Effect of Cement Kiln Dust on Some Properties of Soil

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Abstract

In recent years, use of various waste products in ground construction and modification has gained considerable attention worldwide in view of increasing costs of waste disposal, and environmental constraints. One of these waste products is the cement kiln dust, which is a by-product of Portland cement manufacturing process. It is generated from burning the raw materials in a rotary kiln to produce clinker. The cement kiln dust used in this study was brought from Al-Kufa cement factory.

In this study, the effect of adding different percentages of cement kiln dust on some properties of clayey silt soil was investigated. The results show that the plasticity index, liquid limit and activity of soil decrease significantly as the percentage of added cement kiln dust increases, while the plastic limit increase. The maximum dry density decreases and the optimum moisture content increases as the added cement kiln dust increases. Also, significant improvement in the performance of soil as a subgrade in a highway can be noticed with increase in CKD percentage, due to a reduction in value of the group index.

الخلاصة

استخدام نواتج عرضية مختلفة في تشييد وتحسين خواص التربة اكتسب مؤخرا اهتمام كبير واسع النطاق نظرا للمشاكل البيئية وزيادة كلفة التخلص منها. واحد من تلك النواتج العرضية هو غبار مرسبات افران السمنت والناتج من عملية تصنيع السمنت البورتلاندي والمتولد من حرق المواد الاولية في الفرن الدوار لانتاج الكلينكر. غبار السمنت المستخدم في هذه الدراسة جلب من معمل سمنت الكوفة.

في هذه الدراسة تم التحري عن تأثير اضافة غبار السمنت على بعض خصائص التربة، واظهرت النتائج بان قيم مؤشر اللدونة وحد السيولة والفعالية انخفضت بشكل واضح مع زيادة نسبة غبار السمنت بينما حد اللدونة ازداد ،اضافة الى ذلك فان هنالك تحسن في اداء التربة كطبقة تأسيس في الطرق نتيجة تناقص قيم مؤشر المجموعة. في حين ان قيم الكثافة الجافة العظمى سجلت تناقصا مع ازدياد في محتوى الرطوبة الامثل عند زيادة نسبة غبار السمنت.

Introduction

Cement kiln Dust (CKD) is a by-product of Portland cement manufacturing process. It is generated from burning the raw materials in a rotary kiln to produce clinker. The percentage of (CKD) wasted in a cement manufacturing process is (15-20) percent of the output of the kiln (Mohammed Shamel,2002). The above percent finely pulverized materials will be agitated and thus suspended as dust in gases.

The resources of this dust in Iraq are the cement factories. As an estimation of the annual quantity of this dust , for Al-Kufa factory and after using the collectors and precipitation processes is 350 ton/day (Ayad kadhum,2002). The cement kiln dust used in this study was brought from Al-Kufa cement factory.

In this paper, an overview of physical, and chemical properties related to utilization in ground modification of kiln dust collected from Al-Kufa cement factory. The main objective of this research is to investigate the effect of using CKD on some properties of soil.

Test Materials:

1 – cement kiln dust

Cement Kiln Dust (CKD) is a fine waste generated during the manufacturing of Portland cement. As the raw materials for making cement are heated and tumbled in kiln , dust particles are created and carried with hot exit gases. Sample of CKD was acquired from Al-Kufa cement factory. Table (1) presents the physical and chemical

properties of dust sample. CKD is generally light brown in color and consists of sand-silt-sized, non-plastic particles and is classified as ML using the Unified Soil Classification System based on the grain size (fig.1) and non-plastic characteristics of the material.

The test results showed that CKD sample contain significant amount of calcium oxide (CaO) that give it good pozzolanic characteristics (Talal O.Al-Refeai and Awad A. Al-Karni, 1999).The significant amount of cement forming oxides in the cement dust is about two-thirds of the oxide amounts found in portland cement (Audai Abdul-Elah Ismail,2005).

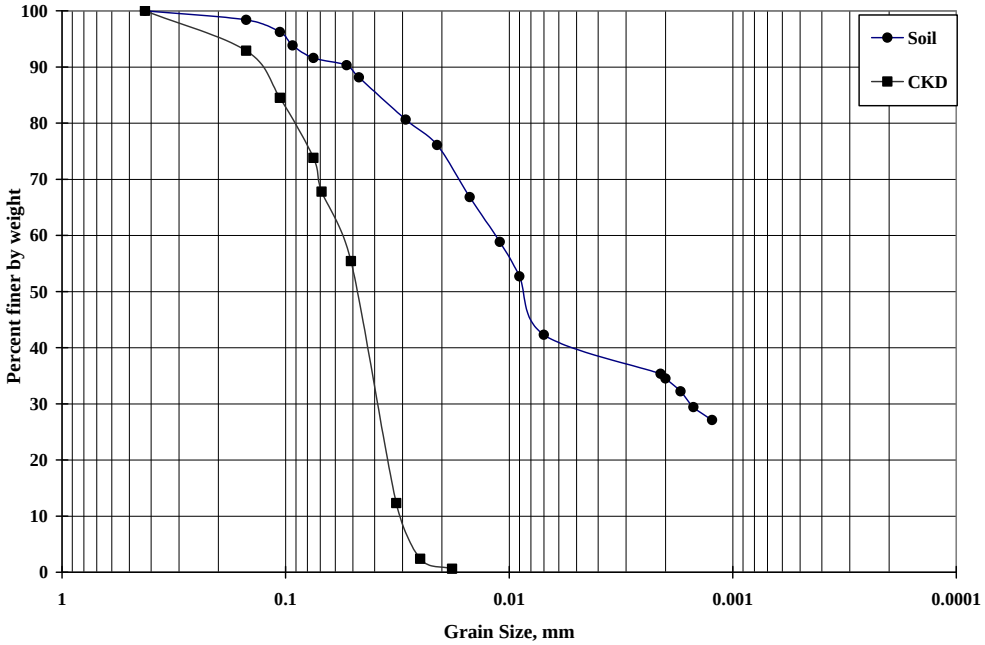

Fig.1 Grain size distribution curve for the soil and cement kiln dust.

Table (1) : Physical and Chemical properties of cement kiln dust
(After Civil Engineering Department – Soil and Environment laboratories)

No.	Property	Value
1	Specific gravity	2.67
2	Sand (%)	26.2
3	Silt (%)	73.8
4	Clay (%)	----
5	Passing sieve # 40 (%)	100
6	Description	Light brown sandy silt
	Chemical compound (%)	
7	Silica (SiO2)	17.18
8	Iron Oxide (Fe_2O_3)	2.04
9	Aluminum Oxide (Al_2O_3)	4.1
10	Calcium Oxide (CaO)	45.64
11	Magnesium Oxide (MgO)	3.1
12	Sulfur Oxide (SO_3)	6.84
13	Loss on Ignition	23.61

2- Soil

The soil used throughout this study was a brownish clayey silt and classified as CL (lean clay) according to the Unified Soil Classification System (USCS). According to AASHTO classification the soil is classified as A- 6 (17).The test soil selected from soil sample found in the soil laboratory, that represent borrow pits in south of babylon city and used as filling materials in roads construction. Table (2) shows some of the properties of the soil. The grain size distribution of the soil is shown in fig.(1).

Table (2): Properties of used soil

No.	property	value
1	Liquid limit,L.L (%)	39.4
2	Plastic limit,P.L (%)	21.6
3	Plasticity index, P.I (%)	17.8
4	Specific gravity, Gs	2.71
5	Passing sieve #200 (%)	91.6
6	Clay (< 0.002 mm) (%)	34.51
7	Maximum dry unit weight, (gm/cm^3)	1.81
8	Optimum moisture content (%)	15.4
9	Unified soil classification	ML
10	AASHTO Soil Classification	A-6(17)
11	Soil description	Brown clayey silt

Test Program and Procedures

Laboratory tests were conducted to assess the feasibility of utilizing CKD to improve some properties of the selected soil. The conducted tests include plasticity, and moisture- density relationships.

1- Plasticity

Plasticity characteristics of the CKD – treated soil were determined by performing the Atterberg's limit tests. The tests were performed in accordance with American Society for Testing Materials (ASTM) Specifications. The percentage of the CKD ranged between 0 and 40%.

2- Compaction test

Compaction characteristics of CKD-treated soil were investigated by performing Modified Proctor Test (ASTM D1557) immediately following mixing.

Analysis of Test Results

1- plasticity

Figure (2) show the effect of cement kiln dust percent on Atterberg limits. This figure proved that the plasticity of the soil was improved by addition cement kiln dust to the soil, since the liquid limit and plasticity index decreased while plastic limit was increased. The decrease in plasticity index observed with adding the first amount of CKD, then the plasticity index decreased with further increased in the amount of cement kiln dust. Since the plasticity index decrease from (17.8%) for untreated soil to (4.3%) for treated soil with (40%) of CKD.This reduction in the plasticity may be attributed to

1- The chemical and cementation effect (The oxides amounts in the cement dust is about two-thirds of the oxide amounts found in Portland cement) on structural composition of the soil. Since the modification of clay particle leading to increase the effective particle size (resulting from interparticle

cementation), consequently the amount of moisture that attracted to this particle decreased.

2- When the cement kiln dust percent increases, there is a reduction in clay content and a corresponding increase in the percentage of a coarse particles as shown in Table (3). In addition there is reduction in the activity (is a measure of the water-holding capacity of clayey soils (Dr.K.R ARORA,1987)) as shown in Figure (3).

The increase in plastic limit may be attributed to the quantity of water used should be just sufficient to satisfy hydration requirements of the CKD and to make the mixture workable.

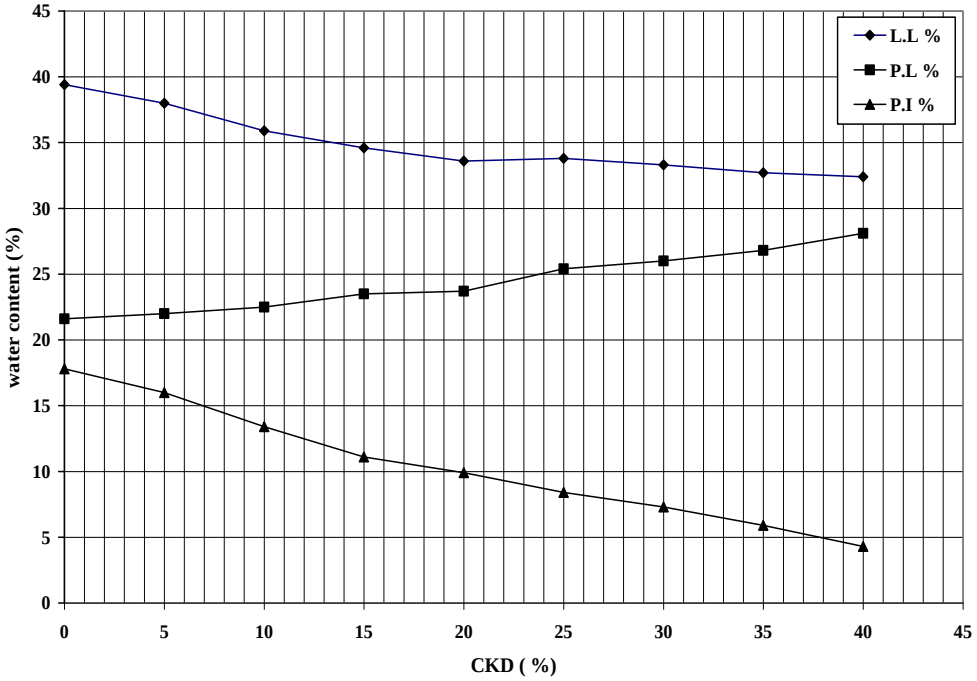

Fig.2 Variation of plastic properties of soil with increasing CKD percentage.

Table (3) Values of Plasticity index and Clay fraction for treated soil

CKD (%)	P.I (%)	Clay Fraction<2μm (%)
0.0	17.8	34.51
5	16	32.87
10	13.4	31.37
15	11.1	30
20	9.9	28.76
25	8.4	27.61
30	7.3	26.55
35	5.9	25.56
40	4.3	24.65

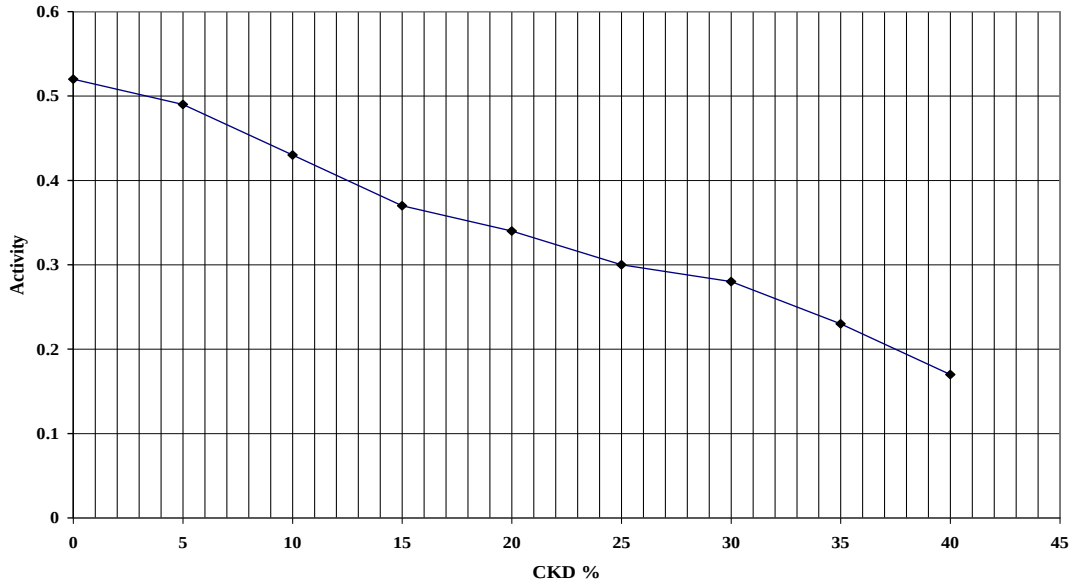

Fig.3 Variation of activity of soil with increasing CKD percentage.(activity = P.I / clay fraction).

Depending on the results of plasticity indices and grain-size distribution, the treated soil can be classified according to (USCS) as ML (silt low plasticity) instead of CL (clay low plasticity).Also, according to AASHTO classification ,and at 40% CKD , the treated soil can be classified as soil group A-4(4) instead of A-6(17).
Where:

A-4 = soil group , (4) = group index (GI)

$$GI= (F200 – 35)(0.2+0.005(L.L – 40)) + 0.01(F200 – 15)(PI – 10)$$

Where:

F200 = percent passing No.200 sieve, expressed as whole number.
L.L = Liquid limit
P.I = Plasticity Index

The group index is used for the qualitative evaluation of the desirability of a soil as a highway subgrade material, the higher the value of the group index for a given soil, the weaker will be the soils performance as a subgrade (Braja M.Ds,2004).

The results of classification for above systems are shown in table (4).

Table (4) The results of classification for treated and untreated soil

CKD (%)	Passing No.200 (%)	USCS	AASHTO classification
0	91.6	CL	A-6(17)
5	90.75		A-6(15)
10	89.98		A-6(12)
15	89.28		A-6(10)
20	88.63		A-4(9)
25	88.04	ML	A-4(8)
30	87.49		A-4(7)
35	86.98		A-4(6)
40	86.51		A-4(4)

2- Compaction Characteristics:

The relationship between the moisture content and dry density for treated and untreated soil using modified compaction test is shown in figure(4). It is noted that the maximum dry density was recorded for untreated soil. When the percentage of CKD increases the maximum dry density decreases and optimum moisture content increases, as shown in fig. (5) and fig. (6).

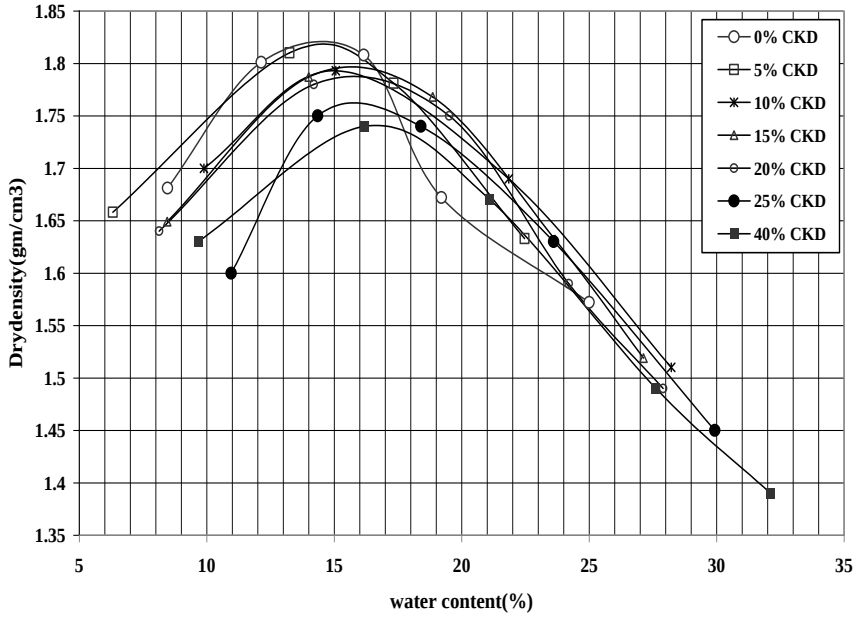

Fig.4 Modified proctor test results on the soil with various CKD percentages.

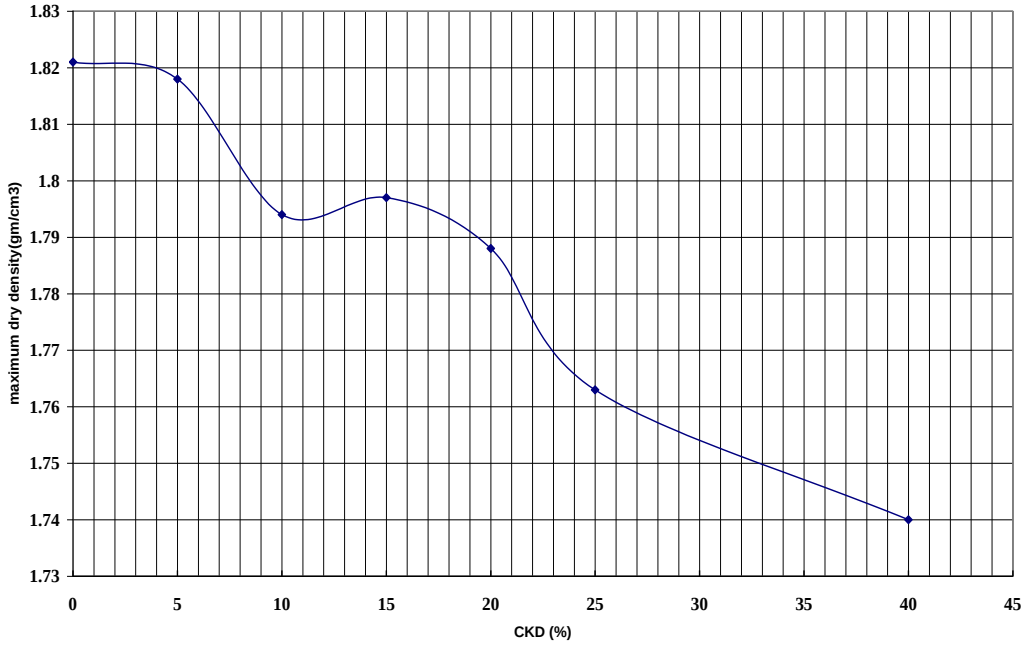

Fig.5 Variation of maximum dry density with CKD.

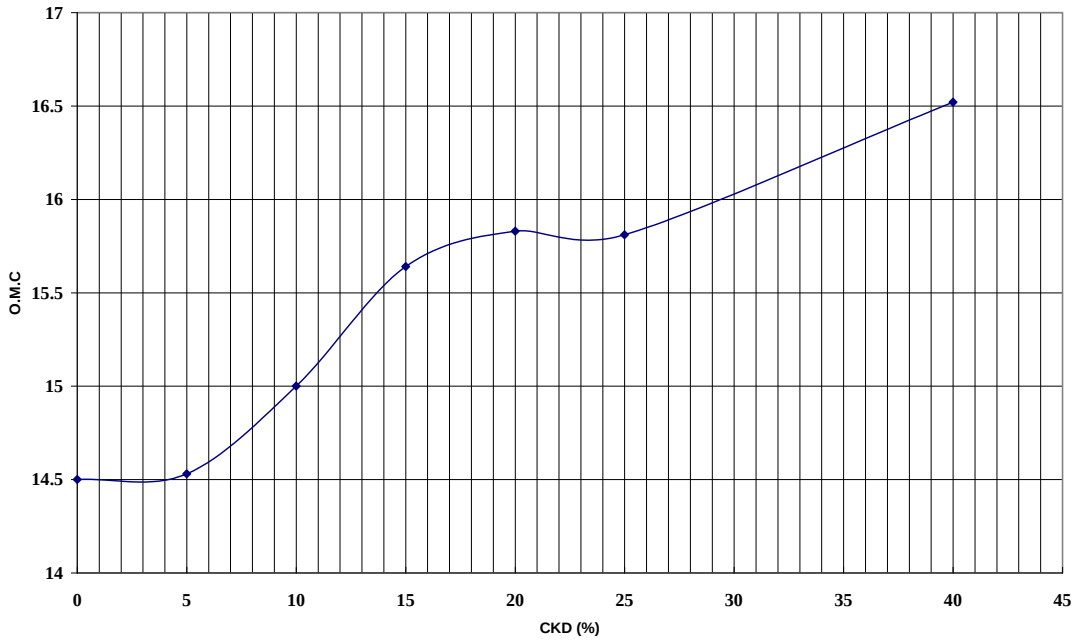

Fig.6 Variation of optimum moisture content with CKD.

Conclusions

This study was carried out to investigate effect of cement kiln dust on some properties of soil. The significant findings are:

1- The additions of cement kiln dust to soil decreases the plasticity index , liquid limit and activity. A reduction in plasticity index and activity means an increase in the workability of the soil having less affinity for water.
2- Significant improvement in the performance of soil as a subgrade in a highway can be noticed with the increase in CKD percentage.
3- Mixing the soil with CKD has resulted in decreasing the maximum dry density and increasing the optimum moisture content for all CKD percentages.

References

Audai bdul-Elah,(2005),"Improvement of Soft Clay under Road Pavement by Cement Dust".MSC.Thesis,Civil Engineering, Al-Rasheed College, University of Technology.

Ayad Kadhum,(2002)," Effect of strain Rate on Strength of Al-Rustamia Soil Stabilized With Cement Dust".MSC.Thesis, Building and Construction Engineering, University of Technology.

ASTM Standard, (1989),Soil and Rock, Vol.04.

Braja M.Das, (2004),"Principles of Foundation Engineering",Fifth Edition, California State University, Sacramento.

Dr.R.ARORA,(1987),"Soil Mechanics and Foundation Engineering" ,Standard publishers Distributors, NAI SARAK DELHI.

Mohammed Shamel,(2002)," Effect of cement kiln dust on some mechanical properties of concrete".MSC.Thesis, Civil Engineering, University of Babylon.

Talal O. Al-Refeai and Awad A. Al-karni,"Experimental Study on the Utilization of Cement Kiln Dust for Ground Modification", J.King Saud Univ. Vol.11, Eng.Sci.(2),pp.217-232(A.II.1419/1999).