STABILIZATION OF SOFT SOIL USING CEMENT KILN DUST

[1]Asst. Prof. Aloka Ranjan Sahu, [2]Asst Prof. Rojali Patra, [3]Sr. Lect. Sridhar Sahu, [4]Sr. Lect .Sagar Priya Sahu, [5]Asst Prof.Sunil Kumar Sabat

[1,2,3,4] Dept. Of Civil Engineering, [5]Dept. Of Mechanical Engineering

Gandhi School of Engineering, Berhampur

ABSTRACT

Presently, disposal of industrial waste products have been a global problem. Their disposals are costly as well as they are harmful to environment. Owing to these problems some researchers are being conducted to utilise these waste products in ground construction and modification. Cement kiln dust (CKD) is the one of these industrial waste products, which is a by-product of Portland cement manufacturing process. Cement is a most widely used construction material, which is result in a huge collection of cement kiln dust from cement plants. Soil stabilization, waste product stabilization, agriculture and cement products are some of the application in which cement kiln dust can be utilised effectively.Poor soil conditions can result in inadequate strength and bearing capacity of soil. Soil stabilization may be broadly defined as the alteration or preservation of one or more soil properties to improve the engineering characteristics and performance of a soil. In this project work, Soil stabilization is done with the addition of CKD which is added from 0%to 30% by dry weight of soil. First of all, native soil properties like compaction characteristics, Atterberg's limits, compressive strength, CBR and permeability has been checked and then compared after addition of CKD from 0% to 30%.

I.INTRODUCTION

Bearing capacity of soil played a major role in decision making on site selection for geotechnical projects. Once the bearing capacity of the soil was poor, the following were options:

- Change the design to suit site condition.
- Remove and replace the in situ soil.
- Abandon the site.

Abandoned sites due to undesirable soil bearing capacities dramatically increased, and the outcome of this was the scarcity of land and increased demand for natural resources. Affected areas include those which were susceptible to liquefaction and those covered with soft clay and organic soils. Other areas were those in a landslide and contaminated land. However, in most geotechnical projects, it is not possible to obtain a construction site that will meet the design requirements without ground modification. The current practice is to modify the engineering properties of the native problematic soils to meet the design specifications. Now a day, soils such as, soft clays and organic soils can be improved to the civil engineering requirements. Keeping in this mind, it has been planned to study the soil characteristics with the soil stabilization method which is one of the several methods of soil improvement. Soil stabilization aims at improving soil strength and increasing resistance to

Softening by water through bonding the soil particles together, water proofing the particles or combination of the two. Stabilizing agents such as lime, fly ash, rice husk ash, blast furnace slag, cement kiln dust etc. are the various waste products. The use of various waste products in civil engineering construction has gained considerable attention in view of economy & eco-friendly. Also increasing cost of waste disposal and environmental degradation are the main concerns due to these waste products. To protect the environment from degradation due to these waste products, the utilization of waste is the major task for the civil engineers. Keeping these objectives in mind this this project is taken for the utilization of Cement kiln Dust as stabilizing agents to enhance the engineering properties of soil.

The main objective of this project is to increase the strength and stability and enhance the feasibility of soil and to reduce the construction cost by making best use of cement kiln dust.

II.OBJECTIVE

The following objectives which can be put forth as follows:

1. Efficient use of CKD for stabilization of clayey soil
2. Increase parameters of soil like strength using cement kiln waste in various proportions.

III.EXPERIMENTAL WORK MATERIALS

The soil was classified as clayey sand with low plasticity and the properties of soil are given in Table 3.1

Properties of Soil Sample Table 3.1

S. No.	Parameters	Values
1.	Specific Gravity	2.65
2.	Optimum Moisture Content	14.10 %
3.	Maximum Dry Density	1.77 g/cc
4.	Liquid Limit	38.00 %
5.	Plastic Limit	18.97 %
6.	Plasticity Index	19.03 %
7.	Category of Soil	
	As per USC System (fines fraction)	Cu = 8.771 Cc = 0.740 Poorly graded sandy soil
	As per USC System (A-line chart)	Clayey Sand (SC) Low Plasticity (CL)

Cement Kiln Dust: As the name implies, Cement kiln dust is fine powder-like by-product of Portland cement production. They are collected from the stacks of high-temperature rotary kilns by the federally mandated dust collection systems (e.g., cyclones, electrostatic precipitators, and/or bag houses). Large quantities of cement kiln dustare produced during the manufacture of cement clinker by the dry process. Several factors influence the chemical and physical properties of CKD, because plant operations differ considerably with respect to raw feed, type of operation, dust collection facility, and type of fuel used. The dust from each plant can vary markedly in chemical, mineralogical and physical composition. The research described in this project work was conducted exclusively with pre-calcinerCKD from Kalyanpur Cements Ltd. Banjari (INDIA) and all results and conclusions of the report are intended to refer to CKD from kalyanpur Cements Ltd. Banjari (INDIA).

CKD consists primarily of calcium carbonate 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. CKD from three different types of operations: long wet. Long-dry and alkali by-pass with precalciner were characterized for chemical and physical traits by Todres et al. (1992). CKD generated from long-wet and long-dry kilns is composed of partially calcined kiln feed fines enriched with alkali sulphates and chlorides. The dust collected from the alkali by-pass of precalciner kilns tend to be coarser, more calcined, and also concentrated with alkali volatiles. 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. Table1 provides the composition breakdown for the three different types of operation and includes a typical chemical composition for Type I Portland cement for comparison.

Table 3.2: **Typical Chemical Composition of Cement Kiln Dust**
(Source: Kalyanpur Cement Ltd. Banjari, INDIA)

Oxide	CaO	Al_2O_3	SiO_2	Fe_2O_3	Mn_2O_3	Na_2O	K_2O	Loss of Ignition
Concentration (%)	50.81	4.71	17.18	1.92	0.002	0.001	1.35	24.03

IV. METHODS

To study about soil stabilization, soil is mixed with CKD and their engineering properties were determined. Laboratory tests have been planned in such a way that it takes into account all the related aspects, such as related percentages of CKD are mixed at calculated OMC and dry weight of soil. Following laboratory tests have been conducted as per IS-2720-(1985) (Reaffirmed 1995):

1. **Soil Compaction Test (Light Compaction Test) as per IS-2720 (Part VII)**
2. **Atterberg's Limit Test (Liquid limit & Plastic Limit) as per IS-2720(Part V)**
3. **Unconfined Compression Test as per IS-2720 (Part X)**
4. **CBR Test as per IS-2720 (Part 16)**
5. **Permeability Test (Falling head method)**

V. RESULT AND DISCUSSION

Following laboratory test results are obtained for different percentages of CKD (0 % to 30 %) when mixed with dry weight of Soil is given in table 5.1

Table 5.1: Laboratory Test Results

CKD (%)	OMC (%)	MDD (g/cc)	W_L (%)	W_P (%)	I_P (%)	UCS (kg/cm^2)	Soaked CBR (%)	Unsoaked CBR (%)	Permeability (k) (cm/ sec)
0	14.10	1.77	38.00	18.97	19.03	0.949	2.64	3.40	$2.661x10^{-5}$
5	14.40	1.75	37.80	19.99	17.81	1.073	3.85	3.96	$2.275x10^{-5}$
10	14.80	1.72	36.75	22.02	14.73	1.441	4.30	4.29	$1.785x10^{-5}$
15	15.20	1.70	35.25	22.60	12.65	1.816	5.02	4.98	$1.644x10^{-5}$
20	15.50	1.69	35.02	24.36	10.66	2.383	5.54	5.27	$1.392x10^{-5}$
25	15.90	1.67	34.78	25.73	9.05	2.629	6.02	5.85	$5.825x10^{-6}$
30	16.30	1.65	33.50	26.00	7.50	2.833	6.74	6.35	$2.565x10^{-6}$

Compaction Test Result:

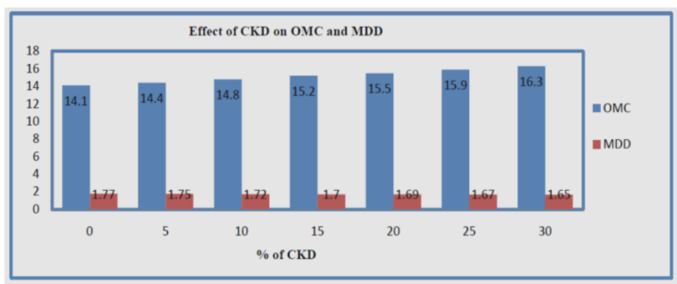

Fig. 5.1 OMC and MDD at varying percentages of CKD

As per above Fig. 5.1, OMC is increasing but MDD is decreasing gradually as finer particles of CKD are increasing. When CKD is used as soil stabilizing additive, Soil particles become large-sized clusters, resulting in texture change.
This flocculation-agglomeration process results in flock formation. The enlarged particle size causes the void ratio to increase. This increase in void ratio

reflects the decrease in MDD and increase of moisture content for the Soil-CKD mixture.

Table 5.2: Liquid Limit & Plastic Limit Test Result

LIQUID LIMIT TEST RESULTS:				
DETERMINATION NUMBER	1	2	3	4
WT. OF CONTAINER(W1)	25	25	25	25
WT. OF CONTAINER+WET SOIL(W2)	52	69	64	52
WT. OF CONTAINER+DRY SOIL(W3)	48	61	56	46
WEIGHT OF WATER(Ww)=W2-W3	4	8	8	6
WEIGHT OF DRY SOIL(Ws)=W3-W1	23	36	37	21
MOISTURE CONTENT(%) W.C=Ww/Ws	17.14%	22.20%	25.80%	28.50%
NUMBER OF BLOWS	156	77	72	54

PLASTIC LIMIT TEST RESULTS:			
CONTAINER NUMBER	1	2	3
WT. OF CONTAINER(W1)	26	27	26
WT. OF CONTAINER+WET SAMPLE(W2)	29	29	29
WT. OF CONTAINER+DRY SAMPLE(W3)	28	30	28
WEIGHT OF DRY SAMPLE(Ws)=W3-W1	2	3	2
WEIGHT OF WATER IN THE SOIL(Ww)=W3-W2	1	1	1
MOISTURE CONTENT (%) W.C= $\frac{W3-W2}{W3-W1}*100$	50%	33.30%	50%

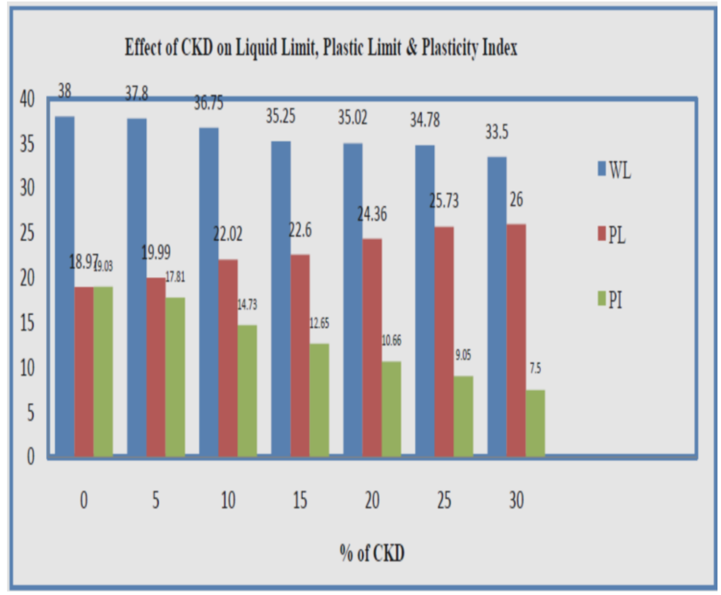

Fig. 5.2 Liquid Limit, Plastic Limit & Plasticity Index at varying Percentages of CKD

Atterberg's limit indices variation with CKD content is shown in figure 5.2. Liquid limit and Plastic limit increased with CKD content, while the Plasticity index decreased with CKD content. This is due to the presence of Ca2+, Si2+, andAl3+cations with increased CKD usage they react with soil particles. This reduction in the plasticity may be attributed to the chemical and cementation effect on structural composition of the soil. Since the modification of soil particles leading to increase the effective particle size (resulting from inter-particle cementation), consequently the amount of moisture that attracted to these particles decreased. The increase in Plastic limit may be attributed to the quantity of water used should be just sufficient to satisfy hydration requirements of the CKD and to make the mixture workable.

Unconfined Compression Test Result:

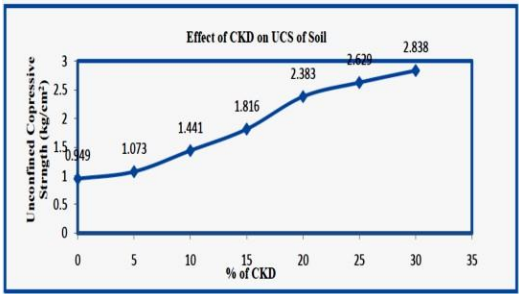

Fig. 5.3 UCS of Soil at varying Percentages of CKD

From above fig. 5.3, it can be seen that the Unconfined Compressive Strength of the Soil sample have increased as the percentage of CKD increases. The Unconfined Compressive Strength at 30% addition of CKD to the soil is 2.833 kg/cm^2. As compared to the untreated soil (at 0% CKD), the percentage increase at 30% addition of CKD to the soil is about 198.52%. This is due to the fact that addition of CKD make available additional amount of Silica and lime than that of present in natural soil only.

CBR Test Result:

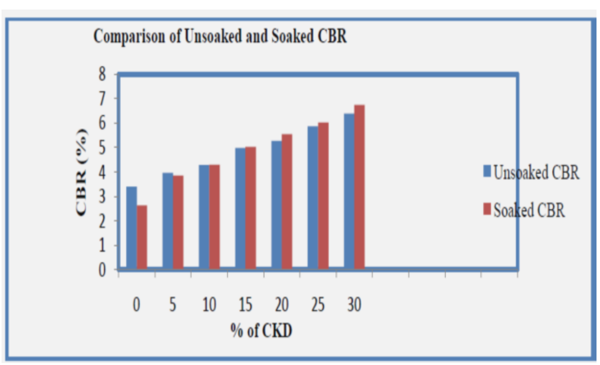

Fig. 5.4 Unsoaked& Soaked CBR Variation of Soil-CKD Mix.

Here, as per above fig. 5.4, Soaked CBR value is greater than Unsoaked CBR value at 10% addition of CKD and onward.

This incensement may be attributed to the chemical and cementation effect (the Oxides amount in the CKD is about 2/3rd of Oxide amounts found in Portland cement) on structural composition of the soil. Presence of Ca2+, Si2+, andAl3+cations in CKD, it react with water and resulting in the formation of Calcium-Silicate-hydrates (CSH) and Calcium-Aluminates-hydrates (CAH). CSH and CAH are cementation products similar to those formed in Portland cement. Time duration and sufficient water favors these reactions.

Permeability Test Result:

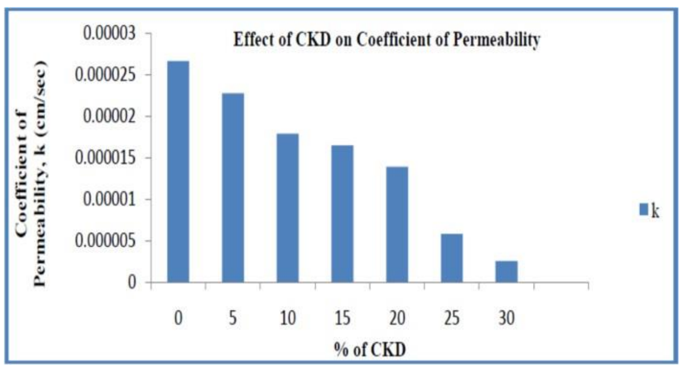

Fig. 5.5 Coefficient of Permeability with varying Percentages of CKD

From above fig. 5.5, it can be seen that the Permeability of the Soil Sample have decreased as the percentage of CKD increased. The Coefficient of Permeability at 30 % addition of CKD to the soil is 2.565x10-6cm/sec. As compared to the Untreated Soil (at 0 % CKD), the percentage decrease at 30 % addition of CKD to the soil is 90.36 %. This is due to the increase in finer material as percentages of CKD increase in the Soil-CKD mixture. Permeability decreases even further because of the growing reaction products (CHS & CAH) and reduction in connected voids.

Fig. 5.6 Sieve Analysis

Fig. 5.7 Liquid Limit

Fig. 5.8 Liquid Limit

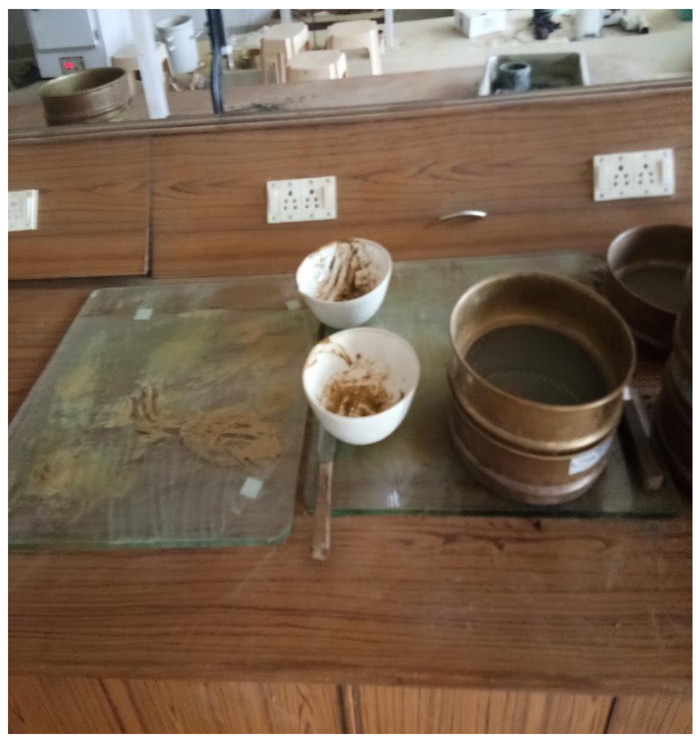

Fig. 5.9 Plastic Limit

VI.CONCLUSION

Based on the obtained results and discussion there of following conclusions can be made:

The compaction characteristics of soils vary significantly with CKD content. The optimum moisture content increases and maximum dry density decreases with increased CKD content.

As compared to untreated soil, the percentage increase in OMC at 30% addition of CKD to the soil is15.60%, and percentage decrease in MDD is 7.27%. Liquid limit decreases and Plastic limit of soil increases as the percentage of CKD increases. The Plasticity index of soil reduces with increased CKD content. Reduction in Plasticity index is 60.58%. Hence the soil samples become less plastic and compressible. With increases of CKD percentage compressive strength of soil increases. Percentage increase in compressive strength of soil is 203.79%. CBR value for soaked and unsoaked condition increases with increases in percentage of CKD. Percentage increase in CBR value for soaked and unsoaked is156.06% and 86.76% respectively. CBR values of soil are indicator of sub-grade soil strength and are often used for design of flexible pavement. The CBR value of CKD treated soil is 6.76% which can be used for the designing of flexible pavement for light and medium traffic Coefficient of permeability i.e., Hydraulic conductivity of soil reduces with increased CKD percentages. Percentage reduction in Permeability of soil is 90.36%; hence stabilized soil may be used for the impervious core in embankment and, the treated soil could be used as a soil-based barrier layer for containment of hazardous waste. This project work concluded that CKD is potentially useful in stabilizing of soil. 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. CKD is an effective soil stabilization agent, based on the results observed and described in this thesis. It is recommended that it can be considered for use in the stabilization of soil.

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