erosion and dust generation. Regardless of the purpose for stabilization, the desired result is the creation of a soil material or soil system that will remain in place under the design use conditions for the design life of the project. Engineers are responsible for selecting or specifying the correct stabilizing method, technique, and quantity of material required. Many of the procedures outlined are not precise, but they will “get you in the ball park”. Soils vary throughout the world, and the engineering properties of soils are equally variable. The key to success in soil stabilization is soil testing. The method of soil stabilization selected should be verified in the laboratory before construction and preferably before specifying or ordering. BC Soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. This BC Soils occurs mostly in the central and western parts and covers approximately 20% of the total area of India. Because of its high swelling and shrinkage characteristics, the BC Soils have been a challenge to the highway engineers. The BC Soils is very hard when dry but loses its strength completely when in wet condition. It is observed that on drying, the BC Soil develops cracks of varying depth. As a result of wetting and drying process, vertical movement takes place in the soil mass. All these movements lead to failure of pavement, in the form of settlement, heavy depression, cracking and unevenness (Figure 1) [1–3].

Red Soil

Red soil in India comprises of more drainage properties than other types of soils as it is formed of clay, created by wearing and tearing of limestone and formed by the breakdown of igneous rocks and metamorphic rocks (Figure 2).

When limestone erodes, the clay enclosed within the rocks remains intact with other forms of non-soluble materials. In oxidizing conditions, rust or iron oxide develops in the clay, when the soil is present above the water table giving the soil a characteristic red colour. Red soil in India lacks nitrogenous material, phosphoric acid, organic matter and is rich in iron. Red soils are formed as a result of the draining down of old crystalline rock, less clayey and sandier in nature. This is having a rich content of iron plus small humus content. The content of essential nutrients like nitrogen, phosphorus and lime is very less in red soils. Slightly acidic, it is incapable of retain moisture. It is due to the presence of iron oxide deposits, that red soils get the unique red tint. Red soil in India is alternatively known as ‘Yellow soil’. The presence of a good concentration of iron oxide is responsible for giving this soil its yellowish or reddish shade. Heavily leached, it consists of a considerable concentration of iron oxides similar to



Figure 1. Black cotton soil.



Figure 2. Red soil.

laterite soil in India. Comparatively, red soils are less clayey and sandier. Moreover, red soils are formed in those areas which receive significantly low rainfall and therefore are less leached in comparison to the laterite soil in India. Further, red or yellow soils build up generally on metamorphic rocks. These soils are acidic in nature and this is one similarity between laterite soils and red soils. Red soils are not able to preserve moisture. A glimpse over the country's map will make one scrutinize that the north-western portions of the peninsular block is covered by black soil while the rest south-eastern half is covered by red soil of various shades of yellow and red. Red soils have matured on older crystalline rocks, under deep and rational rainfall conditions. There are few particular types of red soils which are clays. These types of red clayey soils are used in ceramic projects, either mixed with other materials or alone [4–7]. Stabilization of red soil is required due to its porous nature. It is required to modify because of its inability of preserving moisture.

Saline Sand

Saline sand or marine sand accumulated nearby sea have great influence on highways constructed along the coastal strips. As this sand is formed from the sand stones covering the bank of the sea and transported through saline water of sea, Salinity and Non-cohesion are the two major key parameters of saline sand. Moreover, non-plastic nature, less resistance against friction, excess water absorbing property of saline sand leads the saline sand to be considered as a poor soil. In Saurashtra, a very sizable part of highway is occupied by the coastal strip, starting from Okha, Dwarika, Veraval via Porbandar up to Bhavnagar. The length of this portion of highway is approximately 465 km. This highway is highly affected by saline sand beneath the soil. Patches and honeycombed surfaces of pavements are all time issues for engineers. Of course, engineers are doing very good job to maintain the smoothness of the surfaces but even though it is a fact that the saline sand plays the role of an opposition which leads to a requirement of sure cure solution for this (Figure 3) [8–12].

Cement Waste Dust

Cement Dust used in the test is provided by Saurashtra Cement and Chemicals Limited, Ranavav Dist. Porbandar (renowned by the brand Hathi Cement). It is an industrial waste, in a dust form, collected from packing department as dust settled on the floor during the automatic packing of bags of Portland cement. The cement dust possesses the chemical properties as tabulated in Table 1. As it is a dust formation, properties differ slightly than the basic properties of cement.

Lime Powder

Lime Powder used in the test is collected from the quarry of lime situated near Ranavav Dist. Porbandar. It is the raw material for manufacturing of cement. Usually, lime has a great influence on the temperature. The properties above tabulated are measured at room temperature, in range 27 to 30 degree centigrade. Use of lime with increased percentage in BC Soil was examined for stabilization purpose and the result was evaluated (Table 2).



Figure 3. Saline sand.

Table 1. Properties of cement waste dust.

S.N.	Property of cement dust	% by weight
		##
1	Silicon dioxide, SiO ₂	18.5
2	Aluminum oxide, Al ₂ O ₃	13.5
3	Iron oxide, Fe ₂ O ₃	0.62
4	Calcium oxide, CaO	14.02
5	Magnesium oxide, MgO	0.84
6	Percentage finer (%)	94.33
7	Specific gravity	2.86
##—As per test conducted at NSIC Certi SrNo. 15837 24/8/12, Rajkot		

Table 2. Properties of lime powder.

S.N.	Property of lime powder	% by weight
1	Silicon dioxide, SiO ₂	4
2	Aluminum oxide, Al ₂ O ₃	1.21
3	Iron oxide, Fe ₂ O ₃	1.82
4	Calcium oxide, CaO	40.24
5	Magnesium oxide, MgO	0.16

Boiled Rice Water

Boiled Rice water is a homemade adhesive liquid. This adhesive liquid is used as stabilizing agent to get improvement in physical property of the soft soil. There are plenty of experiments done using rice husk as stabilizing agent, but boiled rice water is yet not tried to get such analysis. Boiled Rice water has a good bonding effect into soil, and it improves the properties of soft soil. But the amount is less than that achieved by cement waste dust and lime.

STABILIZATION PROCESS FOR SOFT SOIL

Soft soil of Saurashtra region was stabilized using (i) Cement Waste Powder, (ii) Lime Powder, (iii) Boiled Rice Water. Natural Properties of these soft soils were first determined. One by one soft soils were tested in the laboratory using above three mentioned stabilizing agents. Cement waste dust and lime powder were taken 7%, 10% and 13% by weight of soil sample each time. Boiled rice water, as in liquid form, was taken 20%, 25% and 30% in volume of weight of soil samples. The percentage of cement waste dust, lime powder and boiled rice water cannot be maintained at same level. This is due to the reason that first two materials are in powder form and third one is in liquid form (Figures 4 and 5).

**Figure 4.** Process for boiled rice water**Figure 5.** Boiled rice water

500 gm of rice was boiled with two liters of water at a constant temperature of 110 degree centigrade. After cooling, the boiled rice water was separated in a bowl. The boiled rice water thus obtained was observed a lubricating–adhesive-property. This boiled rice water was used as stabilizing agent in soft soil and tests were performed to check the change in properties of soft soil. The main drawback of the boiled rice water was that it is required to use immediately after cooling, otherwise it loses the lubrication-adhesiveness it has gained.

The results of boiled rice water treated soils were compared with the results obtained using cement waste dust and lime powder for the same soft soils.

RESULT ANALYSIS OF SOFT SOILS WITH DIFFERENT STABILIZERS

The above narrated soft soils were first examined for determination of its own natural properties and than they were compared with the natural properties required for a working soil. It was found that the gap of requirements in some properties is much considerable and in real conditions such properties are the dominating to others in terms of importance. Table 3 shows the analysis of soft soils and need of properties for a good soil [12–17].

The difference in values between soft soil properties and a real soil were tried to minimize using stabilizing agents, (i) Cement Waste Dust (ii) Lime Powder (iii) Boiled rice water. The percentages of these agents were set to 7, 10 and 13 percentages by weight for first two types and 20, 25 and 30 percentages by volume of soft soil. By this experiment, following results were obtained. Tables 4–6 are results obtained with the use of stabilizing agents and same results are converted to graphical forms to make a clear division between benefits of each stabilizing agents (Figures 6–14).

Table 3. Result analysis of soft soils in original condition.

S.N.	Descriptions	Black cotton soil	Red soil	Saline sand	Requirement for natural soil
1	Water content (%)	2.69	9.35	26.89	-
2	Specific gravity	2.09	1.95	2.13	2.3–2.6
3	Liquid limit: (%)	57	24.5	-	30–35
4	Plastic limit: (%)	1.77	0.125	-	20–22
5	OMC: (%)	16.0	10.0	13.0	15
6	MDD: (gm/cc)	1.649	1.81	1.49	1.8–1.9
7	C-value: (gm/cc)	0.03	0.130	0.885	-
8	Ø value in degrees	30	21	20	-

Table 4. Result analysis of black cotton soil with stabilizing agents.

Black cotton soil										
Material	Cement Waste Dust			Lime			Boiled Rice Water			Natural
%age	7	10	13	7	10	13	20	25	30	-
MDD	1.72	1.780	1.83	1.64	1.680	1.73	1.631	1.674	1.657	1.649
OMC	16	15.75	16.25	18	16.75	16.5	14	20	16.25	16
Ø-Value	18.42	17.44	17.27	12.62	15.64	18.7	11.47	14.00	16.41	30
C-Value	0.204	0.208	0.232	0.224	0.28	0.32	0.203	0.23	0.28	0.03
L.L.	25	27	28	29	32	34.3	31.4	33	36	30
P.L.	8	9	9.5	6	8	12	12	13	15	7

Table 5. Result analysis of red soil with stabilizing agents

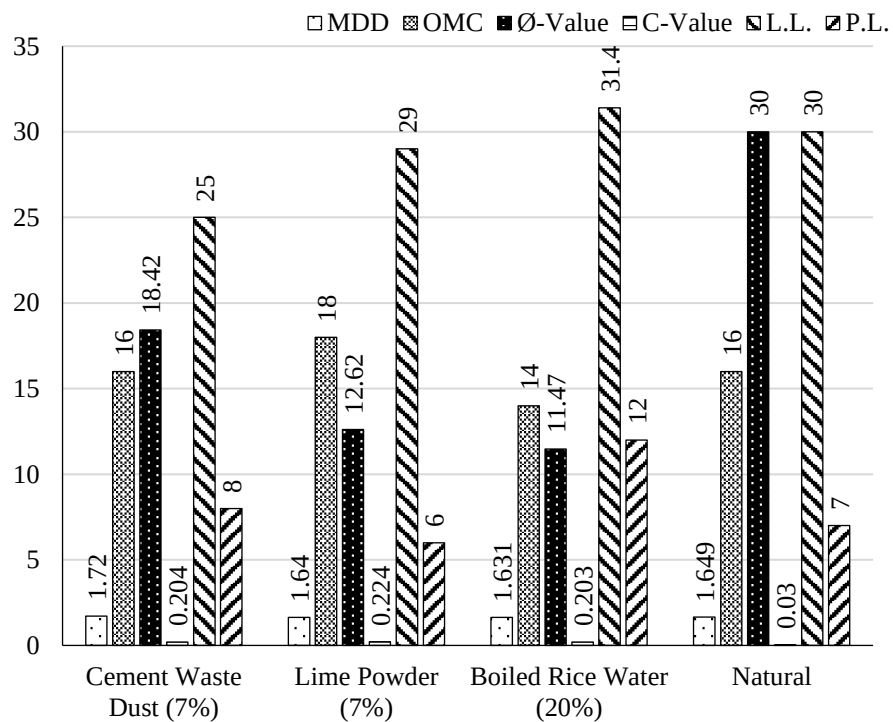
Red Soil										
Material	Cement Waste Dust			Lime			Boiled Rice Water			Natural
%age	7	10	13	7	10	13	20	25	30	-
MDD	1.672	1.664	1.653	1.62	1.64	1.65	1.6	1.647	1.652	1.61
OMC	14.6	15.7	16.1	15.0	16.5	16.3	15.0	19	18.75	10
Ø-Value	14	16	15	12.7	15.6	18.8	11.75	14.74	15.41	21
C-Value	0.194	0.208	0.287	0.24	0.24	0.312	0.223	0.213	0.228	0.13
L.L.	26	27.5	28.3	27	30	31.3	29	28.25	29.75	24.5
P.L.	11	9.75	11.3	10	9.25	12.3	14	15.55	15.85	12.5

Table 6. Result analysis of saline sand with stabilizing agents

Saline Sand										
Material	Cement waste dust			Lime			Boiled rice water			Natural
%age	7	10	13	7	10	13	20	25	30	-
MDD	2.225	2.256	2.217	2.102	2.056	2.17	1.897	1.903	1.884	1.49
OMC	15	13	12.5	14	12	12	18	20	15	13
C-Value	0	0	0	0	0	0	0	0	0	0.287
Ø-Value	26.42	25.12	25.78	26.42	25.12	25.78	21.05	23.46	32.21	22.01

Black Cotton Soil

Comparison of Stabilizing Agents

**Figure 6.** Use of black cotton soil with lower values of stabilizing agents.

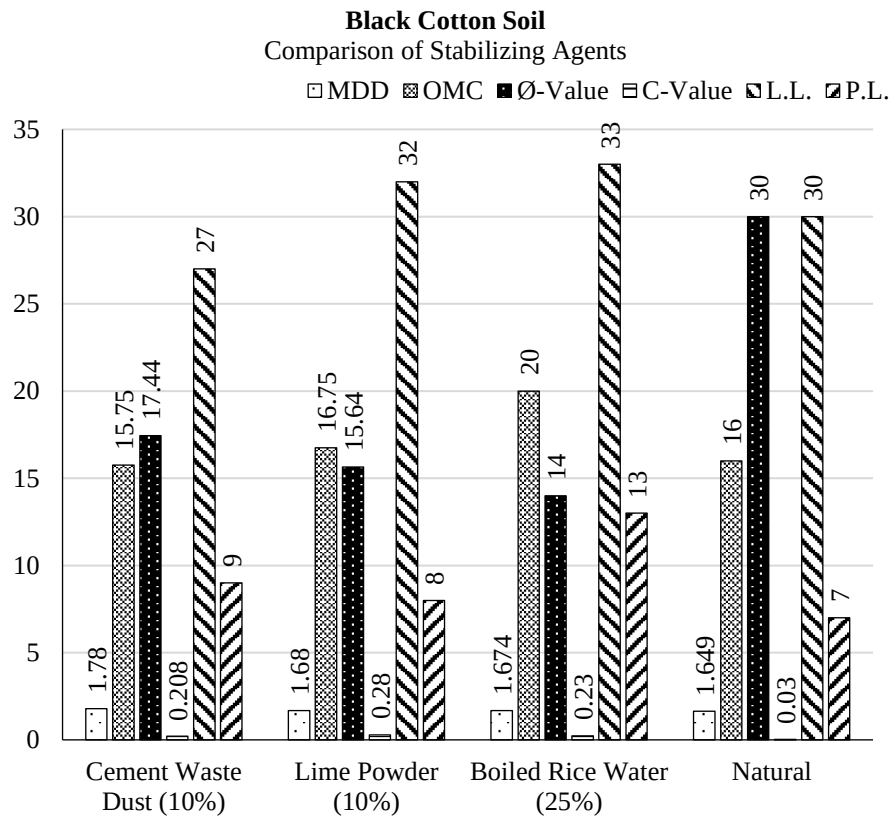


Figure 7. Use of black cotton soil with middle values of stabilizing agents.

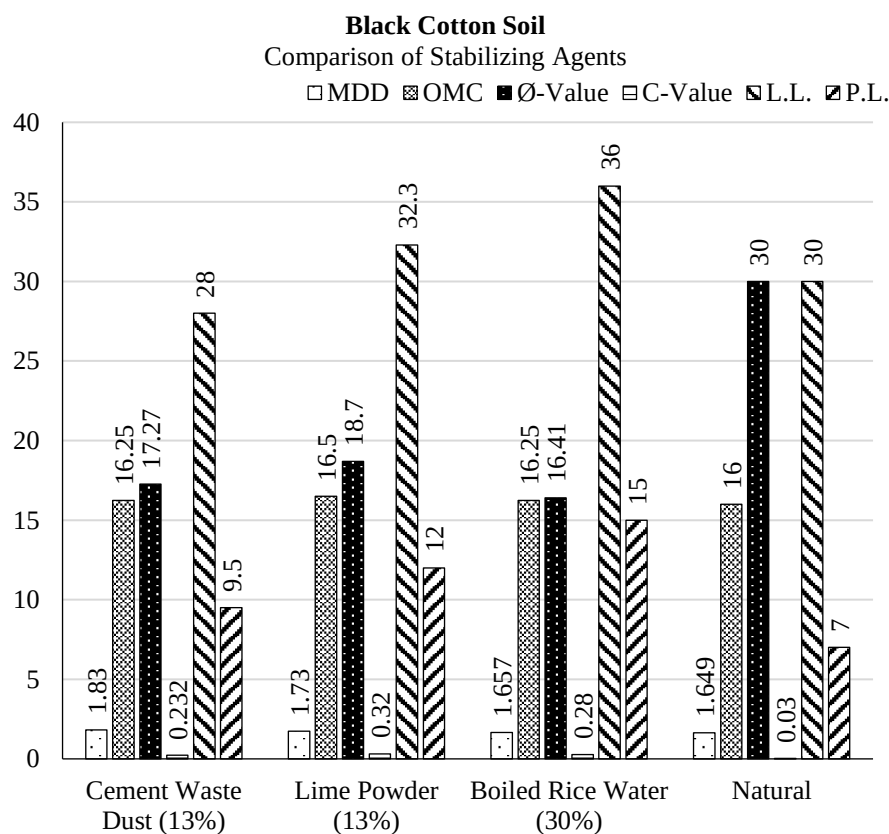


Figure 8. Use of black cotton soil with higher values of stabilizing agents.

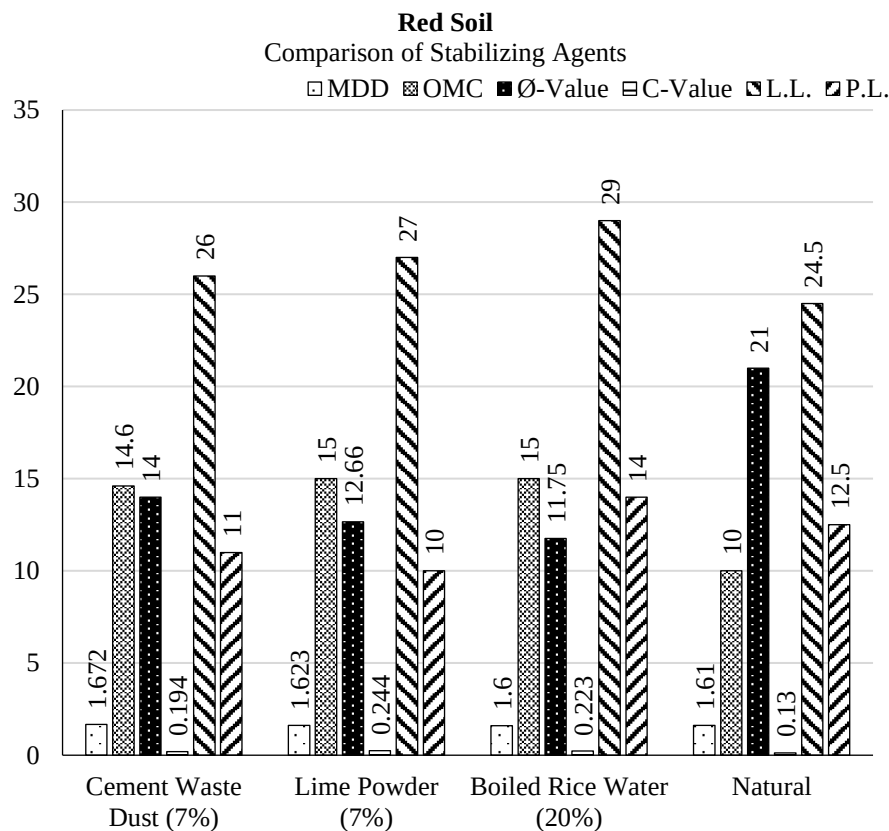


Figure 9. Use of red soil with lower values of stabilizing agents

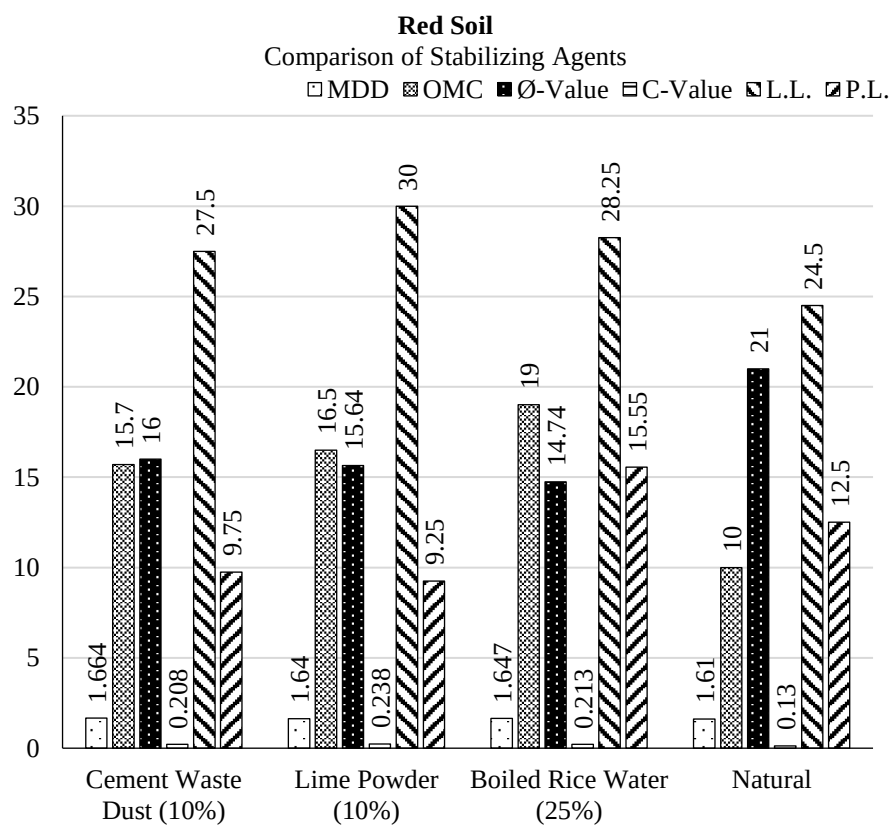


Figure 10. Use of red soil with middle values of stabilizing agents.

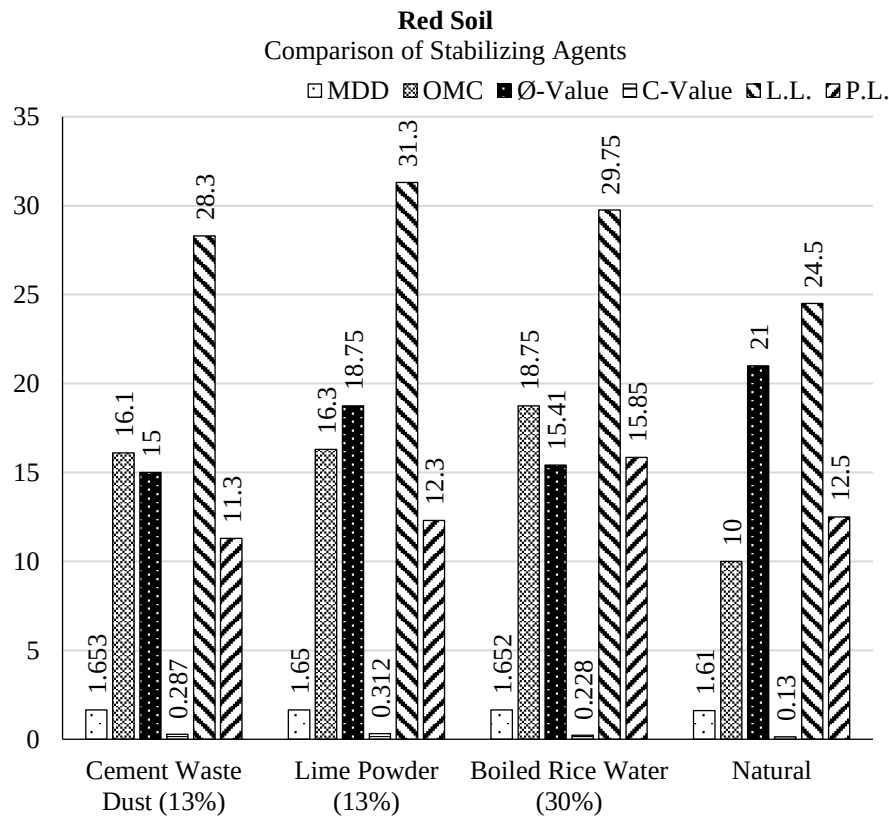


Figure 11. Use of red soil with higher values of stabilizing agents.

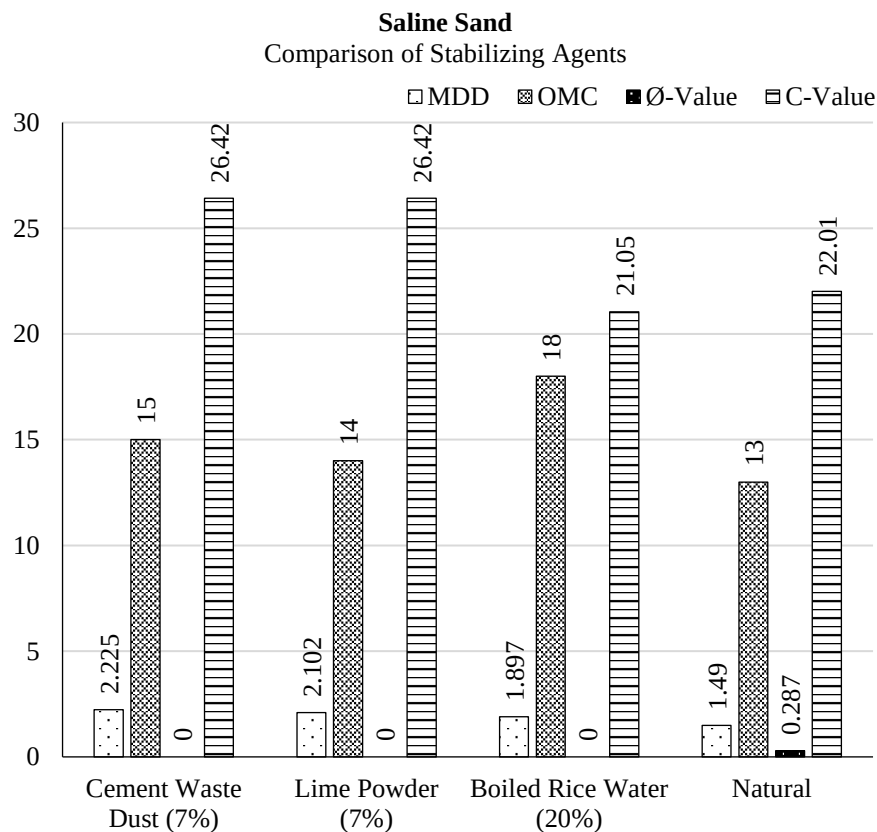


Figure 12. Use of saline sand with lower values of stabilizing agents.

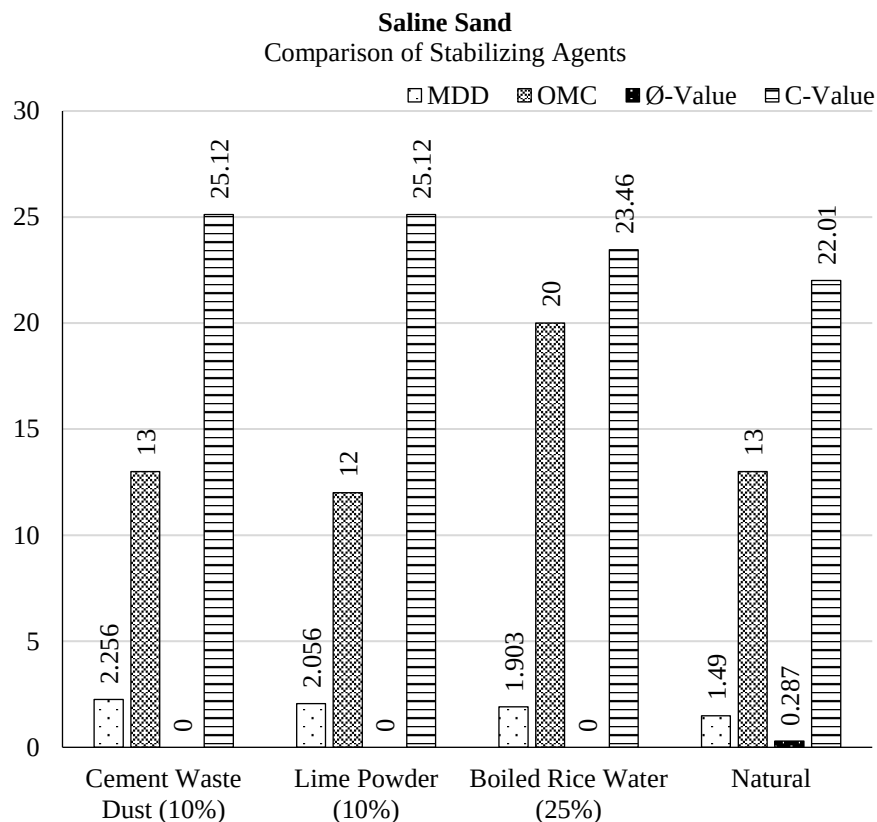


Figure 13. Use of saline sand with middle values of stabilizing agents.

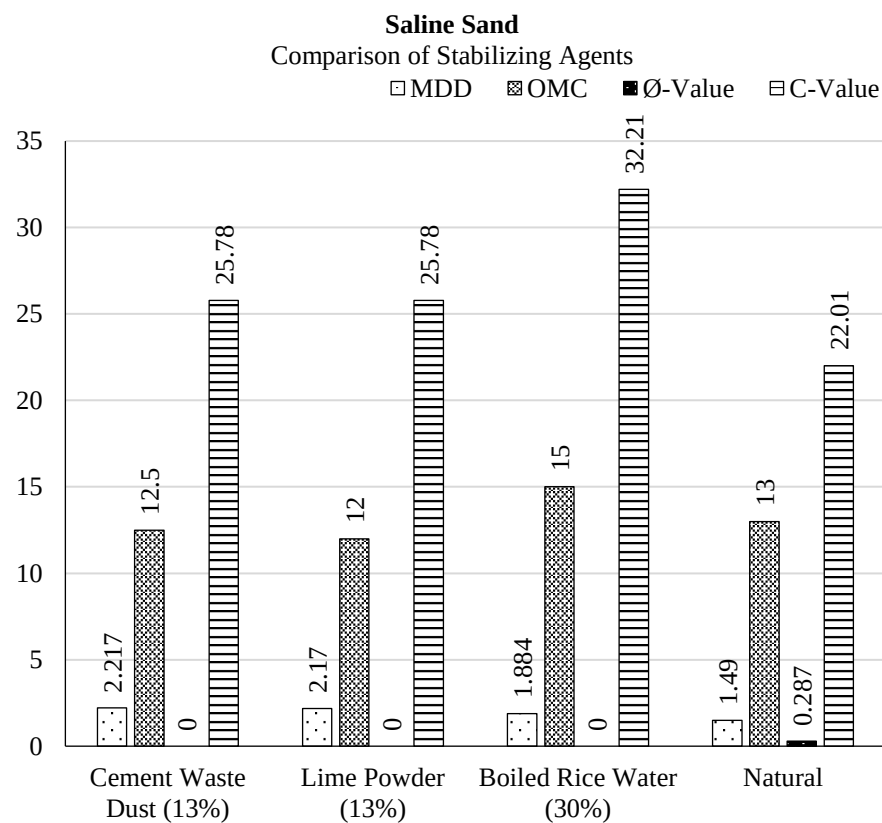


Figure 14. Use of saline sand with higher values of stabilizing agents.

CONCLUSION

From the received data through experiments, it can be said that all stabilizing agents are good enough to expedite the results of soft soil properties. Most effective out of three is ‘*cement waste dust*’ as the values of properties are considerably moved to high values. It also can be observed that cement waste dust has almost same influence on all three types of soils. Lime powder is effective for black cotton soil and red soil but has less improvement in saline sand. Boiled Rice water is more effective to saline sand, but overall performance of boiled rice water is average. Finally, Soils vary throughout the globe, and therefore the engineering properties of soils square measure equally variable. The key to achievement in soil stabilization is soil testing. the strategy of soil stabilization selected ought to be verified within the laboratory before construction and ideally before specifying or ordering.

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