Stabilizing sand dunes using cement kiln dust and gypsum in the Bahar Al-Najaf region

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Abstract:

To study the effect of Gypsum - CKD mixture in different proportions in the Bahr Al-Najaf sand dunes area, and to study the strength of this mixture in resisting wind pressure, the sand dunes were covered in the study location, an area of 4 * 4 m, with nine iterations by adding a layer with a thickness of 1 cm of the studied treatments (D3G0, D3G1, D3G3). Physical and chemical tests were conducted, including penetration strength, shear strength of soil, and stability of soil aggregates. Physical tests showed that the stability of the soil aggregates increased with the increase of Gypsum content, and ranged between 27.4% and 32.1%. As a result, the shear strength of the millings also increased, ranging between 62.69 and 96.83 kN/m^2. The results of the penetration resistance indicated that the treatments containing high Gypsum percentages experienced a decrease in the penetration resistance values over time as a result of the influence of climatic factors such as humidity and precipitation. The penetration coefficient values for the treatments ranged between 5.38 and 6.13 kg.m^2 per second.

introduction:

Industrial waste has become an environmental issue threatening the global ecosystem. Its accumulation poses a threat to the environment and public health in general. Cement kiln dust (CKD) is a by-product of Portland cement manufacturing and its production is constantly increasing, at 15-20% of the amount of clinker or cement produced. In recent years, a lot of research has focused on the use of this waste in various engineering and agricultural fields, with its use to enhance the physical properties of the soil being an ideal solution to address the increasing annual consumption. There is a consensus on the importance of agriculture and industry as real indicators of economic development in our time. The progress that mankind has witnessed in all fields, especially agricultural and industrial development, has led to the emergence of some side effects that require attention. Desertification problems are among the serious environmental challenges facing vast areas of land in areas dominated by dry, semi-arid, and even semi-humid climates. It also has other environmental and economic impacts [1]. Cement kiln dust (CKD) is an industrial waste that is produced in large quantities, which poses a global environmental threat at present. It is a by-product of cement factory production and is dangerous to human health when directly inhaled due to its adverse effects on human health and respiratory functions [2]. Safe disposal of CKD is costly and requires vast tracts of land for landfilling. Thus, recent research has focused on benefiting from these by-products in the production of cement in various fields, with its use in improving the physical properties of the soil as an ideal solution for consuming increasing quantities annually [3].

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Materials and methods:

The sand dunes of the Bahr Al-Najaf axis within the Al-Manathira district in the southwest of the Bahr Al-Najaf region in the Najaf plateau were studied (N 44.31472, E 31.83292) and (N 44.31467, E 31.83115) and (N 44.31472, E 31.83182), for the field application of the treatments that were significantly distinguished and gave higher hardness and resistance to penetration force when applied in the laboratory, Figure (1)

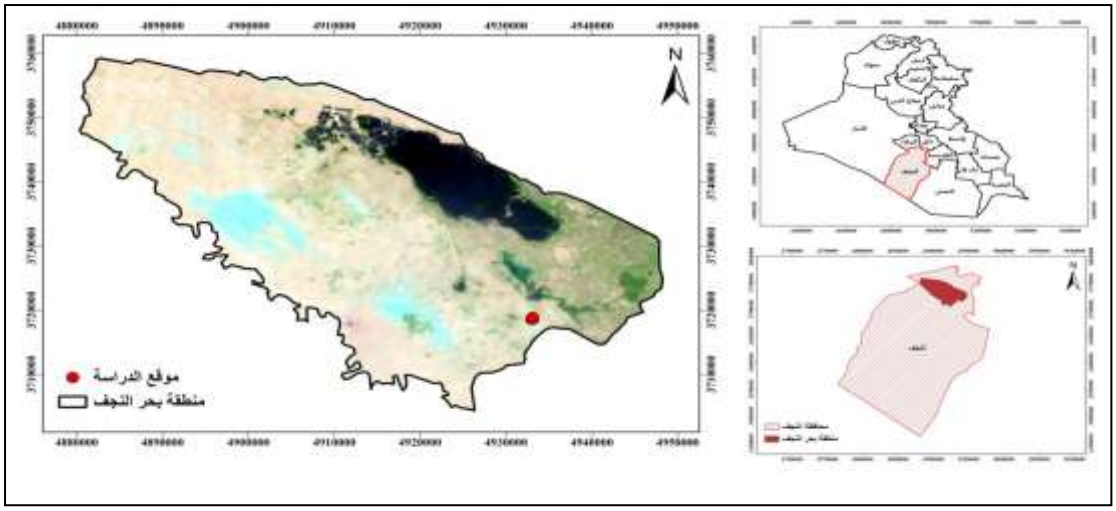

Figure (1) Geographical location of the study area

The area is characterized by an almost flat topography with some high hills and sand dunes. The soil at the study site was classified within the Entisol class and under the order Fluvents and the supergroup Torrifluvents and under the group TypicTorrifluvents according to the modern American classification [4]. Table (1) shows some chemical and physical traits of the soil of the study area:

Table (1) Some of the chemical and physical properties of the soil of the study area

traits	units	values
sand	$g.kg^{-1}$	209.90
silt	$g.kg^{-1}$	570.60
clay	$g.kg^{-1}$	219.5
texture		SILT LOAM
Bulk density	$Mg.m^{3}$	1.35
Electrical conductivity EC	$Ds.m^{3}$	5.6
pH		7.44

Through field tests, it was found that the study area was exposed to desertification processes represented by wind erosion and dune encroachment. In addition, the phenomenon of dune creep is observed, where the movement of sand dunes occurs over short or long

distances due to the influence of the wind, which leads to a change and formation of the floor, and thus led to the various forms of dunes in this region based on the effects of the wind and the factors of the surrounding terrain. These desertification processes may lead to the degradation of agricultural land and reduce agricultural productivity. Therefore, it is important to take action to reduce these phenomena and to maintain the balance of the soil and the ecosystem.

Sample collection:

Sampling areas in the study area were determined randomly, and samples were collected from areas of wind sediment accumulation and sand dunes to a depth of 0-25 cm, and placed in plastic boxes to preserve them, then transported to the laboratory, air-dried and sifted with a 4 mm sieve to prepare them for the required physical and chemical analyzes.The collected samples were prepared in proportions of each as shown in Table (2) to the laboratory to conduct several physical tests to examine the effect of local cement and gypsum kiln dust on these properties. The stability of the clusters was estimated using the method described by [5].Moreover, the shear strength (τmax) and the internal friction angle (∅) were measured using an electric direct shear resistance device, following the procedure described by [6]. Soil penetration resistance was investigated according to Fundamentals of Soil Physics as described in the book [7].

Table (2) Percentages of factors used in the experiment

treatments	Cement Kiln Dust (CKD) %	Gypsum %	wind precipitation%
D3G0	**30**	**0**	**70**
D3G1	**30**	**10**	**60**
D3G3	**30**	**30**	**40**

Results and discussion:

Aggregate stability:

The results shown in Table (3) showed that the stability of field-used coefficient pools (D3G0, D3G1, D3G3) was increased with the increase of Gypsum content in them, where the percentages of stability were (27.4, 29.6, 32.1)%, respectively, with Gypsum content reaching from (0 -10 -30)%, but the stability in the treatment D3G0 was stable due to the uniformity coefficient of the distribution of the sizes of its minutes is good according to the classification coefficient of determination of the treatment and this is what [8] reached.

Table (3) values of stability of clusters for field treatments

W.S.A) %(	samples
27.4	**D3G0**
29.6	**D3G1**
32.1	**D3G3**

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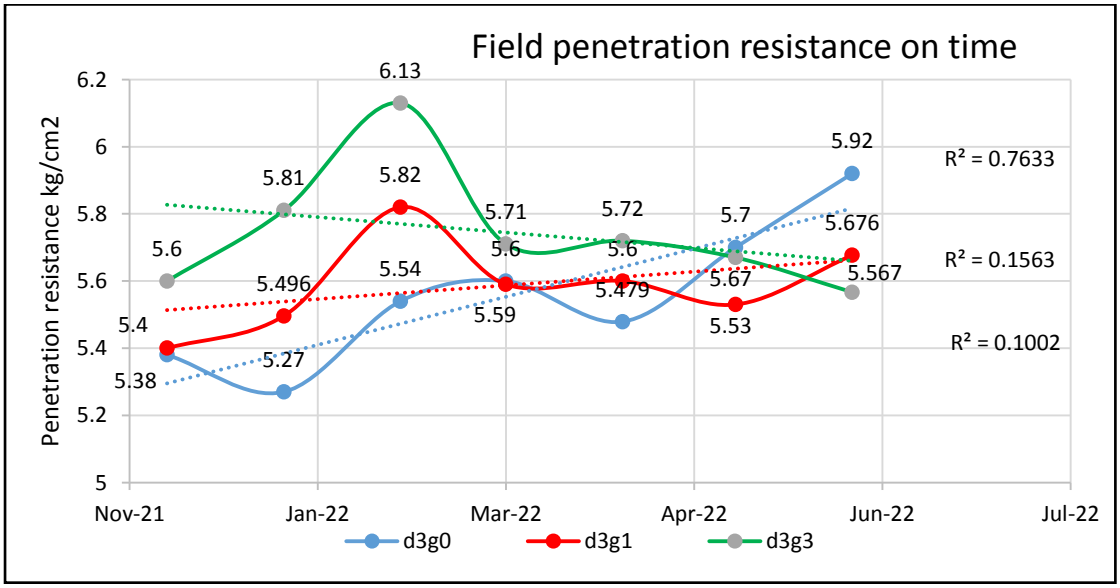
Penetration resistance check:

After distinguishing the treatments (D3G3, D3G0, D3G1) through laboratory tests, they were applied in the field so that we can know the effect of the climatic conditions of the region on the soil resistance to penetration, and the results shown in Figure (2) and Table (4) showed an increase in the penetration resistance value of the treatment G3D3 in February / 2022, when it reached (6.13) kg / cm^2 Then it gradually decreased until June when its value reached (5.56), while the treatment D3G1 was fluctuated and unstable during the months of the field study as it ranged between (5.4 -5.82) kg / cm^2, the reason is that 10% of Gypsum in the treatment turned into salts hydrated calcium sulphate (gypsum), has lower penetration resistance.

Table (4) The monthly rate of treatments resistance for penetration strength

treatments	**Date**						
	December	January	February	March	April	May	June
d3g0	**5.38**	**5.27**	**5.54**	**5.6**	**5.479**	**5.7**	**5.92**
d3g1	**5.40**	**5.496**	**5.82**	**5.59**	**5.6**	**5.53**	**5.67**
d3g3	**5.60**	**5.81**	**6.13**	**5.71**	**5.72**	**5.67**	**5.56**

Figure (2) The monthly rate of penetration resist



ance for field studied treatments

While the penetration resistance of the D3G0 treatment decreased in January 2022, reaching (5.27) kg/cm2, and then it began to gradually increase to reach (5.92) kg/cm2 for the month

of June 2022, and this result is consistent with what was reached by [9]

Through the above figure, it is clear that the coefficient of determination (R2) for the field experimental treatments was that the treatment D3G0 had a coefficient of determination value of 0.7633, and this indicates that the model that was used in the regression analysis explains about 76.33% of the variance in the data. Thus, it can be said that there is a strong relationship between the independent variable(Cement kiln dust percentage) and the dependent variable (Penetration resistance) in treatment D3G0. As for the treatment D3G1, D3G3, the value of the determination coefficient is (R^2 = 0.1563, R^2 = 0.1002), and this indicates that the two models do not explain the variance significantly in the data used in the two treatments D3G1, D3G3, and therefore it can be said that the relationship between the independent variable (ratio Gypsum and cement kiln dust) and the dependent variable (penetration resistance) in the second treatment is weak. It can be concluded that the model in the first treatment has the highest predictive power compared to the other two treatments, while the model in the second and third treatments has less predictive power, and this result is consistent with what was found [10].From the foregoing, it appears that the treatments that contain high levels of Gypsum decrease their penetration resistance values on time as a result of their vulnerability to climatic factors represented by humidity and rain, which affect the physical and chemical properties of the plaster represented by the transformation of gypsum CaSO4 1/2H2O into gypsum again due to the available moisture CaSO4 • 2H2O and this leads to its disintegration and ease of penetration and the weakness of this layer's resistance to penetration

And as he indicated, [11] As for the treatment that contains only CKD, we notice a decrease in its resistance to penetration at the beginning of the experiment due to manual wetting operations, and after that it rained in January. And the drying of this material, which is represented by an increase in the strength of its cohesion with the particles of aerobic sediments due to its cement nature, and the results of the statistical analysis showed Appendix (10) between the three treatments D3G0, D3G1, D3G3, there are no significant differences when analyzed statistically at a significant level (0.05) for the period last month of the procedure Experience.

Direct shear check:

Treatment D3G0 showed the lowest value of shear strength (61.69 kN/m2), followed by treatment D3G1 with a shear strength amount of (96.83 kN/m2), and through Table (18) it is clear that the angle of internal friction for the two treatments was almost equal (° (11-13) and this indicates However, the shear strength was mainly dependent on the cohesion values between the particles more than the internal angle of friction, and the value of cohesion for the treatments was (42.84 and 58.18 kN / m2). The shear and increase in friction angle ratio is due to the reason that the texture class of the grout is sandy.

As for the treatment D3G3, it had a very high value for the shear strength compared to the previous two treatments, as the shear strength reached (208.64 kN / m2), but it is noted that the cohesion strength in it was similar to the cohesion force in the treatment D3G0 (43.81 kN / m2). The shear was mainly dependent on the value of the friction angle, which reached (20°), and these results depended on the nature of the overlap between the coarse particles, which depended on the angle of friction, and the fine particles, which depended on the amount of cohesion between the particles [12].

Figure (3) Table (5) shows the relationship between field experimental treatments with Gypsum content and shear strength, where it is noted that increasing the percentage of Gypsum from (0%-30%) leads to an increase

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in the treatment's resistance to shear, and that the shear strength of the treatment (D3G0, D3G1) It is almost stable when vertical compressive forces of (50-100) kilonewtons.m2 are applied to it on the shear box of the treatment.

This is because the internal angle of friction Ø is small compared to the cohesion C between the particles, and this is the result of the coefficient of good uniformity of the two particles treated according to the Standardization Classification (USCS) for the soil, which in turn leads to the sliding of the particles with some of them whenever the vertical pressure of the hammer increases, and thus the amount of failure of the sample for effort The applied shear is faster than the treatment (D3G3), which shows an increase in shear strength with the increase in vertical stress.

Figure (3) The shear strength increases with the increase of the Gypsum material

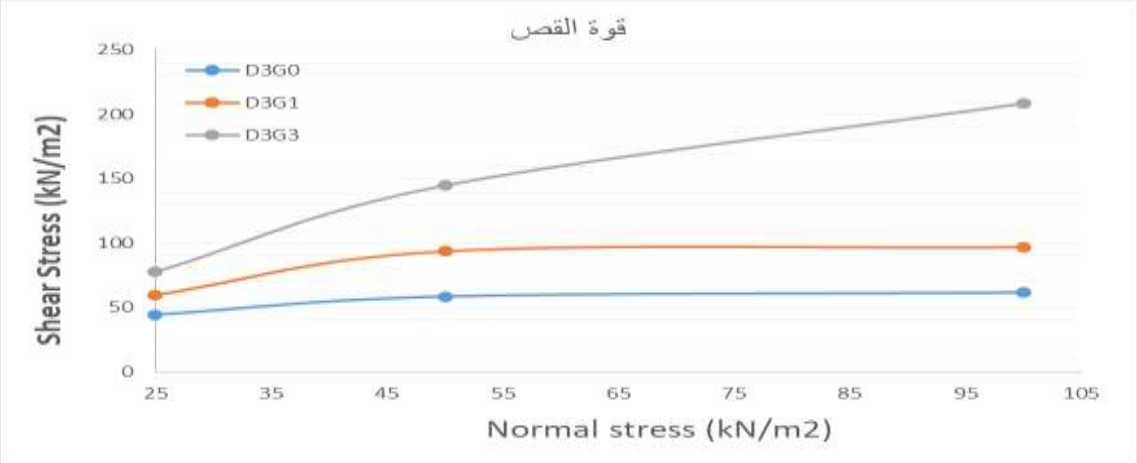

Table (5) Results of the shear strength test for the study samples

internal friction angle Ø	Cohesion)kN/m2(	shear strength (kN/m2)	treatments
11.00°	42.85	61.69	**D3G0**
13.00°	58.18	96.83	**D3G1**
20.00°	43.81	208.64	**D3G3**

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Conclusions:

1. Cement kiln dust, which is considered a non-traditional and recent material in improving the properties of soils, and has high efficiency in improving the properties of aerobic sediments physically.

2. The results of soil penetration resistance test indicate that CKD material increases the resistance of wind precipitation to penetration, reaching 5.92 kg/cm2 with a thickness of 1 cm.

3. The mixing ratio of 30% of cement dust has a significant effect on the penetration resistance of the soil.

4. Addition of Gypsum with CKD increases the sediment penetration resistance, reaching (6.13) kg/cm2 for a limited period, after which it decreases to 5.56 kg/cm2.

5. The values of shear strength, internal friction angle (□) and cohesion (C) of the treated aeolian deposits increase with the increase in the Gypsum percentage, and the cohesion percentage is very high at 10% Gypsum percentage, but the increase in the cohesion ratio (C) is small at 30% Gypsum ratios. .

6.The stability of wind sediment assemblies increases when treated with CKD, and this stability increases with the increase in the percentage of Gypsum (27.4 - 29.6 - 32.1), respectively.

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