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Stabilization of Sabkha soil using Cement Kiln Dust (CKD)

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ABSTRACT

Roads designers are often faced with the challenge to design a stable solid foundation on top of Sabkha soil, which has high salt content, very low bearing capacity and loosing of its strength upon wetting. Roads constructed on this type of soil are mainly facing problems of settlement due traffic loads and very low bearing capacity of Sabkha soft soil. This type of soil need to be stabilized using one of the stabilization techniques. The aim of this paper is study and evaluate the sabkha soil problem, which exist in North-West of Libya, where the main road connecting Libya with Tunis passed. This paper illustrates the results of using Cement Kiln Dust (CKD) in Sabkha soil stabilization. The results show a considerable improvement of sabkha soil properties based on tests conducted specially CBR values.

تثبيت تربة السبخة باستخدام غبار الاسمنت (CKD)

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قسم الهندسة المدنية، كلية الهندسة، جامعة صبراته، صبراته، ليبيا.

الكلمات المفتاحية:
تثبيت تربة السبخة
تربة السبخة وCKD
غبار افران الأسمنت وتثبيت التربة
استخدامات CKD

الملخص

غالبا ما يواجه مصممو الطرق التحدي المتمثل في تصميم أساس متين مستقر فوق تربة السبخة، والتي تحتوي على نسبة عالية من الملح، وقدرة تحمل منخفضة للغاية وتفقد معظم قوتها عند ما تكون مشبعة. تواجه الطرق المشيدة على هذا النوع من التربة بشكل رئيسي مشاكل الهبوط بسبب الأحمال المرورية والقدرة المنخفضة جدا .على تحمل تربة السبخة الناعمة. يحتاج هذا النوع من التربة إلى التثبيت باستخدام إحدى تقنيات التثبيت الهدف من هذه الورقة هو دراسة وتقييم مشكلة تربة السبخة الموجودة في شمال غرب ليبيا، حيث يمر الطريق الرئيسي الذي يربط ليبيا بتونس. يوضح هذا البحث نتائج استخدام غبار افران الأسمنت (CKD) في تثبيت تربة السبخة. أظهرت النتائج تحسنا كبيرا في خواص تربة السبخة بناء على الاختبارات التي أجريت وكذلك تحسين قيمة نسبه كالفورنيا (CBR).

Introduction

Sabkha is an Arabic term that describe recent coastal sediments with a high salt content and are characterized by very low bearing capacities. Sabkha soils are widely distributed over the world, like in India, Australia, USA and Southern Africa as well as the Arabian Peninsula [1].

The geotechnical problems caused by sabkhas are now well definite and although several standard soil improvement methods are broadly used. One of the economical methods of soil stabilization used in roads and highways is the chemical stabilization by adding materials like lime or cement.

Cement Kiln Dust (CKD) are used in this study as additive to improve the Sabkha soil properties. It is estimated that 15 to 20% is generated from the produced cement, which means that millions of metric tons of CKD are produced [2].

There are many studies used CKD as soil stabilizer to improve its geotechnical properties. Examples of these studies are shown in Table (1).

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Table 1: Examples of studies that used CKD in soil stabilization

Study by	Reference Number	Aim of the study	Percent of CKD used
(Sreekrishnavilasam et al,.2007)	[3]	treatment (fresh and landfilled materials	8,15, and20%
(Moon et al.2008)	[4]	stabilization of arsenic contaminated soil	10 to 25%
(Albusoda and Salemm,2012)	[5]	Use CKD for dune sand	4,8 and 12%

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		stabilization.	
(Okofor and Egbe,2013)	[6]	improvement of sub-grade using cement kiln dust (CKD)	2 to 24%
(Alawi, 2016)	[7]	using cement kiln dust (CKD) as a surfacial clay soil stabilizer underneath roads	10,15,20,25 , and 30%
(Shuja et al. 2022)	[8]	stabilization of sabkha soils with cement and CKD	5,10,15 and 20%

This paper presents the test results carried out on Sabkha soil stabilized by using Cement Kiln
Dust (CKD) to improve their bearing capacity and reduce plasticity, swelling, and shrinkage.

Properties of Sabkha soil

Sabkha soil can be divided into two categories [9]:

• Muddy sabkhas: These soils are located near the cost, on depths ranging between +2m to -6m from the sea level.

• Sandy sabkhas: often successive layers of sand and silt and sandy located at great distances from the beach up to tens of kilometers. Table (2) illustrate the properties of both sabkha types.

Table 2: Typical soil properties of muddy and sandy sabkhas [9]

Properties	Muddy Sabkhas	Sandy Sabkhas
Percentage Fines	25 to 95	5 to 25
Salt content (%)	2 to 18	2 to 15
Water content (%)	25 to 90	4 to 40
In-situ density	1.0 to 1.35	1.3 to 1.85
Internal friction	00 to 220	200 to 350
Percentage of Ca CO3 (%)	20 to 90	> 30
Plasticity index	0 to 40	Non plastic
Cohesion (kN/m^2)	0 to 55	Zero
Compression index	0.4 to 0.95	Zero
S.P.T. values (blows)	0 to 4	2 to 10
Static cone resistance (MN/m^2)	0.2 to 2	1 to 6
Bearing capacity (KN/m^2)	15 to 30	30 to 60

To construct, Muddy Sabkha soil considered more problematic comparing with the sandy type.

Aim of the study

To improve the sabkha soil properties by using Cement Kiln Dust (CKD) to improve their strength and reduce plasticity, swelling, and shrinkage.

Methodology

1 Location of the study selection and soil properties characteristics

Samples used in this study were obtained from the port of Zuwarah's road, which is located about 100 km west of Tripoli, the capital. This road were selected because there was settlement problems on the road surface that can be noted clearly.

2 Sample collection

Disturbed and undisturbed sample were collected. The samples were Muddy Sabkha soil with brown color. High water table has been observed with a high percentage of salts.

3 Studying **the characteristics of soil used**

A number of tests were carried out according to ASTM standards to measure the engineering properties of soil samples. Tests results are shown in (Table 3).

Table 3: Summary of test results on soil samples

No.	Test description	Test results
1	Specific gravity	2.26
2	Field density (KN/m^3)	12.57
3	Natural Water content	39.71
4	Plasticity index (PI) %	14
5	Maximum Dry density (KN/m^3)	17.2
6	Optimum moisture content (O.M.C) %	17
7	California Bearing Ratio (Unsoaked) %	44
8	California Bearing Ratio (Soaked) %	25
9	Swelling %	1.93
10	AASHTO soil classification	A-6
11	Unified soil classification	CL
12	Cation exchange capacity	>30
13	PH value	9.02

4 **Selection of stabilization materials**

Cement Kiln Dust (CKD) was chosen as additive to improve the Sabkha soil, which is a product of the manufacturing process of cement before it becomes finalized..Chemical analysis of Kiln cement dust is shown in (Table 4).

Table 4: Chemical composition of Cement Kiln Dust

Compound	%
AL_2O_3	**6.09**
Fe_2O_3	**30.99**
SiO_2	**29.16**
CaO	**37.85**
MgO	**2.01**
Na_2O	**0.20**
K_2O	**1.12**

Cement dust has been selected for use in the stabilization process of the soil, because it contains the main chemical compounds that work to stabilize the soil. CKD were obtained from Cement Factory – Al-Khoms,Libya.

5 Laboratory tests

Cement kiln dust mixing ratios of 8%, 12% .16% was selected, and then conducting laboratory tests on a mixture of soil and cement kiln dust (CKD) after mix them and left them for 24 hours exposed to air at the Laboratory temperature.

A number of laboratory tests were carried out according to ASTM standards to investigate the properties of the plain soil and after adding the decided percent of CKD. These tests include pH value, Plasticity index, maximum dry density, optimum moisture content, unsoaked CBR and soaked CBR.

pH are measured, since it is one of the factors that help to success of the lime treatment process [3]. The high values of pH (because of lime) help in forming cementnous material that help to increase soil strength. The pH values are shown in table 5.

The plasticity index was decreased with increasing of CKD percent added to the soil.

(Fig. 1**)** illustrates the relationship between the proportion of cement dust added and plasticity index. Also, swelling index was reduced with increasing of the CKD added. **(Fig.** 2**)** shows the relationship between the proportion of cement dust added and the swelling index. Small increase in maximum dry density was noticed as the percent of CKD added increase. **(Fig.** 3**)** illustrate the relation between Maximum dry density and percent of CKD added.

Samples of the plain sabkha soil subjected to soaked CBR tests are prepared with the dosages of CKD, and tested according to ASTM standard in addition of the plain Sobkha soil. The samples were sealed and cured for 7 days at laboratory condition of (25) °C. Then, they are soaked in tap water for 4 days before testing. Figure 3 illustrates the relationship between the proportion of cement dust added and the CBR value. Noticeable improve in CBR values as the percent of CKD increased. **(Fig.** 4**)** illustrates the relationship between the proportion of cement dust added and the CBR value.

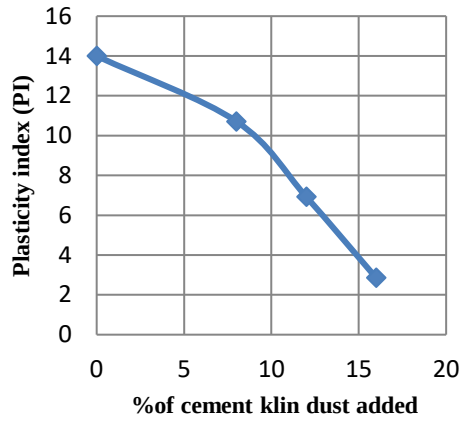

Fig 1: Relation between CKD and plasticity index

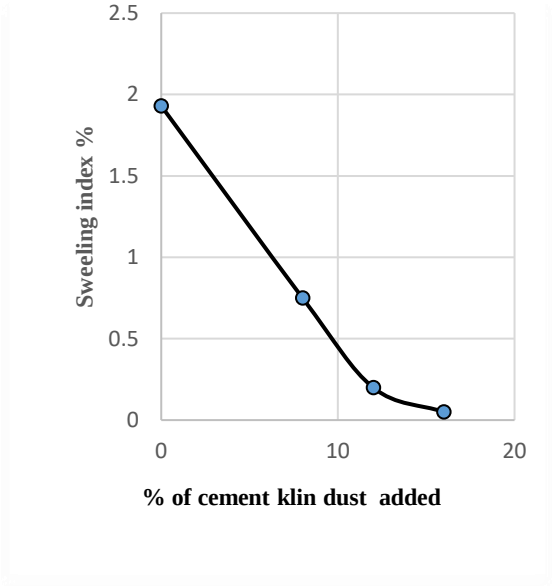

Fig 2: Relation between CKD percent added and swelling index

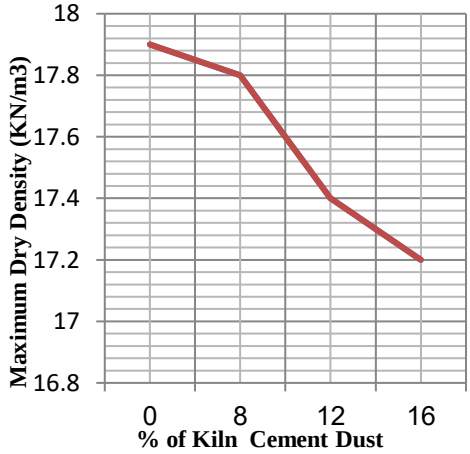

Fig 3: Relation between CKD percent added and maximum dry density

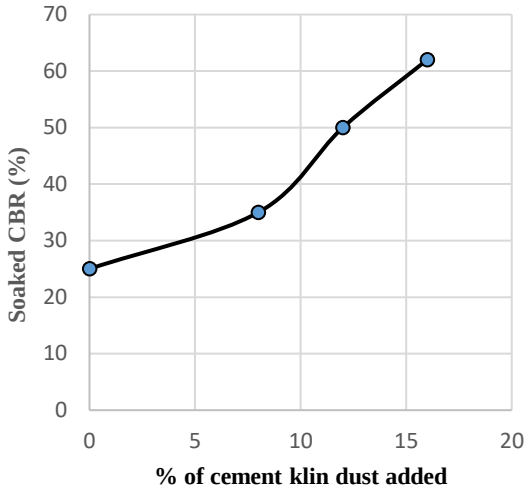

Fig. 4: Relation between CKD percent added and soaked CBR value

Conclusion and recommendations

- Results of laboratory tests shown the possibility of using cement Kiln dust to improve the properties of Sabkha soils, where the water is drained within the internal spaces of the soil, which helps to increase the strength of the soil and reduce swelling and plasticity.
- Small decrease in maximum dry density was noticed as the percent of CKD added increase. similar results was illustrated by (Alawi,2016) and (Okafor and Egbe.,2013)
- Clear improvement in the CBR value can be noted where the percentage increase to more than 100 % compared to the soil without the addition of cement dust. Similar trend was reported by (Abdullah A et al., 2017), (Shuja et al. 2022) and (Okafor and Egbe.,2013)
- Swelling index reduced to about 0.05 %, which is a small percentage compared to swelling index of soil without additives, as well as less plasticity index. Similar results been reported by (Miller and Shahriar,2000) and (Okafor and Egbe.,2013)
- The use of cement kiln dust in soil stabilization, relatively economic compared with cement, lime and other stabilization materials.
- It is recommended to conduct further laboratory experiments at different rates and different treatment period and other additional tests when using the soil in the implementation of slops.

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