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Research Article

Increasing Shear Strength Parameters of Sandy Soil by Lining CKD

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Abstract

Manufacturing process disposable results in huge amounts of waste as undesirable materials and influence the environmental adversely by increasing pollutions. One of these wastes is cement kiln dust (CKD) which is produced by cement plants in all over the world. Utilization of CKD in construction industry is very important as it consumes enormous amounts of CKD, decreases the pollutant impacts on environmental, save further costs of embedding process, and employing CKD as cheap material in civil engineering applications. In this regard, the present study devoted to using CKD to increase the bearing capacity of sandy soil. Several studies have been achieved in this respect by mixing CKD as percentages with the soil. In this work, a new method is introduced by lining sandy soil with CKD in layers of specified thickness. The factors have been discussed; thickness of layer, number of layers, and layers positions. The best position of the CKD layer was specified with direct shear test. The soil was tested in four cases which included 0.15B, 0.2B, 0.25B, and 0.5B, B is the width of the box in direct shear test, and the thickness layer was specified to 0.1B. The results indicate that the best position of the lining layer is 0.5B, and the angle of the internal friction in this case increased about 2.41 times.

Keywords: *Sandy Soil, Lining CKD, Bearing Capacity, Stabilization, and Direct Shear test.*

Introduction

The universally increasing necessity of cement lead to huge amounts of CKD from cement plants. The discarding of this fine material is very problematic and causes an environmental hazard. To overcome this difficulty, researches have been approved in several regions of the world to obtain efficient ways of consuming CKD in different uses as soil stabilization, roadways, cement manufacture, and agricultural science, etc. [Upma, J., and Kumar S., 2015]. Stabilization of soil by exhausting waste materials such as CKD and unaffected soil stabilizer have been effectively employed. Because the soil stabilization system of medium-grained soils necessities calcium (in lime form) by way of the main stabilizing support, it is doable that various CKDs, mainly those elevated in free lime, would also be beneficial in stabilizing clay soils. In sandy soils, which are usually designated in roadway layers, the practice of CKD might afford cementitious supplies when it is blended with water in an approach parallel to the way by which Portland cement give its binding features. Each possible use of CKD, counting sandy and clayey soil stabilization, is controlled by the chemical and physical constituents of CKD [Rahman, M. K., et al, 2011]. Many features impact the characteristics of CKD, for the reason that plant processes vary substantially in raw feed, kind of procedure, facility of dust gathering, and kind of fuel consumed.

The terms conventional or average CKD when evaluating various plants could be unreliable. CKD of each plant might differ obviously in characteristics [Keerthi,Y et al, 2013]. Mohamed et al, 2002 researched the regulatory aspects in soil-based chemical stabilization with cement, CKD, and lime and established that strengthen cement-treated soil with intensifying of cement amount and curing period. The efficacy of cement-treated soil diminutions with mounting clay substance, wetness and soil organic content. The degree of enhancement declines with growing plasticity index of soils. Hossain 2011 observed that stabilized clayey soil with CKD and rice husk ash improved mechanical properties in addition to durability. CKD stabilized soils displays advanced improvement of soil properties than to their RHA equivalents. Albusoda and Salem 2012 illustrates the geotechnical assets of stabilized dune sand using CKD. They obtained that an high reduction in the liquid limit occurred when CKD was blended with sand. The blending of CKD set a limit compaction of the soil at inferior maximum dry unit weight and greater optimum water content. CKD caused increase in φ and c. The shear strength disparity factors became nearly stable after curing for 14 days.

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Characteristics of CKD

In overall, as reported in the literature, CKD sarefine powder comprise of slim, angular particles and bunches of particles with elevated fineness and little sphericity, principally, CKDs particles sized ranged from 1 to 3 µm. Fineness values of the CKD by Blaine method are about 318 to 1400 m^2/kg. It is with light brown or off white in look. Its relative densities usually flanked by 2.6 and 2.8. The hydrated CKD are highly permeable as a result of the reactions of CKD alkali components [Khaliefa, Q. M., 2014]. Mainly, CKD involves calcium carbonate and silicon dioxide as those in raw materials fed to cement kiln, however the quantity of alkalis, sulphate and chloride is frequently much greater in CKD. In long-wet and long-dry kilns, CKD produced with compositions of partly calcined kiln feed fines augmented with alkali sulphates and chlorides [Keerthi,Y. et al, 2013].

Aim of the study

The present study aims to add CKD to the sandy soil in layers with specified thickness, studies the effect of adding CKD on improving bearing capacity of sandy soil by using direct shear test, and specify the best location of the lining layer of CKD.

Materials

Sand properties

Around 2 m^3 of Al-Najaf sand was used in this work, passed sieve No.8 (2.36×2.36 opening size), the sample was dried in air and kept in barrels. Figure (1) shows the grain size distribution curve obtained from sieve analysis, ASTM D 422 – 63, 2007. Table (1) reveals the chemical and physical properties. In Accordance to the Unified Soil Classification System (USCS),the sand was classified as SP type [ASTM D 2487 – 00, 2007]. Maximum of dry unit weight and optimum moisture content for stabilized sandy soil were achieved by modified Proctor test [ASTM D 1557 – 00, 2007]. The results obtained from this test are displayed in figure (3).The maximum dry unit weight was 17.6 kN/m^3, with moisture content 11.41%.

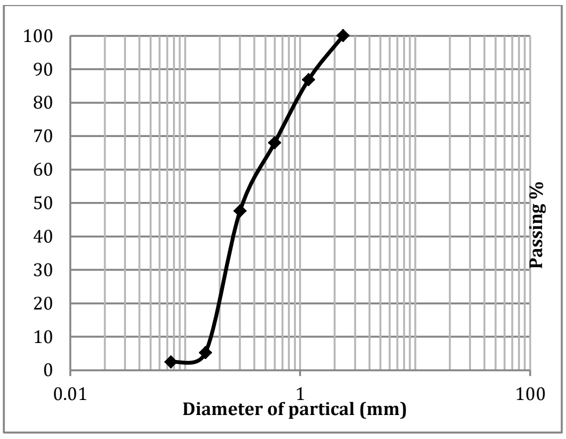

Fig. 1 The grain size distribution curve of the sand

Table 1 The physical and chemical properties of the sand

The Chemical Properties		
Property	**Value**	**Standard**
SO3	0.15 %	British Standard (BS 812: Part: 1988& ICS: 91.100.15 71.080.01 19.020 (manual 895/2003) .
T.S.S	0.75%	
Gypsum content	7.76%	
The physical Properties		
Property	**Value**	**Standard**
Gs	2.6	ASTM (D854-2007)
γ_{dmin} e_{max}	14.18 kN/m^3 0.799	ASTM (D4254-2007)
γ_{dmax} e_{min}	17.65 kN/m^3 0.445	ASTM (D 1557 – 00)
γ_{dused}	16.39 kN/m^3	----------
e_{used}	0.556	----------
n_{used}	35.74%	----------
$Ø_{used}$	37.2o	----------
$R.D_{used}$	68.64%	----------
O.M.C	11.45%	ASTM (D 1557 – 00)
D_{60} D_{50} D_{30} D_{10}	0.45 mm 0.325 mm 0.234 mm 0.184 mm	----------
C_u	2.446	----------
C_c	0.661	----------

CKD properties

Cement dust was taken from New Kufa Cement Plant. The chemical analysis as illustrate in table (2). The grain size distribution is represented in figure (2).

Table 2 The chemical analysis of CKD

Constituents	Percent by weight
SiO_3	15.38
AL_2O_3	3.46
Fe_2O_3	3.15
CaO	42.90
MgO	2.89
SO_3	6.27
K_2O	2.48
Na_2O	1.50
L.O.I	27.72
chlorides	0.91

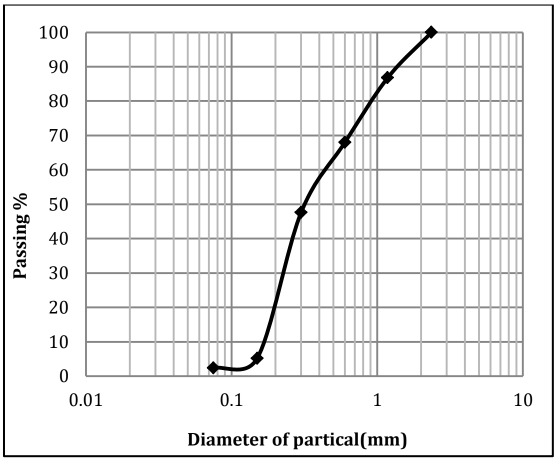

Fig. 2 The grain size distribution of CKD

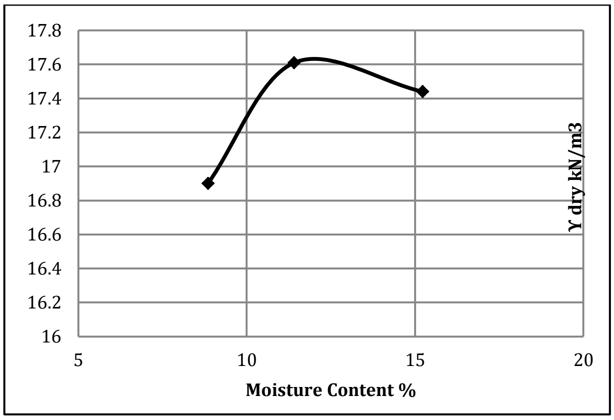

Fig. 3 Results of the modified Proctor test.

Experimental Work

Direct shear tests

A series of direct shear tests[ASTM D3080],were accomplished to investigate the shear strength parameters (c and φ). Four locations of CKD lining were prepared from the top of the sample width. They were 0.15B, 0.2B, 0.25B, and 0.5B, where B is the width of the box in direct shear test. The thickness of the layer of lining was fixed to 0.017B (1 mm). For each case of lining four cases have been prepared, load applied equal to 200 N, 300N, and 400N in first, second, and third samples respectively. Plates 1 (A to E) show the lining CKD of the soil during the test.

Plate 1-A

Plate 1-B

Plate 1-C

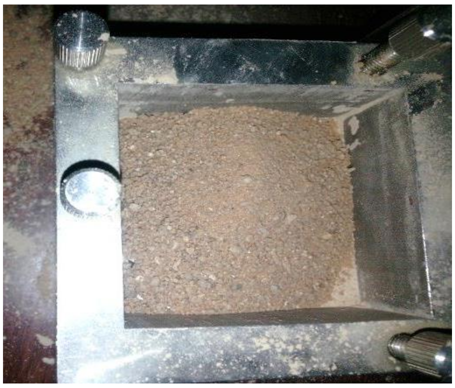

Plate 1-D

Plate 1-E

Plates 1 (A-E) Soil lining with CKD in a box of the apparatus of direct shear test

The relations between the maximum horizontal stress and vertical stress for three samples in each case are drawn to determine φ for each specific case of CKD lining as displayed in figure 4 (A to E). It is clear that the value of φ increased by using CKD lining. The values of φ converged in soil samples with lining depth of 0.15B and 0. 25B, they are about 34.41° and 34.26° for lining depth of 0.15B and 0.25B, respectively. The increase in φ in the soil with lining layer at 0.15B and 0.25B to that of the soil without CKD are 1.72 and 1.71 times, respectively.

While in case of soil samples with lining depth of 0.2B , φ increased when it compared with the value of φ in soil without CKD, but it less than φ values of soils with lining depth of 0.15B and 0. 25B, and it is about 29.91°, and it's increase to φ in soil without CKD is about 1.5 times. The higher increasing in φ value occurred in soil samples with CKD lining at depth of 0.5B. In this case, φ equal to 42.77°, and the increase in it to the φ in soil without CKD is about 2.14 times. The increasing in φ values in soils with CKD lining might be related to properties of CKD. As mentioned earlier, CKDs are fine powder comprise of slim, angular particles and bunches of particles with elevated fineness and relative densities. That means when using CKD lining in soil, the soil was reinforced with strip of bounded particles forms conglomerate and increases cohesion leads to growth in internal resistance to failure at any level inside it. On the other hand, in comparison of the above results with other cases of stabilizing sandy soil by mixing CKD with soil, there is a large difference between the two. When mixing CKD with sand the angle φ is virtually constant with the increase in CKD amounts [Albusoda, B. S., and Salem, L.A. Kh., 2012].Figure 4 shows the variation in φ with the depth of CKD lining.

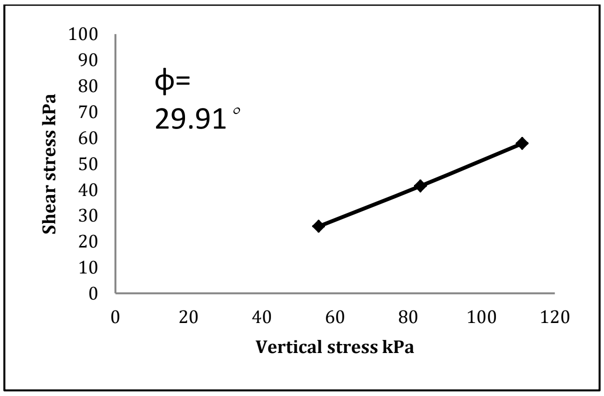

Fig. 3-C Soil with lining CKD at 0.2B

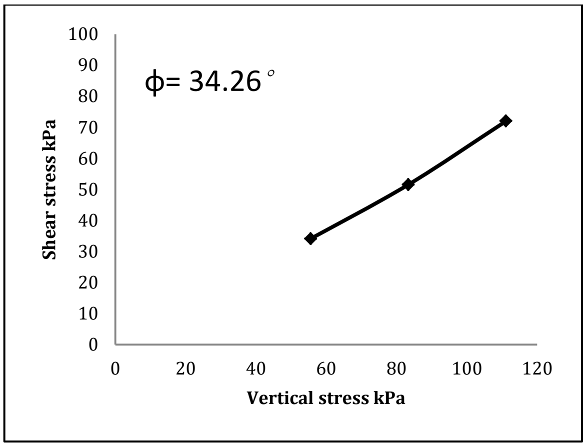

Fig. 3-D Soil with lining CKD at 0.25B

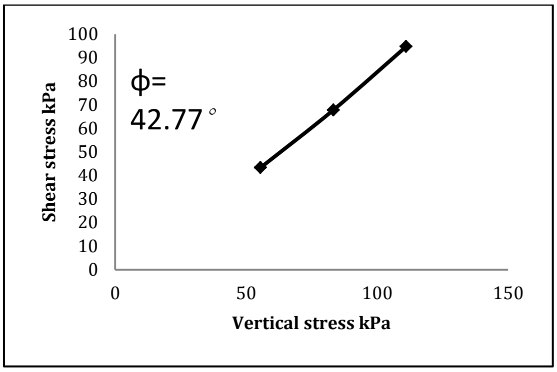

Fig. 3-E Soil with lining CK D at 0.5B

Fig. 3 (A-E) Horizontal stress versus vertical stress for the tested cases

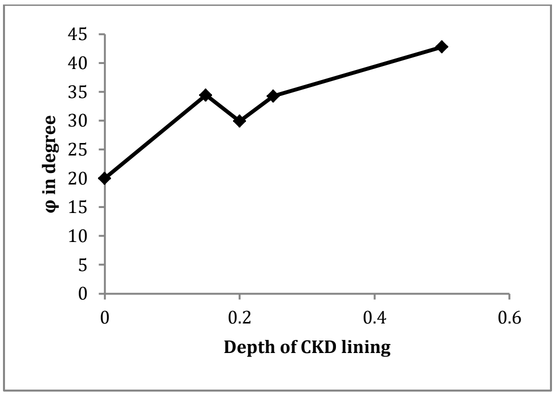

Fig. 4 The variation in φ with the depth of CKD lining

Comparison study

Square footing with dimensions of (2×2 m), as shown in Plate 2, based on sandy soil (D_f = 0), (have same properties of the soil of the current study). The bearing capacity of the soil was determined by using Terzaghi, Meyerhof, and Vesic equation [Bowles, J. E., 1996], as below:

Terzaghi equation

$q_u = CN_cS_c + q\,N_q + \frac{1}{2}\gamma\,B\,N_\gamma S_\gamma$..**1**

C : Cohesion of soil (C= 0 because only pure sand, then first term is equal zero)

N_c, N_q and N_γ: Bearing capacity factors for Terzaghi.

S_c and S_γ: Shape factors for the Terzaghi (S_c = 1.3 and $S_\gamma = 0.8$ for square footing).

γ : dry density of soil under footing.

B: width of footing.

Meyerhof equation

$q_u = CN_cS_cd_ci_c + q\,N_qs_qd_qi_q + \frac{1}{2}\gamma\,B\,N_\gamma S_\gamma d_\gamma i_\gamma$...**2**

C : Cohesion of soil (C= 0 because only pure sand, then first term is equal zero).

N_c, N_q and N_γ: Bearing capacity factors for Meyerhof.

$S_cS_q, S_\gamma, d_cd_q, d_\gamma i_ci_q$ and i_γ: Shape , Depth and Inclination factors for the Meyerhof.
γ : dry density of soil under footing.
B: width of footing.

Vesic equation

$$q_u = CN_cS_cd_ci_cg_cb_c + q\,N_qs_qd_qi_qg_qb_q + \frac{1}{2}\gamma\,B\,N_\gamma S_\gamma d_\gamma i_\gamma g_\gamma b_\gamma \quad \textbf{...3}$$

C : Cohesion of soil (C= 0 because only pure sand, then first term is equal zero).
N_c, N_q and N_γ: Bearing capacity factors for Vesic.
$S_cS_q, S_\gamma, d_cd_q, d_\gamma i_ci_q$, i_γ: Shape, Depth and Inclination factors for the Meyerhof.
γ : dry density of soil under footing.
B: width of footing.

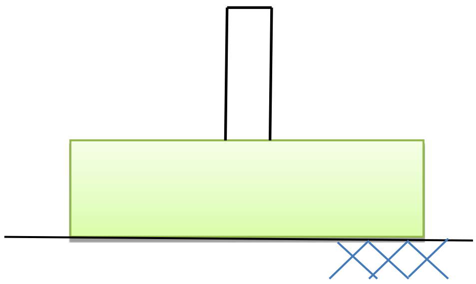

Fig. 5 Square footing based on sandy soil

Table 3 shows the bearing capacity of the stabilized soil. It is obvious that there are noticeable increases in bearing capacity in stabilized soil with CKD in all four cases. The higher results obtained in case of CKD lining at depth of 0.5B. The amount of bearing capacity of soil with CKD lining at 0.5B to that of soil without CKD lining, are increased about 41.92, 52.16, and 36.86 times by using Terzaghi, Meyerhof, and Vesic equations, respectively.

On the other hand, there are further advantages from employing CKD lining in stabilization of soil as; sustainable and environmental benefits as diminishing the pollution and the area of landfill, reducing the additional cost of embedding waste materials, and shrinking the overall volume of foundations or the numbers of piles during construction.

Table 3 Bearing capacity results of the stabilized soil with CKD lining

State of sand	Bearing capacity equations		
	Terzaghi	Meyerhof	Vesic
Sand alone	65.56	57.23	53.1
CKD 0.15 B	514	754.02	433.84
CKD 0.2 B	258.31	334.52	220.3
CKD 0.25 B	493	730.51	422.63
CKD 0. 5 B	2748.2	2985.3	1957.44

Conclusions

1. The results show the high efficiency of using CKD in enhancing the shear strength of sandy soil, as a sustainable cheap material.
2. In comparison of the results of this work with other cases of stabilizing sandy soil by mixing CKD with soil, there is a large variance between the two. CKD lining exhibit more efficiency on soil stabilization.
3. There are obvious increases in shear strength in stabilized soil with CKD in all four cases of study. The higher results obtained in case of CKD lining at depth of 0.5B.
4. The angle of internal friction φ increased by using CKD lining. The higher value of φ happened in soil samples with CKD lining at depth of 0.5B. In this situation, φ equal to 42.77°, and the increase in it to the φ in soil without CKD is about 2.14 times.
5. The increasing bearing capacity of soil with CKD lining at 0.5B to that of soil without CKD lining, are about 41.92, 52.16, and 36.86 times by using Terzaghi, Meyerhof, and Vesic equations, respectively.

References

Albusoda, B. S., and Salem, L.A. Kh., 2012 Stabilization of Dune Sand by Using
Cement Kiln Dust (CKD) Journal of Earth Sciences and Geotechnical Engineering, vol. 2, no. 1, 2012, 131-143, ISSN: 1792-9040(print), 1792-9660 (online), International Scientific Press.

ASTM D422-63, 2007, Standard Test Method for Particle Size-Analysis of Soils.

ASTM D 2487 – 00, 2007, Unified Soil Classification System.

ASTM D 1557 – 00, 2007 Standard Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table.

ASTM D854-05, 2007Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer.

ASTM D4254, 2007, Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.

ASTM D3080, Direct Shear Test of Soils Under Consolidated Drained Conditions

Bowles, J. E., 1996, Foundation Analysis and Design, 5th Edition, McGraw-Hill Book Company.

BS 812, (1988) and ICS 91.100.15 71.080.01 19.020, manual 895/2003, Testing Aggregates, Part 118, Method for Determination of Sulphate Content.

Hossain K. M. A., 2011Stabilized Soils Incorporating Combinations of Rice Husk Ash and Cement Kiln Dust Journal of Materials in Civil Engineering, ASCE, Vol.23, No. 09, pp: 1320-1327.

Keerthi,Y., Kanthi, P. D., Tejaswi, N., Chamberlin, K. S., and Satyanarayana, B., 2013Stabilization of Clayey Soil using Cement Kiln Waste International Journal of Advanced Structures and Geotechnical Engineering ISSN 2319-5347, Vol. 02, No. 02, April 2013 pp 77-82.

Khaliefa, Q. M., 2014 Permeable Reactive Barrier Technology for Remediation of Groundwater Contaminated with Copper and Zinc Ions Ph.D. Thesis, College of Engineering University of Basrah.

Mohamed A.M.O., Hossein M.,and Hassani F., B., 2002 Hydro-mechanical evaluation of stabilized mine tailings. Environ Geol 41:749–759.

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 (1), pp.77-87, available online;www.arpapress.com/ Volumes/Vol7Issue1/IJRRAS_7_1_12.pdf

Upma, J., and Kumar S., 2015Effect of Cement Kiln Dust and Chemical Additive on Expansive Soil at Subgrade Level International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 5, May, pp.3759-3767.