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STABILIZATION OF CLAYEY SOIL WITH CEMENT KILN DUST AND ALCCOFINE 1101

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ABSTRACT

Earth has been used for building for thousands of years throughout the world spanning a diverse range of climates and cultures. Earth itself is a multi-component system usually consisting of stones, sand, silt, clay, water and, near the ground surface, organic humus. Structural stability of earth buildings is maintained by the structural integrity of the sand and stone framework, by the pore filling capacity of the silt and most importantly, by the binding qualities of the clay, which are in turn influenced by the moisture content of the soil. Compared with some building materials earth can be considered to have some disadvantages – it has relatively low compressive strength, tensile strength and abrasion resistance. It may also lose a lot of its rigidity in the presence of water. Nevertheless, it is very cheap, very widely available, environmentally friendly, strongly linked to local cultures and traditions and, with skillful construction, can contribute significantly to the aesthetic appeal and user comfort of buildings. In the present study attempt has been made to increase the strength of soil.

I.INTRODUCTION

1.1. Cement kiln Dust

CKD "is particulate matter that is collected from cement kiln exhaust gases and consists of entrained particles of clinker, unreacted and partially calcined raw materials, and fuel ash enriched with alkali sulfates, halides and other volatiles".

The chemical and physical properties of CKD can be influenced by several factors. Because plant operations differ considerably with respect to raw feed, type of operation, dust collection facility, and type of fuel used, the use of the terms typical or average CKD when comparing different plants can be misleading. The dust from each plant can vary markedly in chemical, mineralogical and physical composition.

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Table 1.1: Chemical and Physical Analysis of Cement Kiln Dust

Chemical Analysis - Chanute	%age	Chemical Analysis - Midlothian	%age
Silicon Dioxide, SiO_2, %	17.62	Total CaO, %	45.0-49.0
Aluminum Oxide, Al_2O_3, %	4.9	as Calcite $CaCO_3$, %	22.0-25.0
Iron Oxide, Fe_2O_3, %	2.58	as CaO (free lime), %	5.5-8.0
Calcium Oxide, CaO, %	62.09	as Calcium Silicate, %	12.0-15.0
Magnesium Oxide, MgO, %	1.93	as $CaSO_4$, %	3.0-5.0
Sodium Oxide, Na_2O, %	0.56	Silicon Dioxide, SiO_2, %	11.0-14.0
Potassium Oxide, K_2O, %	3.76	Aluminum Oxide, Al_2O_3, %	3.5-4.5
Sulfur Trioxide, SO_3, %	5.79	Sulfur Trioxide, SO_3, %	8.0-12.0
Moisture Content, %	0.07	Iron Oxide, Fe_2O_3, %	1.5-2.5
Loss on Ignition, %	4.94	Sodium Oxide, Na_2O, %	0.1-1.0
Available Lime Index, % CaO	33.7	Potassium Oxide, K_2O, %	2.0-10.0
Water-Soluble Chlorides, % Cl	--		
Physical Analysis			
Retained on No. 325 sieve (%)	16.9	Unit weight (lb/ft3)	32.0-44.0
Specific Gravity	2.95	volatiles, %	0.3-1.0
pH	12.4-12.9	Smaller than 0.075 mm, %	55-75

Table 1.1: Typical Composition of Cement Kiln Dust

Constituent	$CaCO_3$	SiO_2	CaO	K_2SO_4	$CaSO_4$	Al_2O_3	Fe_2O_3	KCl	MgO	Na2SO4	KF	Others
% by weight	55.5	13.6	8.1	5.9	5.2	4.5	2.1	1.4	1.3	1.3	0.4	0.7

1.2. Alccofine

Alccofine is a new generation, micro fine material of particle size much finer than other hydraulic materials like cement, fly ash, silica etc. being manufactured in India. Alccofine has unique characteristics to enhance 'performance of concrete' in fresh and hardened stages due to its optimized particle size distribution. It can be used as practical substitute for Silica Fume as it has optimum particle size distribution not too coarse, not too finer. It is manufactured in the controlled conditions with special equipment’s to produce optimized particle size distribution which is its unique property.

Table 1. 2 Physical Properties of Alccofine

Fineness (cm^2/gm)	Specific Gravity	Bulk Density (kg/m^3)	Particle Size Distribution (µm)			
			d10	d50	d90	d95
> 8000	2.9-3.0	600-700	<2.5	<6	<12	< 15

Table 1. 3 Chemical Properties of Alccofine

MgO	SO3	S	LOI	IR	Cl-
8.0%	3.0%	1.5%	5.0%	4.0%	0.1%

Table 1. 4 Compressive Strength As per IS 4031 (Part 6):1988

Day	MPa
3 Day	>20
7 Day	>30
28 Day	> 40

III.PROBLEM FORMULATION

In the field of geotechnical engineering in general and soil stabilization in particular, the parent soils are practically categorized under either cohesionless soils (i.e., sandy and larger particle-sized soils) or cohesive soils (i.e., primarily clay and silt). Since the soil stabilization mechanism of fine-grained soils requires calcium (in the form of lime) as the major stabilizing agent, it is possible that some CKD, especially those high in free lime, would similarly be useful in stabilizing clay soils. In the case of sandy soils, which are commonly selected in the pavement layers, the usage of CKD may provide cementitious materials when it is mixed with water in a way similar to the mechanism by which Portland cements provide their binding characteristics. Any potential application of CKD, in clay stabilization, is governed by the physical and chemical composition of the dust. In practical terms, the dusts vary from plant to plant in chemical, mineralogical, and physical composition, depending upon the feed raw materials, type of kiln operation, dust collection facility, and the fuel used.

III.OBJECTIVES

This work mainly emphasizes on the stabilization of clays and organic soils using locally cement kiln dust and alccofine. This infers the following objectives which can be put forth as follows:

- Efficient use of CKD for stabilization of clays and organic soils
- Study of various characteristics of soil using cement kiln dust in various proportions along with the doses of alccofine.
- Comparative study of enhancement in stabilization of soils using single and double stabilizers.

IV.MATERIALS & METHODOLOGY

To study the effect of CKD in sand mixture on the strength, the following variables will be considered in this study:

1. Percentage of CKD as ratio to sand used (10%, 15% and 20%).
2. Percentage of alccofine as ratio to CKD used (2.5%).
3. Testing period of mixtures (0, 7, 14, and 28day).

Three mixes (Mix (1), Mix (2) and Mix (3)) with three different types of CKD (10%, 15% and 20% by weight of sand) will be used in this study for single additive as follows:

1. Mix. (1) 1sand: 10% CKD (10% of sand weight)
2. Mix. (2) 1sand: 15% CKD (15% of sand weight)
3. Mix. (3) 1sand: 20% CKD (20% of sand weight)

The other mixes will be prepared for double additive as indicated below:

1. Mix. (4) 1sand: 10% CKD (10% of sand weight): 2.5% alccofine (2.5% of CKD weight)
2. Mix. (5) 1sand: 15% CKD (15% of sand weight): 2.5% alccofine (2.5% of CKD weight)
3. Mix. (6) 1sand: 20% CKD (20% of sand weight): 2.5% alccofine (2.5% of CKD weight)

V.RESULTS AND DISCUSSIONS

5.1. Atterberg Limit

Table 6.1. Liquid Limit Test (Cone Penetration Test)

LIQUID LIMIT	Test no.	1	2	3	4
Average penetration	mm	21.50	23.59	24.39	18.47
Mass of wet soil + container	g	22.2	28.25	40.6	16.5
Mass of dry soil + container	g	18.0	24.8	36.1	13.2
Mass of container	g	9.89	18.5	28.01	7.01
Mass of moisture	g	4.20	3.40	4.52	3.31
Mass of dry soil	g	8.12	6.29	8.14	6.28
Moisture Content	%	52.5	54.0	55.0	52.6

moisture content at 20mm cone penetration = **52.4%**

Table 4. 1 Plastic Limit Test

Test no.		1	2	3
Mass of wet soil + container	g	11.7	11.3	11.62
Mass of dry soil + container	g	11.30	10.89	11.19
Mass of container	g	9.62	9.81	9.80
Mass of moisture	g	2.50	1.47	1.79
Mass of dry soil	g	1.58	1.38	1.29
Moisture Content	%	33.61	36.69	34.51

PL (average) = **35%**

The result of plastic limit (PL) which represent the moisture content at which soil changes from plastic to brittle state is 35% determined from oven-dried sample. Plasticity index (PI) is numerically equal to the difference between the liquid limit (LL) and the plastic limit (PL). The plasticity index of the soil is evaluated as the calculation below.**PI :(LL – PL)=17.5%**

5.2. Specific Gravity

Sr. no.	Sample Type	Specific Gravity
1	Soil Only	2.42
2	1sand: 10% CKD (10% of sand weight)	2.67
3	1sand: 15% CKD (15% of sand weight)	2.69
4	1sand: 20% CKD (20% of sand weight)	2.73
5	1sand: 10% CKD (10% of sand weight) : 2.5% alccofine (2.5% of CKD weight)	2.75
6	1sand: 15% CKD (10% of sand weight) : 2.5% alccofine (2.5% of CKD weight)	2.81
7	1sand: 20% CKD (10% of sand weight) : 2.5% alccofine (2.5% of CKD weight)	2.86

5.3. Particle Size Distribution

Table 4. 2 Classification of soil on the basis of sieve analysis

sieve size (mm)	**mass passing (%)**	**Classification**
2	95.6	
0.425	84	Gravel = 11.40
0.063	78.29	Sand = 5.71

0.002	20.78	Silt/Clay =78.29
		Silt = 57.51
		Clay = 20.78

5.4. Standard Proctor Compaction Test

Table 4. 3 Compaction Test Result Consolidated

Sample	**Maximum Dry Density (mg/m^3)**	**Optimum Moisture Content (%)**
Untreated organic clay	1.45	27.00
Clay + 10% CKD	1.39	32.00
Clay + 15% CKD	1.27	37.00
Clay + 20% CKD	1.33	30.50
Clay + 10% CKD + 2.5% alccofine	1.37	33.30
Clay + 15% CKD + 2.5% alccofine	1.41	30.40
Clay + 20% CKD + 2.5% alccofine	1.43	26.50

5.5. Unconfined Compressive Strength (UCS)

Table 4. 4 Summary Result of Unconfined Compressive Strength

Sample	**UCS (kPa)**	**UCS (kPa)**	**UCS (kPa)**	**UCS (kPa)**
	0 day	**7 days**	**14 days**	**28 days**
Untreated organic clay	38	67	131	203
Clay + 10% CKD	78	109	178	220
Clay + 15% CKD	99	148	185	271
Clay + 20% CKD	104	130	181	259
Clay + 10% CKD + 2.5% alccofine	161	201	222	333
Clay + 15% CKD + 2.5% alccofine	183	232	286	755
Clay + 20% CKD + 2.5% alccofine	103	182	239	292

The unconfined compressive strength (UCS) of organic clay and cement kiln dust stabilized clay at 10%, 15% and 20% cement kiln dust at different curing period and the organic clay and cement kiln dust stabilized clay at 10%, 15% and 20% cement kiln dust wth fixed 2.5% alccofine at different curing period. In general, the strength increases with the time, indicating a continuous pozzolanic reaction. From the figure, the strength of clay with 15% CKD at curing period of 28 days was 273kPa, which higher than the strength of clay with 20% CKD indicating the optimum percentage of cement kiln dust as 15% above which the cement dust particles did not corresponds to increase in strength. The, fixed content of alccofine i.e. 2.5% were added with 10%, 15% and 20% cement kiln dust to further stabilized organic clay.

Prior to analysis, indicates that stiffness of organic clay stabilized with CKD will improved with addition of alccofine. Therefore, based on the study it proves that the strength of CKD stabilised clay will increase with addition alccofine. Figure shows that the strength of organic clay, stabilized with 10%, 15% and 20% CKD and with addition of2.5% alccofine for 0,7,14 and 28 days. There was a sharp increase in UCS with addition of alccofine at all ages indicating the abnormal and high strength behavior of alccofine.

Zero Days: In the results it was found that the percentage increase at early ages was very much in comparison at later ages indicating that the cement kiln dust reacts very fast at early ages and the reactivity goes on decreasing at later ages. Similar results were also obtained in case of addition of alccofine. The percentage increase in unconfined compressive strength w.r.t untreated organic clay was observed as 111% for clay with 10% CKD, 169% for clay with 15% CKD, 183% for clay with 20% CKD, 342% for clay with 10% CKD and 2.5% alccofine, 403% for clay with 15% CKD and 2.5% alccofine, 181% for clay with 20% CKD and 2.5% alccofine at 0 days, 62% for clay with 10% CKD, 119% for clay with 15% CKD, 93% for clay with 20% CKD, 197% for clay with 10% CKD and 2.5% alccofine, 243% for clay with 15% CKD and 2.5% alccofine, 169% for clay with 20% CKD and 2.5% alccofine at 7 days, 35% for clay with 10% CKD, 40% for clay with 15% CKD, 37% for clay with 20% CKD, 67% for clay with 10% CKD and 2.5% alccofine, 115% for clay with 15% CKD and 2.5% alccofine, 80% for clay with 20% CKD and 2.5% alccofine at 14 days, 8% for clay with 10% CKD, 33% for clay with 15% CKD, 27% for clay with 20% CKD, 63% for clay with 10% CKD and 2.5% alccofine, 269% for clay with 15% CKD and 2.5% alccofine, 43% for clay with 20% CKD and 2.5% alccofine at 28 days.

7 – Days: This shows that the percentage increase in compressive strength decreases with increase in ages. Also, the percentage increase in compressive strength is increasing at all ages with increase in CKD but at 28days it decreases with addition 20% CKD in comparison to 15% CKD hence optimizing value of CKD. Further the compressive strength increases with addition of alccofine in comparison to without alccofine at all ages but the effect is more predominant at 0 days and 7 days in comparison to 14 days and 28days indicating the early reaction behavior of alccofine in presence of cement kiln dust. The compressive strength was found to be maximum at 28 days with 15% CKD and 2.5% alccofine indicating the optimum percentage of both alccofine and cement kiln dust.

14 and 28 days: This shows that the percentage increase in compressive strength decreases with increase in ages. Also, the percentage increase in compressive strength is increasing at all ages with increase in CKD but at 28days it decreases with addition 20% CKD in comparison to 15% CKD hence optimizing value of CKD. Further the compressive strength increases with addition of alccofine in comparison to without alccofine at all ages but the effect is more predominant at 0 days and 7 days in comparison to 14 days and 28days indicating the early reaction behavior of alccofine in presence of cement kiln dust. The compressive strength was found to be maximum at 28 days with 15% CKD and 2.5% alccofine indicating the optimum percentage of both alccofine and cement kiln dust.

5.6. California Bearing Ratio

Table. 4.15 California Bearing Ratio (Un-soaked And Soaked) Tests Results For Soil-Ckd-Alccofine Mixes

Mix Type	CBR Un-soaked (%)	CBR Soaked (%)
Soil Only	10.55	10.22
1sand: 10% CKD (10% of sand weight)	14.32	12.65
1sand: 15% CKD (15% of sand weight)	16.78	15.48
1sand: 20% CKD (20% of sand weight)	18.98	17.85
1sand: 10% CKD (10% of sand weight): 2.5% alccofine (2.5% of CKD weight)	22.59	21.11
1sand: 15% CKD (10% of sand weight): 2.5% alccofine (2.5% of CKD weight)	28.76	22.57
1sand: 20% CKD (10% of sand weight): 2.5% alccofine (2.5% of CKD weight)	28.65	22.15

VI. CONCLUSION

The result of plastic limit (PL) which represent the moisture content at which soil changes from plastic to brittle state is 35% determined from oven-dried sample.

The value of PI is higher than 10, therefore this soil meets the requirement to be stabilized with stabilizing agent. In this study the clay is stabilized with cement kiln dust or/and in presence of alccofine.

The average value of specific gravity of the soil is 2.42 indicating the soil is light and weak and need to be stabilized with certain additives. The specific gravity was found to increase with addition of CKD and increases further with addition of alccofine.

Based on the results of soil classification test, the soil is classified into fine-grained soil that consists of 78.29% of fine materials (57.51% of silt and 20.78% of clay). As the amount of clay content more than 10%, thus this soil is suitable to be stabilized with CKD. However, the presence of 14.41% organic material will cause the obstruction when CKD is used as well as reducing the effectiveness of CKD stabilization. Therefore, stabilization is considered as having both of alccofine used as an additive in cement kiln dust stabilized organic soils.

The results obtained from Standard Proctor Compaction Test showed that the optimum moisture content increases and the maximum dry density decreases when CKD is added to the soil. It is because of ion exchange and flocculation of soil particle occurs which make soil particle more friable for compaction. the amount of CKD and alccofine added did not cause significant changes in the maximum dry density as well as optimum moisture content. The determination of optimum moisture content is vital during compaction work and prior to the preparation of sample for strength test.

There was a sharp increase in UCS with addition of alccofine at all ages indicating the abnormal and high strength behavior of alccofine. The results showed that the percentage increase at early ages was very much incomparison at later ages indicating that the cement kiln dust reacts very fast at early ages and the reactivity goes on decreasing at later ages.

The percentage increase in compressive strength is increasing at all ages with increase in CKD but at 28days it decreases with addition 20% CKD in comparison to 15% CKD hence optimizing value of CKD. The compressive strength increases with addition of alccofine in comparison to without alccofine at all ages but the effect is more predominant at 0 days and 7 days in comparison to 14 days and 28days indicating the early reaction behavior of alccofine in presence of cement kiln dust. The compressive strength was found to be maximum at 28 days with 15% CKD and 2.5% alccofine indicating the optimum percentage of both alccofine and cement kiln dust.

The un-soaked CBR gave a peak value of 28.76% at 15% CKD (10% of sand weight) : 2.5% alccofine. There were increases in the values of CBR with higher additive contents at higher compactive efforts with a peak value of 22.57% recorded at 15% CKD (10% of sand weight) : 2.5% alccofine. The reduction with respect to the un-soaked CBR values was due to the ingress of water into the specimen when it was soaked for 24 hours, which weakened it and reduced their strength.

REFERENCES

[1.] Parsons, R. L., P.E., M. A., and Kneebone, E. (2004). Use of Cement Kiln Dust for the Stabilization of Soils. in *GeoTrans 2004 July 27-31, 2004* (Los Angeles, California, United States: ASCE). doi:https://doi.org/10.1061/40744(154)101.

[2.] Rahman, M. K., Rehman, S., and Al-Amoudi, O. S. B. (2011). Literature Review on Cement Kiln Dust Usage in Soil and Waste Stabilization and Experimental Investigation. *IJRRAS* 7, 77–87.

[3.] Rao, P. V. K., Kumar, K. S., and Blessingstone, T. (2012). Perfornace of Recron-3S Fiber With Cement Kiln Dust in Expansive Soils. *IJEST* 4, 1361–1366.

[4.] Salahudeen, A. B., Eberemu, A. O., and Osinubi, K. J. (2014). Assessment of Cement Kiln Dust-Treated Expansive Soil for the Construction of Flexible Pavements. *Geotech. Geol. Eng.* 32, 923–931. doi:10.1007/s10706-014-9769-0.

[5.] Shehata, M., Ahmed, A., and Easa, S. (2009). Use of factory-waste shingles and cement kiln dust to enhance the performance of soil used in road works. *Adv. Civ. Eng.*, 1–9. doi:10.1155/2009/143750.

[6.] Siddique, R. (2006). Utilization of cement kiln dust (CKD) in cement mortar and concrete-an overview. *Resour. Conserv. Recycl.* 48, 315–338. doi:10.1016/j.resconrec.2006.03.010.

[7.] Singh, V., and Jain, R. (2012). Effect of Cement Kiln Dust (CKD) on some geotechnical properties of Black Cotton Soil (BCS). *IJIRST* 1, 86–90.