Evaluation and Analysis of Soil Stabilized with Cement Kiln Dust and Ceramic Waste Powder

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Abstract - An Expansive soil was collected locally and then it was stabilized with 3,6,9 and 12% CKD which was admixed with 5,15,25 and 35% ceramic waste Powder(CWP) each. Index properties tests were conducted on the untreated Expansive soil while compaction tests, California Bearing Ratio test and unconfined compressive strength tests were carried out on the untreated expansive soil admixed with varied composition of CKD and CWP. Results from index properties showed that the soil was classified as soil of high plasticity based on unified soil classification system. The maximum dry densities (MDD) were observed to increase with increase in CKD and CWP while the optimum moisture content (OMC) increases in the same order. The unconfined compressive strength (UCS) increased with increase in CWP. The CBR value also increased with increase in CWP. A maximum of 274kPa was recorded at 9% CKD and 35% CWP after 28 days of curing. This maximum value satisfied the requirement for a stabilized material to be used as base course material for highly trafficked roads. Significant increase in UCS was also observed with increase in curing days which signifies the existence of Pozzolanic reaction in the mixture. 35% CWP can therefore be used for effective stabilization of expansive soil.

***Key Words*:** CBR, UCS, Cement kiln Dust, Ceramic waste powder.

1. INTRODUCTION

Expansive soils are one of the most widely found soils across the globe. Due to containment of swelling minerals in considerable proportion with net electro-negative arrangement of ions, these clays possess extraordinary ability to absorb water resulting in low-strength and high-swelling structure of soil. These soils produce some of the major ill effects in the structural elements constructed over them due to their high activity and volume change behavior, seriously hurting the utility of the structure. Chemical stabilizers have proved to be satisfactory modifier of the inherent structure of the soil. Although the conventional stabilizers such as lime, cement and fly ash have shown their ability to successfully enhance the utility of the soils for engineering purposes, their rising cost and environmental concerns including their carbon footprint have led researchers to focus on the more sustainable and environment-friendly form of stabilizers which could replace the former ones. Expansive are characterized by their significant volumetric fluctuations with the varying water content in the soil mass. The strength properties (cohesion, specific gravity, and friction angle) of soils of the same field have different properties. A large part of Central and South India covered with Expansive soils. These soils have high shrinkage and swelling behavior and low shear strength. Due to the dual swelling shrinkage nature of Expansive soil, it poses problems in constructing structures like pavements, multi-story buildings. The Expansive soil sub grade swells during rain and shear failure in the structure occur. Various mechanical and chemical methods were used to mitigate the swelling pressure and heave phenomena of the Expansive soil. Mechanical and chemical stabilization methods are the oldest and traditional methods used to improve the engineering properties of Expansive soils. However, these methods are time consuming and uneconomical. Geo-synthetic has now emerged as one of the cost-effective and sustainable construction materials. The separation, filtration, reinforcement, and stiffening are some of the primary function which can be used to enhance the engineering properties of the sub grade layer.

The focus of this paper is to assess the impact of Cement kiln dust as an alternative reinforcement to

Expansive soil stabilization with the use of Ceramic waste.. The attempt has been made to explore an alternative of traditional cement treatment ceramic waste and Cement kiln dust.

2. LITERATURE REVIEW

Mohammad Sidiq et al. (2023)

CD in different proportions 0%, 6%, 12% respectively and partially replaced the soil to stabilize the soil characteristics. For the atterberg limit test, when the same percentages of CD were added to the soil, both L.L. and P.L. values decreased, while for P.I. the case was different, as up to a 6% increment in CD slightly lead to increase in the P.I. value, but when 12% CD was introduced to the soil, the value of P.I. started to drop and decrease. In the case of carrying out a proctor test, the results showed that the same percentages of CD increased the value of MDD, respectively. but, for OMC, on the contrary the value decreased when the CD added for both percentages 6% and 12%.the result tests for UCBR displayed that addition of the CD .percentages to the soil made improvements in the soil and the values of UCBR increased respectively. Eventually the result values confirmed that CD could be in a great advantageous when used with the aforementioned percentages, because improves the clay soil characteristics.

Saber, S. A.et al (2022) had studied the geotechnical properties of a type of clay soil after addition of ceramic dust in percentages 0%, 5% and 10%.the result values showed that the ceramic dust when added to the clay soil decreased the values of specific gravity, also in atterberg limit the ceramic dust up to 10% usage, decreased both liquid limit and plastic limit. Since only 5% of CD was used, the PI value only slightly increased, whereas if 10% of CD was used, the PI value decreased, there is little impact of CD on the PI toward increasing. The study also focused on another test, known as Proctor test, as in the details showed that the ceramic dust percentages permanently increase the value of maximum dry density (MDD), while decreased the value of optimum moisture content (OMC). An additional test used in research is unsoaked California bearing ratio (UCBR).the data values and the curves Clearly revealed that the addition of CD to the clay soil worked well and raised the values of CBR.

Mahmud et al. (2020) he maximum dry densities (MDD) were observed to reduce with increase in cement and CWP while the optimum moisture content (OMC) reduces in the same order. The unconfined compressive strength (UCS) increased with increase in CWP for specific cement addition, to maximum of 30% CWP after which the values were observed to drop. 30% CWP is therefore the optimal CWP required for maximum UCS strength. A maximum of 2700kN/m2 was recorded at 6% cement and 30% CWP after 90days of curing. This maximum value satisfied the requirement for a stabilized material to be used as base course material for highly trafficked roads. Significant increase in UCS was also observed with increase in curing days which signifies the existence of Pozzolanic reaction in the mixture. 30% CWP can therefore be used for effective stabilization of cement stabilized clay soil

Vivek Singh et al. (2015) in this study cement kiln dust use in the soil and waste materials and thus results of experimental investigation on its use in stabilisation of soil. Soil samples were tested with the CKD from 0% to 22.5% of dry weight of the soil, samples were prepared and results showed a significant increase in soaked California Bearing Ratio and Unconfined Compressive strength values. In this investigation the result shows that CKD has tendency to improve the characteristics of black cotton soil.

Al-hassani et al. (2015) investigate the feasibility of utilization CKD for the stabilization of soil. The characteristics of two types of cohesive soils of different Expansive content treated by CKD were studied. The direct shear test, UCS test, permeability and durability tests were reported. Several tests were carried out to determine the effect of curing period on the UCS and permeability of soil.

Jijo james et al. (2017) Addition of ceramic dust to cement in soil stabilization resulted in significant strength gain at an early age. The gain in strength is better at higher ceramic dust content for all cement contents tested, which may be due to it adding bulk, resulting in an even distribution of active cement.

Singh et al. (2015) presented the laboratory experiments performed to investigate the effect of cement kiln dust on index properties of black cotton soil, an Expansive in nature, that has a very poor geotechnical behavior which renders unfit to the civil engineering projects, such soil need to be improved for construction activities. Aim of study was to evaluate the industrial waste like CKD as stabiliser. Test results in the significant changes in consistency limits of samples containing cement kiln

dust. Liquid limit decreased from 63.62% to 43.82%,Plastic limit from 32.18% to 27.84%,Plasticity index from 31.44% to 15.98% and shrinkage limit increased from 14.56% to 25.73% with the addition of CKD from 3% to 22.5% of the dry weight of black cotton soil. Differential free swell decreased from 31% to 2.5%. From this laboratory research it was concluded that waste material like cement kiln dust generated from cement industry has a potential for stabilizing the characteristics of Expansive behavior of black cotton soil. There is a significant improvement in the index properties of black cotton soil on addition of CKD. The Expansive behavior of clay has been reduced to great extent.

Salahudeen et al. (2014)showed that the index properties of the soil improved with CKD treatment. Peak unconfined compressive strength of 357.07 kN/m^2 and California bearing ratio CBR of 7 % as well as resistance to loss in strength of 44 % were recorded at 10 % CKDtreatment. Reduction in the particle sizes with curing period was observed when samples were viewed through the scanning electron microscope. The study showed that CKD can be beneficially used to improve the subgrade of lightly trafficked roads and as admixture in lime stabilization during construction of flexible pavements over Expansive soil.

Y. Keerthi et al. (2013) established that the chemical compounds found in soil; quartz, feldspar, dolomite, calcite, montmorillonite, kaolinite etc. react with the chemical constituents found in different identified chemical stabilizers. The purpose of using CKD, and the other additives, is to improve the texture, increase the strength and reduce the swell characteristics of the various soils. This paper represents the stabilization of Expansive soil using cement kiln waste. The soil taken from Ravendrapadu in Andhra Pradesh containing different properties in various percentages is mixed with CKD in different proportions and parameters like dry density and moisture content were found out. By examining the values obtained ideal values were obtained at 50% proportional mix of CKD in total percentage.

Kumar et al. (2013) investigated shear strength characteristics as well as mechanical strength of Kaolinite clay soil treated with 5, 10, 15, 20 and 25 % by weight of cement kiln dust. It was observed that up to 20 % mixing of admixture, unconfined compressive strength and undrained shear strength increase significantly then decrease with further increase in percentage of stabilizer. However, when the same samples were tested for mechanical strength by performing CBR tests, it was observed that the CBR values increases with increase in percentage of CKD. Overall, it was observed that the cement kiln dust effectively increases strength and hence make clays suitable for building pavements over it.

Colangelo et al. (2013) carried three different samples of solid industrial wastes CKD, granulated blast furnace slag and marble sludge were in a cold bonding pillarization process for the sustainable production of artificial aggregates. The activating action of cement kiln dust components on the hydraulic behavior of the slag was explored by evaluating the neo-formed phases present in several hydrated pastes. Finally, lightweight concretes were obtained, proving the suitability of the cold bonding pillarization process in artificial aggregate sustainable production.

Oza et al. (2013) tested Black Cotton Soil using three different stabilizing agents Cement waste dust collected from the cement plant, Cement Dust, Lime Powder. The results provided satisfactory reason to use the Cement dust as a stabilizing agent for the purpose to improve Plasticity Index of Black Cotton Soil compare to other two combinations. After satisfying result of Plasticity Index, Cylindrical Samples of Black Cotton Soil with all three combinations were prepared to identify the compressive strength of stabilized soil. Moisture content taken was the optimum percentage of plastic limit in each combination. Compressive strength of Cement dust stabilized Black Cotton Soil was found more reliable.

Nandan A. Patel et al (2013)the quality and life of asphalt is enormously influenced by the sort of subgrades. The CBR of this subgrade have low strength, so it needs to more thickness of pavement. In the accessibility of suitable sub base and base materials for asphalt development have prompts a look for financial technique for changing over generally accessible tricky soil to suitable development materials. Soil stabilization is very necessary by the addition of admixtures in suitable dosages for road pavement foundation because it improves the engineering properties of soil to bear load carrying capacity in terms of quality and quantity of performance. In this work the Recron-3s Fibre is used as the stabilizers in improving engineering properties soil. This experiment evaluates the effect of the Recron-3s on the some basic engineering properties of soil by using of Recron-3s fibres from 0.5% to 2.0%. Four proportion of recron-3s fibre i.e. 0.5%, 1.0%, 1.5% and 2.0% were used to quantify the optimum quantity of Recron-3s on

the performance in terms of CBR value and UCS of the soil.

P.v koteswara rao et al (2012) studied the performance of recron-3s fibre with CKD in Expansive soils. In this study the influence of polymer fibres on the properties of locally available Black cotton soil with and without admixture. This study results that fibre reinforcement improves the soil properties in terms of improved stress-strain patterns and progressive failure in place of quick post peak failure of samples. The UCS of Expansive soil is increased by 7 times with stabilization and 9 times for admixture with fibresamples. Stabilization of soil and admixture with fibre, results the shear parameter of soil increased. The California Bearing Ratio value also increased significantly for soaked CBR tests. The Liquid limit of the mixture is decreased 23 % by the addition of cement kiln dust, where plastic limit is increased by 41%. Plasticity Index of the mix is decreased by 57%.

P.SowmyaRatna et al (2008) studied the Performance of Recron-3s Fibre with Lime in Expansive Soil Stabilization. The properties of black cotton soil can be altered in differentways asmechanically, thermally and chemically. Therefore soil stabilizationis necessary to ensure the better stability of soil so that soil can successfully bear the load of the superstructure especially in case of soil which is highly active. In this work, an attempt has been made to study the compaction and CBR test for black cotton soil mixing with different proportion of lime and Recron-3s Fibre to determine the optimum percentage. Test results shows that stabilizing Expansive soils with lime and imparting Recron-3s fibre enhance the strength. The study yielded the following conclusions based on the laboratory experimentation carried out in this investigation. Addition of lime has shown decrement in liquid limit from 84% to 67% and improvement in plastic limit from 55% to 60.5% and plasticity index decrease from 29% to 26.4% when the lime content varies from 0% to 6% mixed in Expansive soil, result of cation ions from the lime which reduces the volumetric changes.

3. Materials

3.1 SOIL

The Expansive soil used in this investigation was collected Locally. The soil was brought to lab in bags and soil was dried in oven for one day followed by pulverization. Soil was pulverized to pass the soil through 4.75 mm size sieve and stored in such way that, there is a very minor chance of absorption of moisture by soil. Sieve analysis tests were conducted on soil to find out the soil classification, soil results and soil can be grouped as CH (Highly compressible Expansive soil).

Table 1: Properties of virgin soil

S No.	Properties	Results
1	Specific gravity	2.67
3	Liquid Limit (%)	64
4	Plastic Limit (%)	31.7
5	Plasticity index (%)	32.3
6	Classification of soil	CH
7	Maximum Dry Density (kN/m^3)	18.5
8	Optimum Moisture Content (%)	14
9.	UCS	165
10.	CBR	10.40 (Soaked)
		10.75(unsoaked)

3.2 CERAMIC WASTE POWDER

A ceramic tile is an inorganic, non-metallic, solid material. The earliest ceramics made by humans were pottery objects made from clay either by itself or mixed with other materials like silica. Later ceramics were glazed and fired to create smooth, coloured surfaces, decreasing porosity. The raw materials to form tile consists of clay mineral mined from earth crust, natural mineral such as feldspar.

Table 2: Chemical Properties of CWP. (Mohit and Sharifi, 2019)

Sr. No.	Properties	Value
1	SiO_2	64.04%
2	Al_2O_3	21%
3	CaO	1.29%
4	Na2O	2.07%
5	Fe2O3	6.51%
6	SO_3	0.11%
7	LoI	1.1%

Table 3: Physical Properties of CWP. (Mohit and Sharifi, 2019**)**

Sr. No.	Properties	Value
1	Moisture Content (%)	0.2
2	Specific density(kg/m3)	2540
3	Specific surface area (m2 /kg)	554

3.3 CEMENT KILN DUST

Cement Kiln Dust is fine grained solid and highly alkaline waste which is removed from kiln by the air pollution control devices. CKD stabilise the different type of soil and sludge as filler in asphalts, as a partial addition to produce blended cement for concrete construction work. It may be recorded that, most of the work performed has been limited to freshly generated cement kiln dust while issue or reusing already land filled material. It is taken from Ambuja cement plant.

Table 4: Chemical Properties CKD

Sr.	Constituent	% by weight
1	$CaCO_3$	55.5
2	SiO_2	13.6
3	CaO	22.58
4	K_2SO_4	5.9
5	$CaSO_4$	5.2

4. EXPERIMENTAL RESULTS

4.1 Standard Proctor Test.

Table5: Compaction Test results for Expansive Soil and CKD

S No.	[CS:CKD:CWP]	MDD (kN/m^3)	OMC (%)
1.	100:0:0	18.5	14
2.	97:03:0	18.65	14.5
3	94:06:0	18.80	14.8
4.	91:09:0	19.05	15.1
5.	88:12:0	18.90	15.6

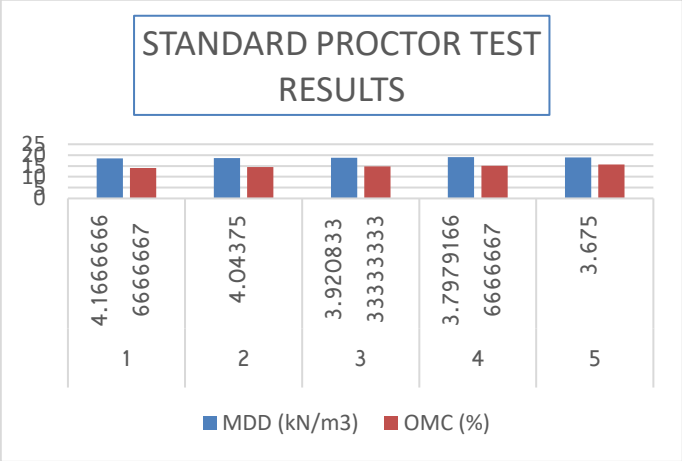

Fig 1: OMC and MDD of Expansive soil with CKD mix

Table 6: OMC and MDD Results of Expansive soil and Cement Kiln Dust and CWP

CS : CKD:CWP	M.D.D(g/cm^3)	O.M.C %
86:09:05	19.15	15.9
76:09:15	19.6	16.05
66:09:25	20.10	16
56:09:35	19.8	16.10

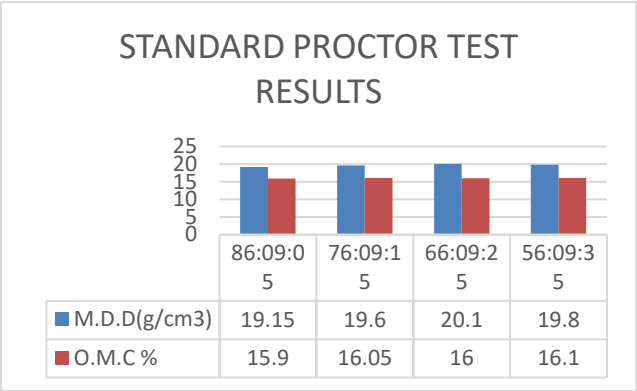

Fig 2: Graph of MDD and OMC for Soil Cement Kiln Dust and CWP

4.2 Unconfined Compressive Strength Test

The unconfined compressive strength is the parameter which shows the ability to bear the compressive load by the soil. In this test various samples has been done and kept for 3 days, 7 days and 28 days for curing for testing. The motive of keep it under curing to make the pozzolanic action to take place. The results show that with an increase in curing days there is vast increase in the strength of the samples. The increase in the strength after curing period is varying from 60 kPa to 274 kPa. The results also shows that with an increase in the curing period the strain value also goes on increasing but at greater strength, which shows that sample at 28 days resist much amount of load and save our structure from sudden collapse.

Table 7: UCS values of various mixes together

Proportion CS: CKD:CWP	**UCS (kPa)**	**UCS (kPa)**	**UCS (kPa)**	**UCS (kPa)**
	0 day	**7 days**	**14 days**	**28 days**
100:0:0	60	95	135	165
97:03:0	72	110	155	180
94:06:0	80	155	190	215
91:09:0	87	185	210	235
88:12:0	85	175	195	220
86:09:05	95	195	225	240
76:09:15	115	210	245	255
66:09:25	110	215	250	265
56:09:35	117	218	258	274

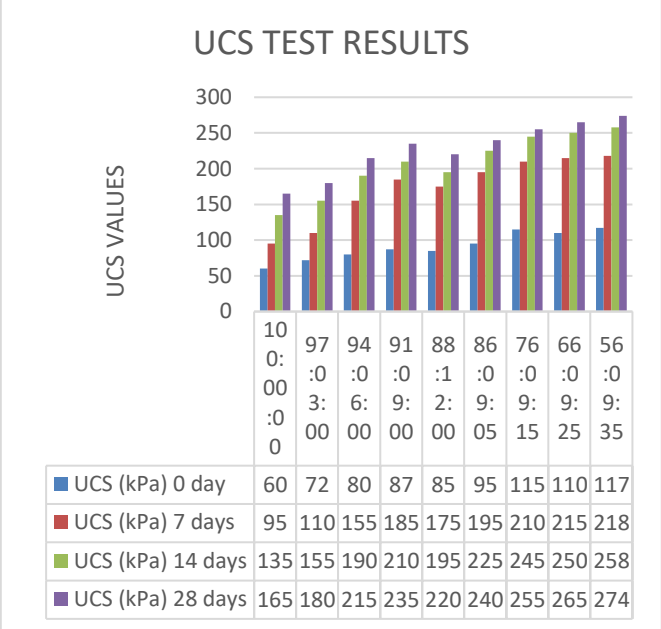

Fig 3: Showing values of SOIL,CKD, and CWP

4.3 California Bearing Ratio

The California bearing ratio represents the bearing capacity of the soil at how much load how much penetration happens in the soil surface. The load and area of the surface leads to calculate the stress value. With the penetration we get the deformed values, with the help of which we achieve to the strain value. With the value of stress and strain we achieve to the value of modulus of elasticity. The modulus of elasticity shows the ductility of the soil which indicates earlier the soil is going to be failing under the load with the help of which we can prevent our structure to get fail. The increment in the CBR value is shown in the optimum mix (86.25:09:04:0.75) sample under dry condition is from 10.57% to 31%.

Table 8: California Bearing Ratio (UNSOAKED and SOAKED) tests results for SOIL,CKD and CWP

Mix Type	CBR Unsoaked (%)	CBR Soaked (%)
100:0:0	10.75	10.40
97:03:0	16.40	15.60
94:06:0	19.60	18.40
91:09:0	21.50	20.40
88:12:0	21	19.20
86:09:05	23.30	21.30
76:09:15	26	24.75
66:09:25	28.50	26.25
56:09:35	31	29.60

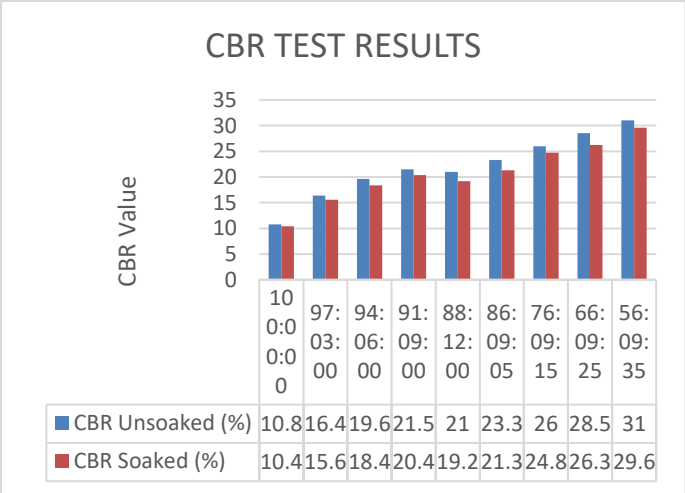

Fig 4: Representing the curves that are obtained from California Bearing Ratio Test for SOIL,CKD,CWP mixture.

5. DISCUSSIONS

5.1 Standard Proctor Test:

- An increase in OMC from 14% to 16.10% and an increase in MDD from 18.5kN/m^3 to 20.10 kN/m^3 was observed when the percentages of CKD used were 3, 6, 9 and 12% respectively and with varying percentage of CWP.
- This increase in MDD was due to the hydration process between cement and water, in which Calcium Silicate Hydrate gel (C-S-H) and calcium hydroxide $Ca(OH)_2$were formed. The gel so formed helped in binding the Expansive soil particles and therefore the strength increased.

5.2 UCS Test

- The increase in UCS strength was recorded on addition of 35% CWP and 9% CKD to the clay soil. The increase in UCS strength with increase in composition of CWP and curing days in the presence of CKD, confirm the Pozzolanic reaction between the CWP and calcium hydroxide generated as byproduct from the reaction of CKD on addition of water. Maximum UCS strength of 274kN/m2 recorded at 9% CKD and 35% CWP is adequate for a soil material to be used as base course material for highly trafficked road bases

5.3 CBR Test

- The CBR value obtained from the tests revealed that the optimum mix proportion is value increases up to 09 CKD 35% CWP. At this proportion the value of CBR increases from10.75% to 31% for soaked samples.

CONCLUSIONS

On the basis of experimentations, the following conclusions have been drawn:

- When percentage CKD increases in soil there is increase in MDD. and decrease in OMC for some values.
- With the increase in quantity of CWP the value of O.M.C. And MDD increases.
- The optimum value of CKD to be used for further work was 9%.
- The best ratio obtained was 66% soil: 9% CKD: 25 CWP.
- UnSoaked CBR value increases from 10.75% for virgin soil to 31% for the best ratio of the mix.

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