International Journal of Engineering Innovation & Research
Volume 10, Issue 2, ISSN: 2277 – 5668

Effect of Cement Dust on Engineering Properties of Silty Sand Soils

Fauzi H. Jarushi [1*] and Abduallh Taliballh [2]
[1] Assistant Professor, Department of Civil Engineering, University of Tripoli, Libya.
[2] Grad Student, Department of Civil Engineering, University of Tripoli, Libya.
*Corresponding author email id: F.jarushi@uot.edu.ly

Date of publication (dd/mm/yyyy): 03/04/2021

Abstract **– Cement by-pass dust or cement kiln dust (CKD) is one of the most plentiful and versatile of the industrial by-products, which contributes to environmental pollution. This calls for establishing strategies to use the same effectively and efficiently. This study presents a series of laboratory tests for investigation the adequacy of CKD on silty sand soil. The Index properties of silty sand soil like liquid limit, plastic limit with and without CKD have been compared. Along with these Atterberg limits, grain size distribution, direct shear, compaction and consolidation tests have also determined. Increasing percentages (by weight of dry soil) of CKD, ranging from 5% through 50% in 5% increments were added and the geotechnical properties assessed. It was observed, for all the soils that increasing cement dust contents brought about increasing improvements. The above experimental results were compared among them to obtain a percentage concentration of cement dust with lower value of compressibility and higher strength. The results of silty sand soils treated with cement dust showed that the strain decrease from 9% to 4% which indicated that the cement dust played an important role in reducing compressibility of the silty sand. The proposed materials can be used according to geotechnical criteria, as suitable materials for subgrade and base course construction, leading to safe and economical disposal of these materials that otherwise would be disposed as wastes**

Keywords **– Cement Dust, CKD.**

I. Introduction

Cement is a fine powdery by-pass dust is generated in large quantities worldwide during the production of Portland cement. Cement kiln dust (CKD) is a by-product of the cement manufacturing process and has traditionally been considered as an industrial waste product. Global cement production capacity in 2017 was ~4.99 billion tons per year [1], while the cement dust production rate ranged from 54 to 200 kg per ton of produced cement clinker [3]. CKD is composed of fine, powdery solids and highly alkaline particulate material, and is similar in appearance to Portland cement.

Large quantities of wastes are being generated worldwide due to rapid industrialization and excessive urbanization. The conventional disposal of these wastes causes a lot of environmental problems. In developing countries like India, where land-to- population ratio is very low and environmental protection measures are limited, it is necessary that the researchers should focus their research towards the utilization aspects of these wastes particularly in geotechnical applications for bulk consumption.

The different stabilizer such as lime, cement, bitumen and sodium chloride are the most common, and cement dust is considered one of the most prominent potential of additions to the improvement of the soil. Cement dust or cement kiln dust is a fine powder that is off-white to fawn or light brown in color that a by-product from the manufacturing of Portland cement that contains calcium compounds, calcium silicate compounds, other calcium compounds containing iron and aluminum, and other inorganic compounds generated in the cement manufacturing process. When heating the raw material at a temperature near 1400-1500°C [9].

Cement dust is an industrial waste coming out of from cement factories in most cities of the world causing serious environmental problems and therefore it requires a large land area for its disposal. Table 1 presented a summary of worldwide production.

Table 1. Annually worldwide CKD production.

No	Author & Year	Country	Tons Produced
1	[16]	World Wide, 2012	510-680 million tons
2	[15]	Oman	25,000 to 30,000 tons
3	[11]	American cement industry	15 million tons
4	[17]	Turkey	4.2 million tons
5	[3]	Al-Kufa factory, Iraq	350 ton/day
6	[9]	Egypt	5 million tons

There are no indications of the risk of this dust, and cannot rely sense of discomfort or pain to identify the injury, the only effective means of avoiding injury or illness involves minimizing contact, particularly contact with wet cement kiln dust. And this calls for the development of strategies to take advantage of this product is environmentally friendly and efficient manner and at a low cost, one of these strategies is to use the biggest part of the CKD in the soil stabilization in different geotechnical applications, because of the few of use of CKD in construction purposes.

II. Objectives

The main objective of this research was to:

- Study and evaluate the properties and compressibility of silty sand soils mixed with cement dust as waste material,
- Demonstrate the potential of using the cement dust material reduction through recycling or re-use according to geotechnical criteria, leading to safe and economical disposal of these materials.

III. Literature Review

Many researchers have pointed out the importance on re-use of industrial waste for soil stabilization and geotechnical application.

Study by [12] presented a comparative study on behavior of soft soil using various admixtures. It was concluded that the consistency limits decreases with the addition of fly ash, CKD, rice husk ash and RBI Grade 81. The unconfined compressive strength and CBR value of treated soil mixture increases with the increase in percentage of cement dust and RBI Grade 81.

investigated the characterization of CKD on stabilized black cotton soil [8]. The Black cotton soil was admixed with CKD varied percentage (i.e. 4%, 8%, 12%, 16% and 20%) and they found that both of liquid limit and plastic limit increases with increase in CKD percentage. When percentage CKD reached 12%, a consequent reduction in plasticity index occurs. Black cotton soil admixed with 12% CKD showed significant increase in maximum dry density with a corresponding reduction in optimum water content which is desirable.

Investigation by [10] on black cotton soil using CKD used as a chemical admixed to improve the characteristics. Increasing percentages (by weight of dry soil) of CKD, ranging from 5% through 25% in 5% increments were added for curing periods (1, 3,7,14 & 28 days). It was observed, for all the soils that increasing CKD contents brought about increasing improvements.

Work conducted by [2] on investigation the characteristics of cohesive soils stabilized by CKD. The content was chosen as 0%, 5%, 10%, 15%, and 20% by dry weight of soil. It was shown that the strength was increased while plasticity and coefficient of permeability were substantially reduced. Moreover, the treated samples showed a reasonable durability for both wetting-drying, and freezing-thawing.

Conducted a study on effect of CKD on engineering properties of black cotton soil [14]. The results showed a significant increase in soaked CBR and unconfined compressive strength values. Different free swelling on black cotton soil reduced from 31% to 5%. The maximum dry density increased from 1.73 Mg/m^3 to 2.03 Mg/m^3 where the optimum moisture content decreased from 20.04% to 10.94%. Permeability increased from $4.80x10^{-6}$ m/s to $1.43x10^{-5}$ m/s.

In the work of [13] on assessment of CKD on expansive soil for the construction of flexible pavements. Results showed that the index properties of the soil improved. 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 sub-grade of lightly trafficked roads and as admixture in lime stabilization during construction of flexible pavements over expansive soil.

Carried out a study to improve expansive soil by using CKD [17]. It was added to the soil at 0 to 12 percent by weight. Tests were repeated with lime (3%, 6% and 9%), cement (3%, 6% and 9%) and sand (3%, 6%, 9%, 12% and 15%) instead of CKD for comparison. The addition of 12 % CKD showed that swelling percentage of expansive soil decreased from 36.63 % to 6.74 % without curing and from 35.58 % to 6.32 %, and 33.63 % to 6.00% for 7and 28 days curing respectively.

Concluded that the CKD caused an irregular decrease in the liquid limit [1]. The material allowed compaction of the soil at lower maximum dry unit weight and higher optimum water content OWC. Also they found an increase in values of angle of internal friction φ and cohesion c. Higher cohesion was reached with higher percentage of CKD.

Investigated the potential of CKD in sub-grade improvement [4]. It was found that the Atterberg limits decreased with the addition of CKD up to 12% and then increased slightly with further increase in the addition. The results also indicated that between 0% and 12% of CKD content, the maximum dry density increased from 1.83 Mg/m^3 to 2.60 Mg/m^3. The result showed also that the CBR for unsoaked sample increase from 22% to 80% with increase in CKD content from 0% to 24% respectively.

Made a study on improving the strength of sandy silt soils by mixing with CKD [5]. Three numerical models were built for an embankment of a canal to examine the introduced method to overcome slope stability problems. The results showed that adding CKD led to significant improvement of the slope stability.

Conducted an investigation on stabilization of clayey soil using CKD waste maximum dry density [7], unconfined compressive strength tests and other tests were conducted, maximum dry density increased but at appoint started decreasing and same was noticed for unconfined compressive strength. It was observed that 50%

of CKD was optimum percentage for clayey soil stabilization.

Presented a series of laboratory tests for investigation the effect of CKD on some geotechnical properties of black cotton soil [6]. The results showed that the plasticity index and free swell were reduced from 24.2% to 16.5% and 48% to 35% respectively. The maximum dry density reduced from 1.77 Mg/m^3 to 1.68 Mg/m^3 at 10% CKD. The reduction in the values of plasticity index and free swell are indication of improvement in the swelling and shrinkage property of black cotton soil.

IV. Testing Methodology and Sample Preparation

An experimental study was carried out to investigate the potential of using industrial wastes, namely CKD or kin cement dust. Thus making the possibility of its applications in solving many real-world problems. Laboratory tests were carried out according to ASTM specification on silty sand soils (SM) using cement dust as a chemical admixed to improve the characteristics of the silty sand soils. Increasing percentages (by weight of dry soil) of CKD, ranging from 5% through 50% in 5% increments were applied and examined.

The tests included soil classification, chemical analysis, specific gravity, Atterberg limits, direct shear, Proctor compaction and compressibility test.

A. *Engineering Properties of Soil*

A soil specimen particle size distribution and engineering properties are presented in table 2. The soil was classified according to American Association of State Highway and Transportation Officials (AASHTO) as A-4 soils and According to the Unified Soil Classification System (USCS) as Silty Sand soils (SM).

Table 2. Soil engineering properties and classifications.

Property	**Value**
Gravel %	0
Fine Sand	56.13
Coarse to medium Sand %	0.47
Silt %	43.4
Clay %	0
Soil Classification	
USCS	SM
AASHTO	A-4
Physical Property	
Specific Gravity	2.647
Liquid Limit %	19.1
Plastic Limit %	17.15
Plastic Index %	2

B. *Physical Properties and Chemical Compositions of Cement by-pass Dust*

International Journal of Engineering Innovation & Research
Volume 10, Issue 2, ISSN: 2277 – 5668

The chemical composition of CKD sample under this study were carried out in Libyan Geological Researches Laboratories table 3.

Table 3. Chemical compositions of CKD.

Compound	%
LOI	20.90
Al_2O_3	5.05
Fe_2O_3	2.35
SiO_2	15.70
CaO	52.14
MgO	1.4
Na_2O	0.28
K_2O	1.35
SO_3	0.85

V. Results and Discussion

Test results variations of LL, PL, DFS, OMC, MDD and compressibility properties with the addition of CKD up to 50% by dry weight of soil are presented below.

The LL and the PL of the different soils shows slight increase with increasing CKD content (from an average of about 20.0% to an average of about 25% when comparing the values at 0% and 50% CKD contents).

It was observed that with increasing CKD contents, the optimum moisture contents increased (from an average of about 11% to an average of about 15% when comparing the values at 0% and 50% CKD contents) while the maximum dry densities decreased from an average of about 1.92 Mg/m^3 to an average of about 1.76 $Mg/m^3$when comparing the values at 0% and 50% CKD contents.

The final value of dry density at 50% CKD has placed the modified soils, according to geotechnical criteria, as suitable materials for subgrade and base course construction. The angle of internal friction obtained constant between 35 degree and 37 degree.

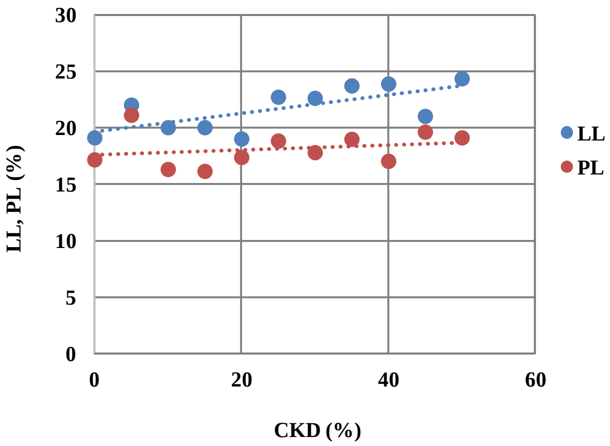

Fig. 1. Effect of CKD on index properties of silty sand soil.

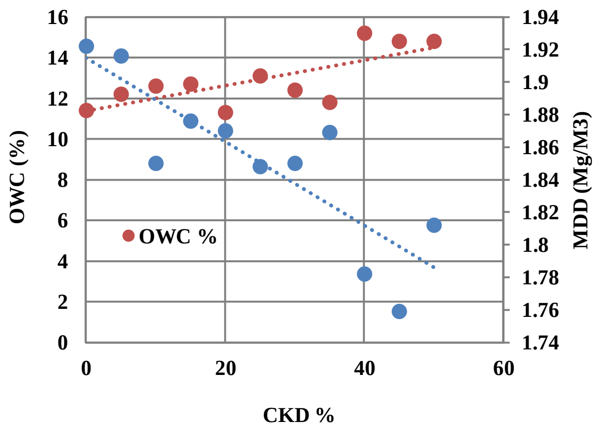

Fig. 2. Compaction characteristics vs. CKD (%)

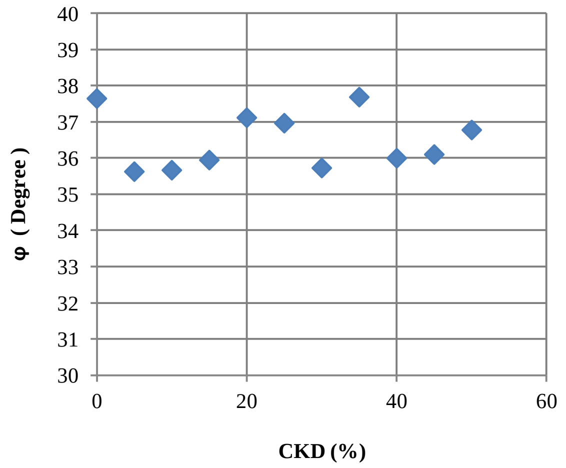

Fig. 3. Angle of internal friction vs. CKD.

A. *Consolidation Test Results*

Consolidation theory is required for differential settlements that can lead to structural failures due to tilting should be avoided. Otherwise, you’ll need extreme measures to save your structure. A series of consolidation test is implemented for investigation on the CKD composite settlement. Consolidation test given in the ASTM is used for the saturated and partially saturated samples.

This test was performed in order to the determine magnitude and rate of volume reduction of soil sample, which is laterally limited and suffers the different vertical pressures. By the obtained void ratio-effective stress curves and settlement- log time, the results were calculated. The achieved results on TABLE III are illustrated that an association between initial and amount of additives.

B. *Coefficient of Consolidation*

The coefficient of consolidation c_v is revealed the amount of settlement in each loading period. At 90 %, the coefficient of consolidation ranging from 2.61x10-6 to 1.35x10-6 m2/s. Fig. 1 presented the relationship between c_v with CKD. It seems that by adding more CKD up to 20 percent, the c_v was 0.6x10-6 m2/s, which had the most significance effect on swelling index of sand treatment with CKD. Nonetheless, sand stabilization with more than 20 percentage of CKD lead to increment in c_v that was increased to 1.52x10-6 m2/s.

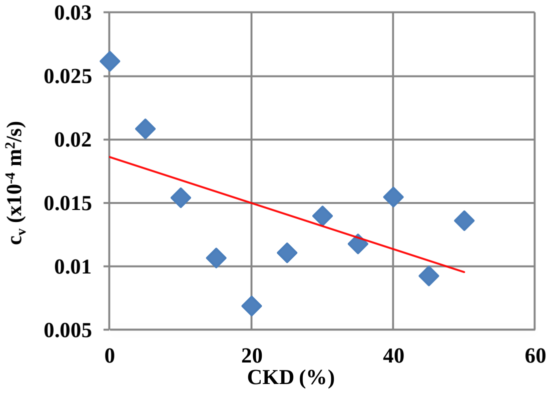

Fig. 4. Coefficient of consolidation vs. CKD (%).

C. *Compression and Recompression Index*

The final sample settlement showed decrees from 1.8 mm at 0% CKD to 0.85 mm at 50% which can be concluded that use of 50% can help reducing settlement by 4% of the total height.

Swelling curve of samples with CKD are revealed that soil characteristics of treated samples have a diverse behavior in each mixture of additives as shown in Fig. 4. In general, by the amount of compression index was reduced in CKD treated samples. This decreasing has a continuously trend until sample with 50% of CKD.

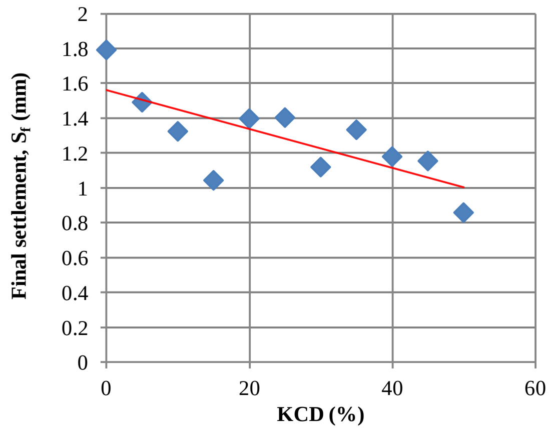

Fig. 5. Final settlement vs. CKD (%)

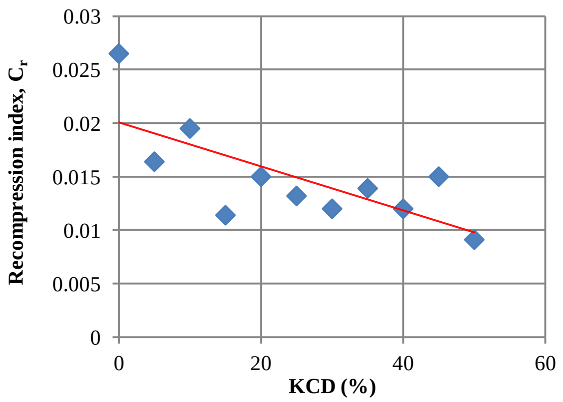

Fig. 6. Recompression index vs. CKD (%).

D. *Coefficient of Compressibility and Permeability*

Figs. 6 (a)-(b)) illustrate the relationship of specimens with different amounts of CKD. It is evident that the coefficient of compressibility and coefficient of permeability were decreased up to 20% CKD and then increases considerably.

As for the explanation of the causes of increasing the coefficient of compressibility (see Fig. 5) when CKD increases at an average higher than 20%, it may be due to the new arrangement of granular gradient of the soil sample and the additive. The other reason may be that the form of CKD granules, where CKD granules are round. The round granules are characterized by strong compressive strength and low void among them.

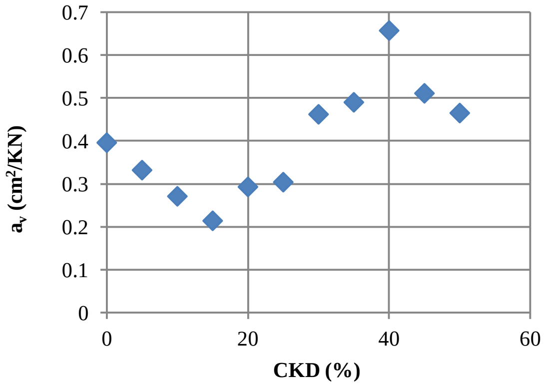

Fig. 7. Coefficient of compressibility vs. CKD (%).

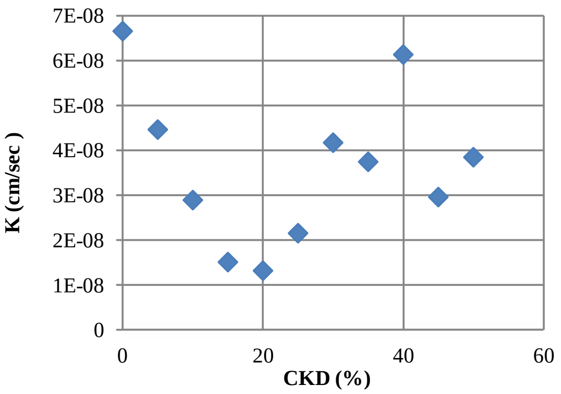

Fig. 8. Permeability vs. CKD (%).

VI. Conclusions and Recommendations

This paper presented the effect of CKD on geotechnical and compressibility parameters of sandy soils and to demonstrate the potential of using the CKD material reduction through recycling or re-use according to geotechnical criteria, leading to safe and economical disposal of these materials. From the data presented in this paper, the following conclusions can be drawn:

- Atterberg limits of samples are slightly increases with the increasing of CKD into the silty sand soils,
- Optimum moisture content increased from 11 % to 15 %,
- Maximum dry density has reduced from 1.92 Mg/m^3 to 1.76 Mg/m^3

- There is no effect on cohesion and internal friction angle in samples.
- The results indicate that the compressibility of treated specimens were developed.

In overall, the results reported that a downward tendency in swelling index data of CKD specimens. Nevertheless, the lowest amount related to sample with 20 percent CKD.

From this research, it can be concluded that CKD has a potential to modify the characteristics of loose silty sand soils to make it suitable in geotechnical applications.

The results of the consolidation test showed that the higher the addition of CKD to the soil, the greater value of each c_v, C_c, and a_v. The results showed that the increase in the percentage of CKD, the lower the value of C_r, ε, and S_f.

It has been observed that 20 % of CKD is the optimum amount required to minimize the compression index and the coefficient of consolidation.

The study recommends using the value of 50% of the addition to the proposed materials which led to a suitable geotechnical criteria as waste material, leading to safe and economical disposal of these materials that otherwise would be disposed as wastes.

REFERENCES

[1] Albusoda B.S. and Salem L.A. Stabilization of dune sand by using cement kiln dust (CKD). J. of Earth Sciences and Geot. Engineering. 2012 Jan; 2(1):131-143.
[2] Al-hassani A.M., Kadhim S.M., and Fattah A.A. Characteristics of cohesive soils stabilized by cement kiln dust. International Journal of Scientific & Engineering Research.2015 June; 6(4):2032-2038.
[3] Al karagooly Y.J. Effect of cement kiln dust on some properties of doil. J. of Babylon University/Engineering Sciences.2012 April; 20(4): 1150-1156.
[4] Andrew E E. Potentials of cement kiln dust in subgrade improvement. Faculty of Engineering, University of Nigeria.2012.
[5] ElMashad M. and Hashad A. Improving the strength of sandy silt soils by mixing with cement kiln dust. J. of Eng. Sciences, Assiut University. 2013 July; 41(4):1-10.
[6] Iorliam A.Y., Agbede I.O. and Joel M. Effect of Cement Kiln Dust (CKD) on Some Geotechnical Properties of Black Cotton Soil (BCS). The Electronic Journal of Geotechnical Engineering (EJGE) 2012, Vol. 17, Bund. H.
[7] Keerthi Y., Kanthi D.P., Tejaswi N, Chamberlink S, Satyanarayana B. Stabilization of Clayey Soil using Cement Kiln Waste. International Journal of Advanced Structures and Geotechnical Engineering. 2013 April; 2(2):77-82
[8] Kumar P. and Devendra S. Characterization of cement kiln dust stabilized black cotton soil. International Journal of Research in Engineering and Technology. 2016 May; 5(14):104-107.
[9] Naik Tarun R., Fethullah C., and Chun Y. (2003). Uses of CKD other than for flue gas desulfurization. College of Engineering and Applied Science the University of Wisconsin. 2003.
[10] Pujar P and and Sudeep M. Stabilization of expansive soil using cement kiln dust. Imperial Journal Of Interdisciplinary Research. 2016 July; 2(7):1089-1095.
[11] Rahman M.K., Rehman S., and Al-Amoudi O.S. Literature review on cement kiln dust usage in soil and waste stabilization and experimental investigation. International Journal of Recent Research and Applied Studies. 2011 April; 7 (1): 77-87.
[12] Raj S., Gupta N. and Sharma L. Comparative study on behaviour of soft soil using various admixtures. International Journal of Modern Engineering Research. 2017 Feb; 7(2):72-77.
[13] Salahudeen A.B., Eberemu A.O. and Osinubi K.J. Assessment of cement kiln dust-treated expansive soil for the construction of flexible pavements. Geotech Geol Eng (Internet). 2014 April.Avaiable from http://www.elearnica.ir. doi: 10.1007/s10706-014-9769-0.
[14] Singh V. and Jain R. Effect of cement kiln dust (CKD) on engineering properties of black cotton soil. International Journal for Innovative Research in Science & Technology. 2015 May; 1(12):86-90.
[15] Taha R., Al-Rawas A., AI-Harthy A. and AI-Siyabi H. Use of cement by-pass dust in soil stabilization. Engineering Journal of the University of Qatar.2001 June; 14 (1): 61-76.
[16] Upma J. and Kumar S. Effect of cement kiln dust and chemical additive on expansive soil at subgrade level. International Journal of Innovative Research in Science. 2015 May; 4(5):3795- 3767.
[17] Yilmaz M.K. Improvement of expansive eoils by using cement kiln dust. Middle East Technical University. 2014 May.

AUTHOR'S PROFILE

First Author
Fauzi H.M. Jarushi is with the Civil Engineering Department, Tripoli University, Tripoli, Libya (phone: +218917630068).

Second Author
Abduallh Taliballh is a master degree student at the Libyan Academy School of Applied and Engineering Sciences /Department of Civil Engineering, University of Tripoli, Libya.