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Comparative Study on Stabilization of Expansive Soil using Cement Kiln Dust and Ceramic Dust

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Abstract
In India, expansive soils cover about 20% of total land area, these soils increase in volume (swell) during winter season and decrease in volume (shrink) during summer season. Due to this contradiction behaviour many civil engineering structures constructed on expansive soils get damaged severely, out of which pavement is the most because they are lightweight and extend over large areas. Stabilization of Expansive soil is of most importance, since to increase the strength of soil and to reduce the construction cost by making best use of locally available materials. The effects of Cement Kiln Dust (CKD) and Ceramic Dust (CD) on expansive soil by conducting the laboratory tests like Atterberg's limit, Compaction characteristics, Unconfined Compressive Strength, California Bearing Ratio, and Free Swell Index etc were studied. Locally collected Black Cotton (BC) soil was mixed with addition of industrial waste materials such as; CKD and CD from 0 to 6% with an increment of 2%. From the analysis of test results, it was found that Liquid Limit (LL), Plasticity Index (PI), Optimum Moisture Content (OMC) and Free Swell Index (FSI) were decreased with an increment of CKD and CD percentage. Plastic Limit (PL), Maximum dry density (MDD), Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) were increased with an increment of CKD and CD percentage. From this study we have concluded that CKD has very high lime (CaO) content up to 60% and CD has very high Silicon dioxide (SiO_2) because of these characteristics, they can be used as effective utilization in roads, embankment and soil treatment for foundation.

***Keywords**: Expansive Soil, BC soil, soil stabilization, CKD, CD*

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INTRODUCTION

Road construction in India faces the big challenge to complete huge projects in the shortest possible construction time. In the booming economy, thousands of new road kilometers are needed and will be built over the short years to expand the network of traffic arteries in the country. Now a day, the major roads are damaged within a short interval of time because of limitation and faster construction. We are focusing on the same problem arising in Sakkarakottai village, Ramanathapuram town, Tamilnadu, India there is a lot of damages occur in the road within a very short interval of time, since the contractor provided the road without strengthening the sub grade. And also the main problem is a huge amount of Expansive soils are present in that area. When load is applied to Expansive soil, it causes serious problem on civil engineering structures, pavements and canal linings due to its tendency of swelling when they absorbs water and shrinks when they dry out. Therefore, it is necessary to stabilize these BC soils before constructing the roads in order to achieve useful and long lasting life [1, 2]. There are numerous innovative foundation techniques have been available in the field to overcome the problem of expansive soils, but they are not suggested in the field, since they are uneconomical [2]. In economical and strengthening point of view, Soil stabilization with various additives is the best method for improving the strength of in-situ soil by means of mechanical or chemical [3–5]. Out of these, chemical stabilization is the vital role for many of the geotechnical engineering applications to avoid the damage due to swelling action of the expansive soils [6, 1, 2]. Since it is a time saving and efficient method that enables the sub grade to formulate good strength as compared to costly excavation and replacement with borrow material.

According to earlier studies they mainly focused on the utilization of chemical additives such as cement, lime, fly ash etc., but they have kept the cost of construction of stabilized road financially high [7, 3, 4]. In order to make the problematic soils useful and meet geotechnical engineering design requirements, we are focusing more on the use of potentially cost effective materials that are locally available (industrial waste). On the other hand, there are many problems arise from the growth of industries in the country. One of them is the proper and effective disposal of its waste in the land, since they causes many serious environment problems [8, 3, 6, 7]. Using industrial waste in construction industry, it is beneficial in many ways such as disposal of waste and also it helps to improve the engineering properties of the soil. In this study, the local expansive soil was mixed with addition of industrial waste materials such as CKD and CD from 0 to 6% with an increment of every 2%. The choice and effectiveness of an additive depends on the type of soil and its field conditions [3, 7]. The main aim of the present work is, to develop an optimum mix composition which can be economically used for stabilization of expansive soil [9].

PROBLEM DESCRIPTION

Clay soil is the major soil naturally occurring near Sakkarakottai village, Ramanathapuram town, Tamilnadu, India. Clay soils are generally classified as expansive one. This means that there is a contradiction, (i.e., shrink and swell) behavior because of seasonal moisture content variation this will create major changes in civil engineering structures all over the world. All civil engineering structural components may crack and heave as the underlying expansive soils become wet and swell. In sometimes the cracking and heaving appear temporarily as the soils dry and shrink as sown in Figure 1. To solve this problem, we need to take preventive measures such as draining of excess water, by mixing the existing soil with different soil which has the same characteristics as that of BC soil and soil stabilization. Purpose of this study is to find the suitable additives for soil stabilization which will give good results and as well as economical one.

Fig. 1: *Cracks in Expansive Soil when Soil is Dry.*

STUDY METHODOLOGY

Selection of Site

In Ramanathapuram city, near Sakkarakottai there is a lot of damages occurs in the road within a short interval of time. Since, a huge volume of BC soils is present in that area; the cracks are induced in the road because of its variation of seasonal moisture content in the soil. To overcome this situation, we are planned to stabilize the soil with different additives such as CKD and CD. The soil sample has been collected from that location at a depth of 1m from the ground level to study the various properties of soil as per IS 2720 code of practice and it was shown in Table.1.BC soil used for this study was classified as well graded soil as per IS Soil Classification system based on the grain size (Figure 2).

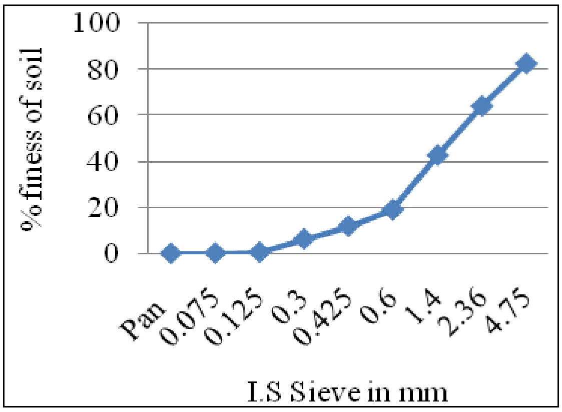

Fig. 2: *Grain Size Distribution Curve for Expansive Soil.*

Table 1: *Properties of Expansive Soil.*

S.No	Characteristics	Description
1.	Grain size Analysis	
	• Sand content (%)	99.5
	• Silt content (%)	0.4
	• Clay content (%)	0.1
2.	Specific Gravity	2.8
3.	Atterberg's Limit	
	• Liquid Limit (%)	50
	• Plastic Limit (%)	26.71
	• Plasticity Index (%)	23.29
4.	Compaction Characteristics	
	• Maximum Dry Density (MDD) in kN/m^3	14.13
	• Optimum Moisture Content (OMC) in %	18
5.	Unconfined Compressive Strength (UCS) in kN/m^2	74
6.	California Bearing Ratio (CBR)	1.60
7.	Free Swell Index (%)	31.80
8.	Color	Black

Selection of Materials as Soil Stabilizers

After studying the literatures on soil stabilization using various additives and visiting various industries, it has been decided to choose the CKD and CD as best suitable additive with expansive soil for stabilization. The main reasons for choosing these materials are they are economical, they have disposal problem since they are waste products and also they are locally available materials [10, 11, 4].

MATERIALS

Cement Kiln Dust (CKD)

Globally growing demand of cement; results in huge emission of kiln dust from cement plants. It is important to dispose this waste material in an economic and safe manner. To overcome this problem, research is being carried out in different parts of world for utilization of CKD in various applications like soil stabilization, cement production, pavements, agriculture and cement products etc. [12, 13, 6, 7].

Production of CKD

CKD is a by-product of Portland cement manufacturing process. Generally, for each one ton of clinker, a typical kiln generates around 0.06 to 0.07 ton of CKD. More than six crore fifty thousand lakhs tons of CKD, unsuitable for recycling in the cement manufacturing process were disposed of annually [13]. Most of the wastes are deposited in landfills, creating a disposal problem and gradual loss of landfill space. And about more than 1 crore tons of CKD, that are not suitable for recycling, are disposed-off annually by cement manufacturing companies in India. In parts of the country CKD is being used increasingly for soil stabilization.

Characteristics of CKD

CKD consists primarily of calcium oxide and silicon dioxide which is similar to the cement kiln raw feed, but the amount of alkalis, chloride and sulphate is usually considerably higher in the dust [6, 8, 13]. However, the alkali by-pass process contains the highest amount by weight of calcium oxide and lowest Loss on Ignition (LOI), both of which are key components in many beneficial applications of CKD [14, 7]. The CKD collected from Ramco cement production plant located in Ariyalur. Because of the high calcium content present in CKD, the hydration process will occur quickly it will induce good bonding characteristics. With this characteristic, we are using this material as additive for soil stabilization.

Chemical Properties of CKD

CKD have different physical and chemical properties and it depends upon the source, type of raw materials used, type of plant operation, fuel type used and disposal practices [15,12]. Table 2 shows the chemical properties of CKD and CD. Generally CKD is grayish in color.

Table 2: *Chemical Properties of CKD and CD.*

CONTENT	CKD (%)	CD (%)
Silicon dioxide (SiO_2)	17.62	68.58
Aluminum Oxide (Al_2O_3)	4.90	27.45
Iron Oxide (Fe_2O_3)	2.58	0.47
Calcium Oxide (CaO)	62.09	0.17
Magnesium Oxide (MgO)	1.93	0.16
Potassium Oxide (K_2O)	3.76	1.84
Sodium Oxide (Na_2O)	0.56	0.32
Sulphur Oxide (SO_3)	5.79	0.13
Titanium oxide (TiO_2)	-	0.75

Ceramic Dust (CD)

In the world a lot of CD is produced during production, transportation and placing of ceramic tiles.

This wastage or scrap material is inorganic material and hazardous. Hence its disposal is a problem which can be removed with the idea of utilizing it as an admixture to stabilize BC soil, so that the mix prove to be very economical and can be used as sub grade in low traffic roads or village roads.

Production of CD

It has been estimated that about 30% of daily production in the ceramic industry goes to be CD. The disposal of which creates environmental and economical problem. To overcome this situation this industrial waste can be used in different application, one of prime is soil stabilization.

Characteristics of CD

CD consists of high SiO_2, Al_2O_3 and Fe_2O_3 contents reaching up to 96%, but the amount of Fe_2O_3 and Tio_2 is 1.22% [16]. The CD collected from Government Ceramic Institute (ceramic plant), Vridhachalam, Tamilnadu, India. Because of high silica content present in CD, the binding capacity of soil is increased.

EXPERIMENTAL STUDY

Preparation of sample

BC soil has been tested to find the various properties using additives such as CKD and CD with partial replacement of weight of soil. CKD and CD is added to natural soil for preparation of sample from 0 to 6% with every increment of 2%.

Total of seven different specimens were prepared to study the properties of stabilized soil. For the preparation of each specimen all the materials were mixed thoroughly by hand so that homogenous sample can be prepared.

Testing Procedure

Different soil laboratory tests carried out on the above samples as per IS-2720 such as Particle size distribution, Specific gravity, Atterberg's limit, Compaction Characteristics, UCS, CBR and FSI etc. From these test results, Geotechnical and Engineering properties of the soil were determined. For UCS test, the sample is prepared at OMC and MDD.

RESULTS AND DISCUSSIONS

Soil has been tested with the additive at different proportion to find the basic index properties like Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI), Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Free Swell Index (FSI) and Engineering properties such as Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR).

The result analysis is carried out for both admixtures and the results are as shown in the following figures.

Effect of Additives on Atterberg's Limits

The results of Liquid Limit (LL) tests on expansive soil treated with different percentage of CKD and CD are shown in Figure 3. From the figure, it can be seen that the LL of soil goes on decreasing with increase in percentage of CKD and CD [17, 18]. The effect of CKD on LL shows better performance than CD.

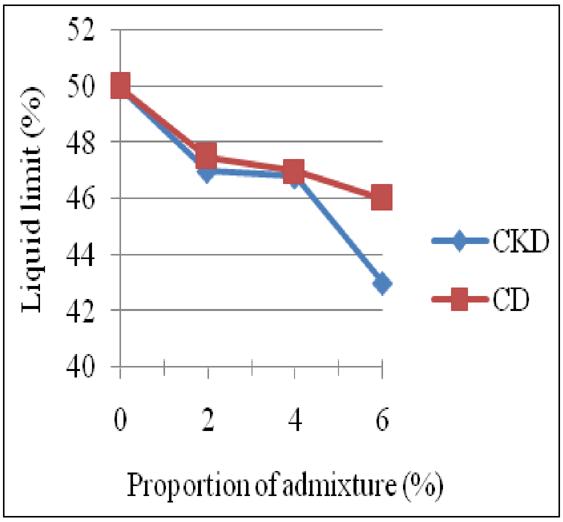

Fig. 3: *Comparison of LL for CKD and CD.*

The results of Plastic Limit (PL) tests on expansive soil treated with different percentage of CKD and CD are shown in Figure 4. From the figure, it can be seen that the PL of soil goes on increasing when the soil is treated with different percentages of CKD and the PL of soil goes on decreasing when the soil is treated with CD up to 4%, after that it was increasing [18, 19].

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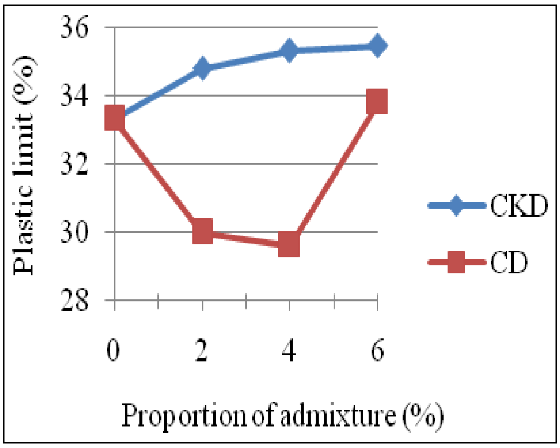

Fig. 4: *Comparison of PL for CKD and CD.*

The results of Plasticity Index (PI) on expansive soil treated with different percentage of CKD and CD are shown in Figure 5. From the figure, it can be seen that the PI of soil goes on decreasing with increase in percentage of CKD and CD [18, 19]. If lesser the PI, the strength will be high and also the workability of soil will increase having less affinity for water [20].

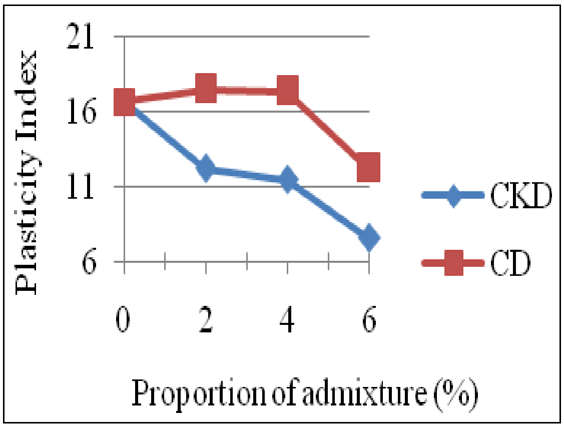

Fig. 5: *Comparison of PI for CKD & CD.*

Effect of Additives on MDD and OMC

The results of standard Proctor tests on expansive soil treated with different percentage of CKD and CD are shown in Figures 6 and 7. From the figure, with increase in percentage of CKD up to 4, the MDD of soil goes on increased and after that it was decreased in 6% but OMC was increasing [19]. With increase in percentage of CD, MDD of soil goes on increasing but OMC was decreasing [18]. Reason of such behavior is due to replacement of additive particles having high specific gravity with soil particles having low specific gravity.

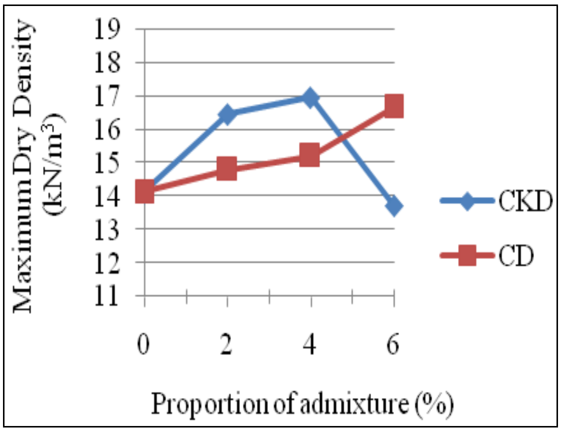

Fig. 6: *Comparison of MDD for CKD & CD.*

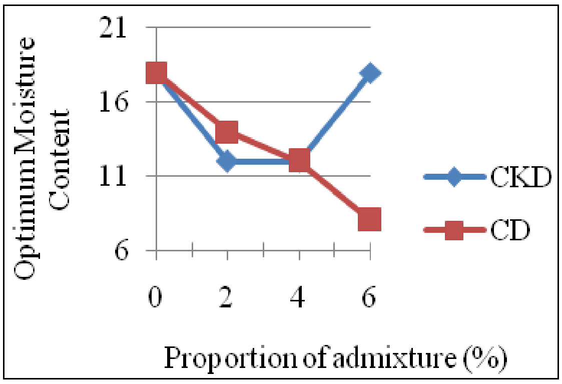

Fig. 7: *Comparison of OMC for CKD and CD.*

Effect of Additives on CBR

The results of CBR on expansive soil treated with different percentage of CKD and CD are shown in Figure 8. From figure it has been concluded that the value of CBR constantly increases with the increase in proportion of CKD. With increase in percentage of CD up to 4%, the CBR of soil goes on increased and after that it was decreased in 6% [18]. CKD has more effective than CD in soil while doing the CBR test.

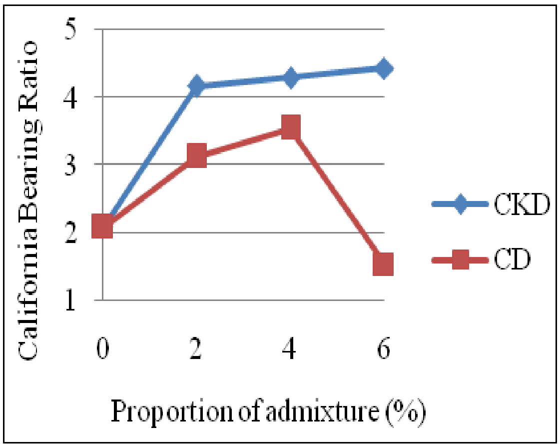

Fig. 8: *Comparison of CBR for CKD and CD.*

Effect of Additives on UCS

Figure 9 shows the UCS tests results for both admixtures used in soil. With increase in CKD and CD content leads to an increment of the strength [18, 19].

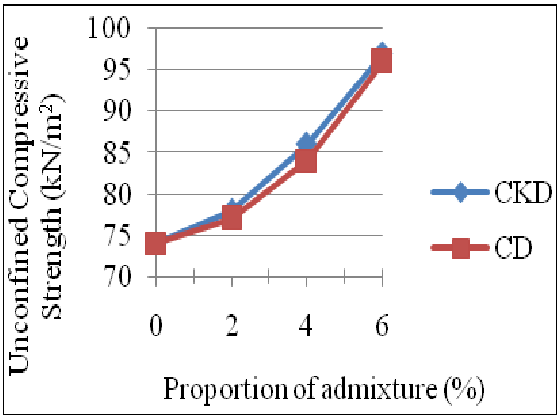

Fig. 9: *Comparison of UCS for CKD and CD.*

Effect of Additives on FSI

Table 3 shows the FSI value for expansive soil before and after the treatment. The results showed that the FSI value decreases with increase in percentage of CKD and there is no swelling in the soil, after treating the soil with CD.

Table 3: *Comparison of FSI for CKD and CD.*

Proportion of admixture (%)	FSI for CKD	FSI for CD
0	31.08	31.08
2	22	Nil
4	18.18	Nil
6	18.18	Nil

CONCLUSION

LL, PI and FSI properties was decreased but PL and CBR value was increased when CKD was added with BC soil. MDD value was increased with 4% addition of CKD and it was decreased while 6% addition with BC soil. But OMC value decreased with 4% usage of CKD and with 6% usage of CKD, the OMC value was same as untreated expansive soil. With addition of CD to BC soil, LL, PI and OMC value was decreased but MDD was increased, there is no free swell occurs in the soil. While using CD up to 4%, the PL and CBR value was increased and after that it was decreased with 6% addition with BC soil. With these test results, in economic and strengthening point of view we have suggested that up to 4% both the additives, (i.e., CKD and CD) are effective for stabilizing the expansive soil in road works. But, CKD is more effective than CD for stabilization of soil.

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