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# Expansive Soil Stabilization Using Industrial Solid Wastes a Review

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**ABSTRACT—**This paper highlights the results of works done by different researchers on soil stabilization using different waste materials that primarily emanate from industries all over the globe, it is seen that most of the materials used for this purpose have proven to be very effective in improving the engineering properties of expansive soils. material wastes such as cement kiln dust, red mud, copper slag, brick dust, ceramic dust, polyvinyl waste, fly ash etc. laboratory tests such as California bearing ratio (CBR), unconfined compression strength test (UCS), free swell index, liquid limit, plastic limit, x-ray diffraction, compaction etc. were conducted, the research methods and results are discussed in this article.
**Keywords—** California bearing ratio (CBR), black cotton soil, expansive soil, soil stabilization, industrial wastes etc.

## I. INTRODUCTION

The importance of soil for construction purpose in civil and highway engineering is of great significance. Virtually all civil engineering infrastructure has their foundation on the soil, in order to have a structure that will stand its design life, accurate studies of the engineering properties of soil in the proposed site of construction is to be conducted and if the soil is found wanting, adequate engineering techniques that have been tested and proven worthy are then applied to improve these wanting Engineering properties. The improvement of soil engineering properties to meet up the standard for economical, safe and long lasting structures is what is termed as soil stabilization. Most wastes materials have been used in this process and have been found very effective, for this article, we will discuss the effect of industrial solid wastes even as mentioned below.

### 1.1. AIM

The review is aimed at reviewing and presenting recent works found in different recent literature works in stabilization of black cotton soil or expansive soil using industrial solid wastes, to obtain the gaps noticeable in this area of study that needs to be bridged,

### 1.2. Cement Kiln Dust

Wastes emanating from various processes in industries are called industrial wastes, these wastes could be solid, Liquid or gaseous, however our concern here is about the solid wastes and not the rest. Some of the research done in soil stabilization using these solid wastes from industries is as shown below.

Rahman et al (2011) did a literature review on cement kiln dust usage in soil and waste stabilization and experimental investigation and found that results from experiments showed the use of 34% CKD has the potential to bring the pH of sludge above 10, which is enough to stabilize the sludge.

**Table 1: Basic properties and Typical Oxide composition of Cement Kiln dust**

| Oxides | Concentration (%) |
|---|---|
| CaO | 50.81 |
| $Al_2O_3$ | 4.71 |
| $SiO_2$ | - |
| $Fe_2O_3$ | 1.92 |
| $Mn_2O_3$ | 0.002 |
| $Na_2O$ | 0.001 |
| $K_2O$ | 1.35 |
| pH | 11.2 |
| Gs | 2.22 |

Source: Moses and Saminu (2012)

Hesham (2013) studied cement kiln dust chemical stabilization of expansive soil exposed at El-Kawther Quarter, Sohag Region, Egypt, Chemical analysis was conducted on both cement Kiln dust and lime. 16% was found optimum for (CKD) while 14% (CKD) and 3 %( L) Was found optimum percent for the combination of both (CKD) and (L).

Keerthi (2013) did an investigation on Stabilization of clayey soil using cement kiln waste. Maximum dry density, Unconfined Strength tests and other tests were conducted, MDD increased but at appoint started decreasing and, same was noticed for UCS.it was observed that 50% of CKD was optimum percentage for clayey soil stabilization.

Peethamparan and Olek (2008) studied the stabilizing impact of four cement kiln dusts that possessed varying chemical and physical properties on Na-Montmorillonite clay. On addition of cement kiln dust, there was a significant decrease in the plasticity index (Ip), increment in the, initial pH value, UCS and stiffness of the clay.

Vivek and Rajesh (2015) studied Effect of Cement Kiln Dust (CKD) on Engineering Properties of Black Cotton Soil. Samples of Soil were tested with CKD from 0% to 25% of dry weight of the soil, result showed a significant increase in soaked CBR and UCS values. DFS of the expansive soil was found to reduce from (31%) to (5%).Compaction test showed an increase in maximum dry density (MDD) from 1.73 gm/cc to 2.03gm/cc and a considerable reduction in optimum moisture content (OMC) from 20.04% to 10.94%. Permeability was noticed to have increased from 4.80x10-4 cm/s to 1.43x10-3 cm/s. It was thus, concluded that CKD has the potential of increasing the desirable engineering properties of expansive soils.

Upma and (2015) studied effect of cement kiln dust and chemical additive on expansive soil at subgrade level. The investigation includes the study of engineering properties of expansive soil using CKD and chemicaladditive RBI grade 81(Road Building International grade 81) at various percentages and for different curing periods. Compaction, Atterberg's limit, (C.B.R.), (U.C.S.) tests were the tests carried out on soil samples and soil with stabilizers. It was noticed that there was a 67.80% reduction in increment in chemical additive RBI grade 81 and CKD increased significantly strength of the soil. There was 450% increment in UCS value. The optimum mix Obtained is soil: CKD: RBI Grade 81 in proportions of 81:15:04.

Sallahudeenet al. (2014) made an investigation on expansive soil with cement kiln dust. It was concluded that cement kiln could be used for improving low volume roads and in lime stabilization as admixture, since cement kiln dust has high loss on ignition(LOI) it was recommended that it should be avoided in avoided in soil stabilization of expansive soils.

Heeralal and Praveen (2011) conducted a study on effect of fibre on cement kiln dust (CKD) stabilized soil. The aim was to investigate the effects of discrete short polypropylene fibre (PP-fibre) on the strength and mechanical behaviour of soil and soil+ CKD mix. PP-fibre content prepared at with soil mix at different proportions (i.e. 0.25%,0.5%,1.0% by weight of the soil) and cement kiln dust content was as well treated in three percentages of 3%,5%,8% by weight of the soil, other tests conducted were, UCS, direct shear test and C.B.R tests. After 28 days of curing, UCC test was conducted. It was noticed that there was an increment in the UCS, axial strain at failure, shear strength, decrement in stiffness, and a change in d soil's brittle characteristics to one of higher ductility, the unsoaked CBR also increased significantly.

A study conducted by Srivastava et al (2010) on stabilisation of engine oil contaminated soil using cement kiln dust, it was aimed at evaluating theeffectiveness of CKD as material for stabilization at varying proportions of 2%, 6%, and 14% on engineering characteristics of soil contaminated soil with engine oil. The result proved that the specific gravity and consistency of contaminated soil limits increased significantly. The consistency limits had a minimal change; plasticity index (PI) observed a minimal increase as a result of contamination. CKD increased the consistency limits of soil. There was a decrease in compaction behaviour of stabilised soils. Optimum moisture content (OMC) increased with increase in CKD. There was an increment in free swell Index of contaminated soil 75% from 20% in uncontaminated soil. However, a decrement FSI decreased with increase in CKD.UCS of soil increased AS there was an increment in CKD.It was thus concluded that CKD is effective as stabilizing agent.

Bushra and Lubna (2012) studied Stabilization of Dune Sand by Using Cement Kiln Dust (CKD). The aim was determining the engineering characteristics of Stabilized dune sand with the use of Cement Kiln Dust (CKD) with the bias of accessing assessing the suitability of resting shallow foundation on it, Laboratory test were conducted and the results showed that CKD caused a significant decrease in the liquid limit when mixed with sand. The addition of CKD facilitated compaction of the soil at lower maximum dry unit weight and higher optimum water content. There was a noticeable increase in angle of internal friction (φ) and Cohesion (c). After curing for fourteen days; the strength characteristics were noticed to be constant. Thus CKD was recommended for use even as it could have a huge advantage economically.

Ewa and Egbe (2013) investigated the use of cement kiln dust as partial replacement to ordinary Portland cement in hollow lateritic blocks. Investigation on effect of partial replacement of cement with cement kiln dust (CKD) on the compressive strength of laterized hollow block was conducted. A total of 270 number of 450mm x 225 mm x 150mm hollow blocks using different mix were moulded and tested at 7, 14, 28 days withreplacement by CKD ranging from 10-50%. The results showed that there was a decreases in e compressive strength with increase in cement kiln dust content. The 28-day compressive strength for 10% CKD replacement for 1:8 and 1:10 mixes were observed to exceed the minimum strength of 1.75N/mm2 required by the Nigerian National Building Code for individual block. The strength of the laterized blocks however increased as the curing age's progresses.

Ali et. al. (2012) investigated the effectiveness of cement kiln dust in stabilizing recycled base materials using both bench-scale resilient modulus and seismic modulus tests. Recycled materials included road surface gravel (RSG) and recycled pavement material (RPM). Modulus generally increased with curing time with more hydration; however, decrease in the modulus of the RPM mixed with 15% CKD during curing was attributed to swelling potential of the CKD. Lower rate of increase in modulus of CKD mixtures compared with cement mixtures with curing time was observed. Attributable to the combined effects of stiffness gain with continuing hydration and stiffness reduction with freeze-thaw cycles, the final modulus of the recycled materials mixed with CKD is 2 to 5 times higher than that of untreated RPM and RSG materials. This study also showed that modulus change of stabilized granular materials can be estimated from seismic Young's modulus.

Athraa et al (2015) studied the Characteristics of Cohesive Soils Stabilized by Cement Kiln Dust — Cement kiln dust CKD is a waste obtained in the process of cement production, it constitutes environmental hazards if not properly treated. The study was done with the bias of investigating the feasibility cement kiln dust utilization in stabilization of soils. The properties of two kinds of soil where studied. The direct shear test / unconfined compression tests, the coefficient of permeability, and durability tests (freezing-thawing and wetting-drying) were reported. Treatment with cement kiln dust was found to be an effective option for improvement of soil properties, based on the testing conducted as a part of this research. Strength was improved and plasticity and coefficient of permeability were substantially reduced.

Ahmadi and Lubem (2014) studied the impact of cement kiln dust (up to 16%) on10% quarry fine stabilized black cotton soil and found there was a reduction in IP, maximum dry density (MDD) and an increment in California bearing ratio and optimum moisture content (OMC).

Mohie and Ahmed (2013) made a study on improving the strength of sandy silt soils by mixing with cement kiln dust, the research studied the improving of sandy silt soils by mixing with cement kiln dust. Laboratory tests were carried out to evaluate the improved soil properties. Three numerical models were built for an embankment of a canal to examine the introduced method to overcome slope stability problems. The natural soil slope stability safety factor was calculated from the first numerical model. The second model used to calculate safety factor after applying the improved soil properties that were determined from the laboratory works. The third numerical model was built to simulate improving natural soil by using the traditional soil reinforcement technique. The results for the two improvement methods were compared. The results showed that the proposed method caused significant improvement for slope stability.

Prasad and Sudeep (2016) investigated on Stabilization of Expansive Soil Using Cement Kiln Dust. Black cotton also known as expansive soils undergo excessive changes in volume due to change in moisture content, making their use in the construction of civil engineering projects very difficult. In this investigation Cement Kiln Dust (CKD), was used as a chemical admixture to improve the characteristics of the expansive soil with partial replacement by CKD (5%,10%,15%,20% &25%) and also for different curing periods (1,3,7,14 &28days) and many laboratory experiments were conducted. This investigation showed an improvement in the properties of soil at varying proportions of CKD and with the curing.

Moses and Saminu (2012) made a study on effect of cement kiln dust (CKD) on stabilization of expansive soil. It was found that the soil stabilized with CKD witnessed a significant reduction in California Bearing ratio, unconfined compression test and durability tests, thus not considered for use in both base and sub-base material.

**1.3 Red Mud**

Prabha and Ali (2015) studied soil improvement using red mud and fly ash. Different proportions of fly ash and red mud were added to the disturbed soil, initially 3% Red Mud was added to soil with 3% fly ash then CBR Value was 3.124 after then 6%, 12%, 18%, 24%, 30%, 36% Red Mud added to soil and 3% Fly ash then CBR values were 3.924, 4.856, 5.957, 6.856, 7.354, 6.654 respectively obtained. 30% of Red Mud mixing and CBR value of 7.354% was observed to be optimum value with soil and Fly ash for better improvement of soil and its stabilization.

Kusum et al (2014) evaluated characteristic properties of red mud for possible use as a geotechnical material in civil construction.

Tests conducted where Particle size distribution, Atterberg's limit, OMC, Specific gravity, and MDD. It was found that red mud is suitable for use in geotechnical works and as well in road base and sub-base precisely for low volume roads.

**Table 2: Typical composition of Red Mud**

| Composition | Concentration (%) |
|---|---|
| $Fe_2O_3$ | 30-60% |
| $Al_2O_3$ | 10-20% |
| $SiO_2$ | 3-50% |
| $Na_2O$ | 2-10% |
| CaO | 2-8% |
| $TiO_2$ | 12-25% |

Source; Prabha and Ali (2015).

Kalkan (2006) did investigated stabilized expansive clay with red mud and noticed a significant increase in strength and a decrement in hydraulic conductivity.

Satayanarayana et al (2012) investigated the Characterization of Lime Stabilized Red Mud Mix for Feasibility in Road Construction. In this study Red mud was stabilized with 2, 4, 6, 8,10and 12 percentages of lime and unconfined compressive strength, split tensile strength and California bearing ratio tests were conducted at 1, 3, 7 and 28 days curing periods respectively. From the experimental findings it was observed that 10% lime has shown higher values compared to other percentages. At 28 days it has shown maximum values than other curing periods for all percentages of lime. The CBR value obtained for 10% lime at 28 days is 25% so that it can be used as subgrade and sub base material in road construction.

Kuldip (2014) conducted analysis on utilization of cement kiln dust stabilized red mud for road construction. In the experimental work the Red mud is stabilized with different percentage (i.e. 2, 4, 6, 8, 10 and 12%) of Cement Kiln Dust and Unconfined Compressive strength, Compaction Strength at addition of higher percentage of CKD has shown higher values up to 8% addition further addition of CKD does not play any vital role in increasing the strength of Red mud CKD mix. At 28 days curing period the mix has shown maximumvalues at all percentages of CKD addition. The agglomeration of particles is very good as the percentage of CKD increases. Red mud replaced with 8% CKD can be used effectively as a sub base and sub grade material.

## II. COPPER SLAG

Havanagi et al. (2006) experimented by mixing copper slag which is by product in the production of copper with fly ash and expansive soil. This was mixed in varying proportions and the suitability of these materials in construction embankment, subbase and base courses were assessed. The stabilization process was done in increasing proportions of 3%, 6% and 9% of cement in order to ensure its suitability base course. Table 3: Chemical Composition of Copper Slag.

Composition Fe2O3 Al2O3 SiO2 Na2O CaOMgO Weight 56 3.4 34.4 0.57 0.5 3.2 Source; venkata and Nanthakumar (2016).

Venkata&Anthakumar (2016) investigated with both Copper slag and lime and these were used in different percentages that ranged from 5% - 30% and 2%-10%. The results indicated that increase in copper slag lead to a corresponding increase in strength properties of the soil under investigation with the maximum strength obtained at 30% addition of copper slag.

Mary Jessy Dcruz, &AswathySasikumar. (2016). Studied effect of Lime and Cement on the Strength Improvement of Copper Slag Stabilized Soil. It was observed that combination of 25% slag and 75% soil showed about 86% improvement in Unconfined Compressive strength. When copper slag was varied between 20% -25% the strength increased significantly. At 6% lime or cement and 25% slag was found to be effective for soil stabilization thus the optimum percentages. It was found that Cement showed to be a better additive as compared to lime from strength consideration. Lime was considered more beneficial or economical as a result its availability and cost. It was thus concluded that copper slag is a good stabilizing agent in improving the engineering properties of week soils. III. BRICK DUST Sachin et al (2014) had studied the effect of burnt brick dust on engineering properties on expansive soil. Laboratory tests were conducted which included swelling tendencies, Atterberg's limits, compaction and linear shrinkage of expansive soils in the natural state and then mixed with burnt bricks in varying proportions from 30%, 40% and 50%. The result showed that increase in brick dust significantly decreased the swelling potentials of soil, with about 50% decrement observed. About 50% reduction in shrinkage was observed, while Maximum dry density increased, optimum Moisture content decreased on increment of brick dust. Atterberg's limits values decreased. It was concluded that brick dust has positive impact on the soil and half of its dry weight when replaced gave the optimum performance. It was thus, recommended for use due to its stabilizing effect and waste reduction potential. Abd EL-Aziz and Abo–Hashema (2013) made a study using expansive clay with lime and homra as stabilizing agents, it was observed that the strength parameters of the soil improved significantly. There was an increment in the values of California bearing ratio

(CBR), Cohesion (C), internal angle of friction(Ø), while there was adecrement in the swelling potentials, consolidation settlement, plasticity of soil and maximum dry density (MDD). IV. POLYVINYL WASTE Oyekan et al. (2013) made a study on the effect of ground polyvinyl waste on expansive soils, Laboratory tests such as compaction, Unconfined compression test (UCS), California Bearing ratio(CBR), etc. The Unconfined compression test (UCS) was observed to have about 60% increment, the California Bearing ratio(CBR) (unsoaked) had 50% increment. Table 4: Typical composition ofPolyvinyl Waste. Mineral content Fe2O3 Al2O3 SiO2 Na2O CaOMgO K2O SO3 Amount (%) 2.20 1.71 2.55 3.10 74.20 2.70 1.12 0.05 Source; Oyekan (2013) V. CERAMIC DUST Akshaya (2012) investigated the effects of waste ceramic dust on, Atterberg's limits, California bearing ratio (CBR), Unconfined compression test (UCS), compaction, swelling potentials and shear strength of expansive soils. Ceramic dust was blended with soil at percentages varying from 5% to 30% with 5% increment in ceramic dust at each stage. It was observed in the laboratory tests conducted that Atterberg's limits, swelling pressure, cohesion(C) and optimum moisture content(OMC) noticed a decrement, on the other hand, California bearing ratio (CBR), unconfined compressive strength(UCS), maximum dry density(MDD) and internal angle of friction were seen to have had a significant increment as ceramic dust was increased. It was concluded that the optimum value of ceramic dust with effective stabilizing impact was 30% which was as well considered to be very economical and found worthy of improving the soil strength parameters for construction of subgrade of flexible pavements. Table 5: Typical composition of Ceramic Dust. Element Fe2O3 Al2O3 SiO2 Na2O CaO Content (%) 0.00014 0.000380 0.02300 0.30100 55.5600 Element MgO K2O P2O5 MnO TiO2 LOI Content (%) 0.26000 0.03700 0.037300 0.00210 0.00O34 42.48 Note; LOI – Loss of Ignition. Source; AltugSaygılı(2015)Chen and Idusuyi (2015) studied the effect of waste Ceramic Dust (WCD) on Index and Engineering Properties of Shrink - Swell Soil. It was found from the work that plastic limit(PL), plasticity index(PI), liquid limit(LL), swelling pressure, free swell and optimum moisture content (OMC) decreased with increase in WCD. While California bearing ratio (CBR), unconfined compressive strength (UCS) and maximum dry density (MDD) increased with increment in Ceramic dust. X-ray diffraction analysis performed on the shrinkswell soil indicated that the soil had high montmorillonite content and the primary element found. This findingwas almost the same with the work done by Akshaya (2012) as it was noticed that the optimum value of ceramic dust was 30%. Jijo and Kasinatha (2016) made an investigation on effect of Micro Ceramic Dust on the Plasticity and Swell Index of Lime Stabilized Expansive Soil The research indicated that ceramic dusts improved the swell properties and plasticity characteristics of the soil while the soaked California Bearing ratio(CBR) had about 20% increment. The optimum percent of Polyvinyl Waste was found to be 30%. VI. FLY ASH Karthik et al (2014) investigated the effect of fly ash stabilized soil, it was found that increase in Fly Ash lead to a significant increase in the California bearing ratio(CBR) of the used soil. It was found that the optimum percent of CBR was found to be 6%. Thus was concluded that the use of fly ash could reduce the pavement thickness and as well improve the bearing capacity ofexpansive soil. Gyanen et al (2013) studied the effect of fly ash on expansive soil, the soil was treated with fly ash 5% increment at each stage this was 5%,10%,15%,20%, and 25%. At 20 % the Liquid limit (LL) was observed to have reduced by 55%. Plasticity index reduced by 86% at 20%addition of fly ash. At 15% blending of fly ash and soil, 75% decrease was noticed in the swelling index of the soil and the specific gravity of the soil thus improved. Table 6: constituents of Fly Ash. S/No. Mineral Constituents Mineral content (%) 1. SiO 55.0 2. Al2O3 20.3 3. Fe2O3 6.3 4. CaO 12.0 5. MgO 3.5 6. Alkali 1.0 7. SO3 1.5 8. Heavy metals Trace Source; Robert (2009)

## III. RECOMMENDATIONS

It is recommended from the review that cost analysis or economic consideration and possible comparison between un-stabilized and stabilized roads should be done in further research works with much precision.

## IV. CONCLUSION

It is observed that most research conducted on industrial solid wastes are bereft of economic details and precision on how much cost will be saved as a result of using these wastes, longevity and reliability seem to be minimal, methods and best construction equipment and processes are hardly mentioned, very few works consider the mineral content of expansive soils in exact proportions through appropriate laboratory tests. Generally, almost all the industrial wastes examined in this work have the ability to improve expansive soils.

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