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Sand Dunes Stabilization Using Silica Gel and Cement kiln Dust

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Abstract

This research includes the study of adding some available cheap and Local materials to Sand Dunes (SD) such as, Silica Gel (SG) and Cement kiln Dust (CKD) which are used as stabilizers and sand improvement . The Laboratory tests out on (June 2013 to November 2013 .(

Some Physical and chemical characteristics of(SD),(SG) and (CKD) were obtained, also Grain Size Distribution(GSD) and chemical composition were obtained.

The program was divided into two stages the first one includes preparing four mixtures three of them Silica gel were added to tape water to make solution (2.5%,5% and 7.5%) , then adding to the sand dunes, which is denoted by (m1, m2 and m3) respectively , the fourth mixture represent reference(sand dunes) ,these mixtures aging for (7, 14 and 28) days. Pure sand dunes and these three mixtures were tested to determine the wind velocity effects on drifting sand, shear strength force, cohesion and penetration .The second stage includes determining the best results of three previous mixtures, which called typical mixture, and (2.5%,5% and 7.5%) of CKD were added to the typical mixture, which is denoted by (m41, m42 and m43) respectively , these mixtures aging- curing period- for (7, 14 and 28) days.

Generally, this study showed significant improvement in the performance of sand dunes by using Silica Gel and Cement Kiln Dust, which means that, they can be used as stabilizer and soil improvement as economic and available materials .

Keywords: Stabilization, dunes, sand, Dust, Silica

1- Introduction

Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available is not suitable for the intended purpose. A cementing material or chemical is added to a natural soil for the purpose of stabilization. Soil stabilization is used to reduce the permeability and compressibility of the soil mass in earth structure and to increase its shear strength. Soil stabilization is required to increase the bearing capacity of foundation soil. However, the main use of stabilization is to improve the natural soils for the construction ,airfields ,deserts and green fields.[1]

The interaction between wind and land surface can in most parts of the world result in serious consequences for any type of land occupation. Wherever a granular soil surface is left unprotected it can become victim of wind erosion and dune formation can occur.[2]

2- Environmentally Impacts

Sand dunes is one of the serious problems and factors which leads to desertification formation , desertification is dangerous problems facing all the countries. Destruction of arable land is jeopardizing development while, simultaneously, lack of development is preventing any action against desertification. Action can only be successful if it is an integral part of a comprehensive development plan and strategy, which takes fully into account the communities directly. Affected by drought or desertification, the causes of drought and desertification in west of Iraq have been identified as meteorological, pedological, geological and agriculture, loss in soil fertility, movement of desert environment, population migration, and great losses in human and material resources.

The negative effects of desertification includes loss of lands for habitation and agriculture, loss in soil fertility, movement of desert environment, population migration, and great losses in human and material resources. All these constitute serious threats to human and animal life. No one state or country alone can successfully combat drought and desertification.[3]

The Middle East and North African countries are well known to suffer from strong dust storms that may cover the whole region in many occasions and many times during the year. Dust storms may even cross the Mediterranean and /or the Atlantic and cause severe damage to health and material there. Dust storms on the ground are shown in figure (1) from Iraq indicating the severity of some storms. [4]

Dust and sand storms are persistent problem in Iraq and Middle East Region. The regional dust storms had bad effects on health of human life which can cause asthma, bronchitis and lung diseases, due to their carrying micro-organisms (such as bacteria, fungi, spores, viruses and pollen) and their sharp edged particle.

Several researches have shown that microorganisms mobilized into the atmosphere along with desert soils are capable of surviving long-range transport on a global scale, Dust-borne micro organisms in particular can directly impact human health via pathogenesis, exposure of sensitive individuals to cellular components (pollen and fungal allergens, etc.)[5]

Figure 1: Dust storm in Iraq indicating severity and potential damage [4]

Table (1) and figure (2) show the average monthly and yearly dust of Iraqi governorates on 2007 .[6]

Across the Middle East and North African region, people have always contended with excessive heat, dust storms, shortage of rainfall and harsh geography. In this century, industrial development, climate change, political upheaval, and war have left a legacy of environmental impacts and health problems. Scarce fresh water is diverted, misused and polluted with hazardous wastes, sewage, agricultural waste and other chemicals. Arable land is being lost to desertification and unplanned urbanization. Coastal zones are mismanaged and polluted with oil, threatening pristine coral reefs, mangroves, wild fowl, and fishing areas. Unprecedented unplanned urbanization, industrialization and migration of traditionally rural peoples and resettlement of political refugees and foreign workers strain city services and give rise to air pollution. [4]

Table 1: Average monthly and yearly dust of Iraqi governorates [6]

Governorate	Sites	Average (gm/m^2/month)												
		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	yearly
Ninwa	10	8	7	8	7	10	11	15	11	11	5	9	14	10
Kirkuk	3	-	49	45	48	48	51	50	53	47	43	45	46	48
Sala'adien	3	16	4	12	16	-	20	-	-	11	12	16	11	13
Dyala	3	8	8	9	9	10	-	-	10	9	-	-	-	9
Anbar	3	9	9	9	9	10	10	11	11	7	9	8	-	9
Baghdad	3	9	18	19	16	24	-	43	18	7	31	7	9	18
Babylon	6	28	29	30	33	31	54	41	43	59	40	18	16	35
Wasit	2	12	12	8	8	-	9	8	7	5	7	-	-	8
Karbala	4	17	14	14	16	18	23	28	28	20	23	15	17	20
Qadesyah	2	13	13	13	13	13	14	14	15	15	14	14	14	14
Najaf	4	30	39	41	42	43	46	46	34	34	27	25	26	36
Muthana	3	15	16	17	9	46	50	99	90	102	88	54	53	53
Messan	2	34	40	44	40	46	34	42	41	50	61	57	60	46
Thiqar	2	54	68	73	83	100	132	128	122	111	116	73	45	92
Basrah	6	15	17	12	12	14	17	22	31	29	31	31	11	20

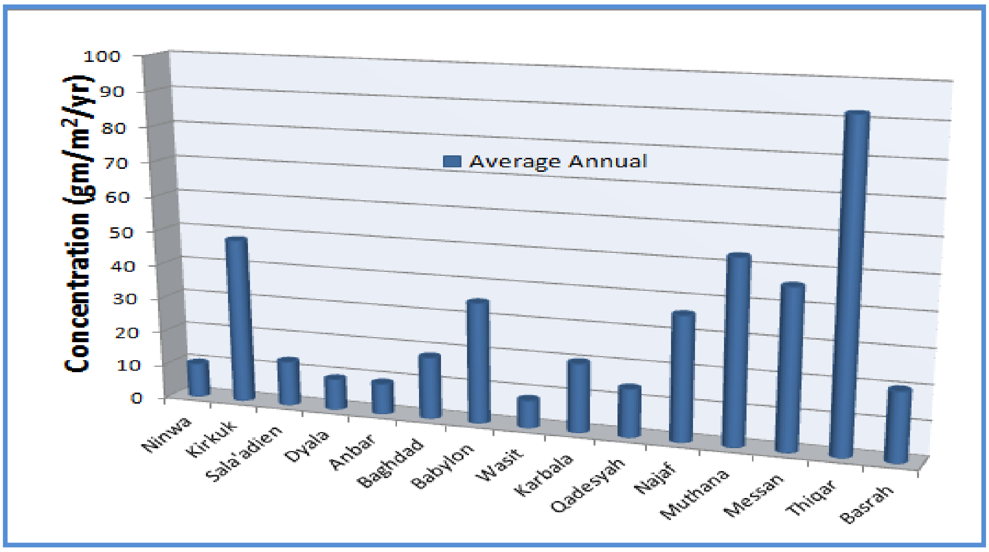

Figure 2: Average yearly dust of Iraqi governorates[6]

3- Iraqi Sand Dunes

The deserts lands represent (42.5%) of the Iraqi lands, and about (90%) of the Iraqi lands are affected by one of the desertification factors with fluctuated ratios. The total sand dunes area in Iraq is about (9.3%) of Iraq area which represent seriously threats to cities, infrastructures, roads, irrigation systems.

Figure (3) show the sand dunes areas in Iraq, There are many sites of sand dunes in Iraq , such as BIJI , AL-Aieth in Salaaldien Governorate ,AL-Hadhar area, the area between Ramadi and AL-Tharthar Lake and AL-Hamad groundwater basin near the Iraqi-Jordanian border. Also the sand dunes existed as longitudinal area at the Euphrates right bank between Najaf and Samawah cities, and the area from Babylon City along with AL-Massab AL-Aam Project to Thiqar marshs , finally there are some small areas at Almuqdadyah and AL-Udhayem within dyala ,west Imarah city and west of basrah city .[7]

Sand dunes can be classified according to their shapes into the following:

1) Embrogonic Dunes: It forms because of the natural factors especially plants and grass .

2) Barckhan Dunes: It take crest shape due to the wind effect on the sides without middle of the dunes.

3) Transvers Dunes: The dunes collect perpendicular to the wind direction to form transverse shape (perpendicular to the wind direction).

4) Longitudinal Dunes: It takes longitudinal shape along to wind direction.

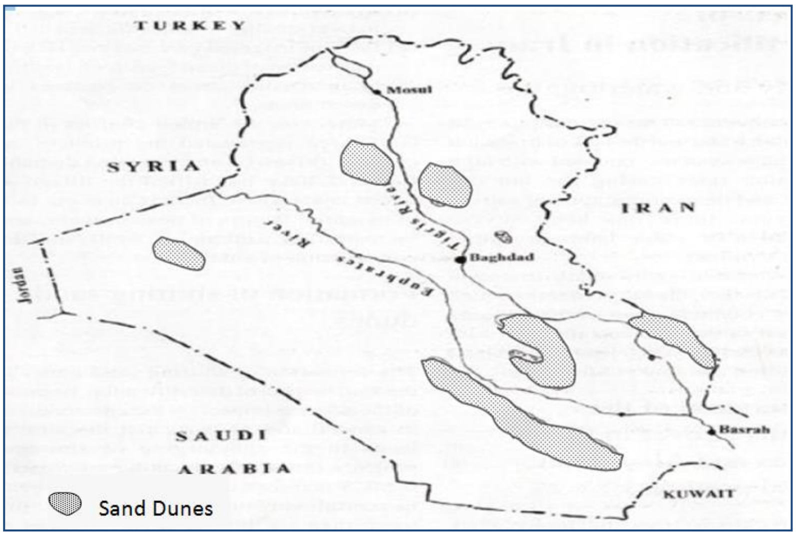

Figure 3: show the sand dunes areas in Iraq.[7]

The Iraqi Sand dunes are captured by colored space pictures using Thematic Mapper Apparatus , these pictures show three sand dunes formation as follow:

1) Western sand strip: this formation extends to south between Makhool , Himreen mountains and the Iraqi-Iranian mountain (border). This formation includes Biji, AL-Aien and AL-Teeb in Salaldien, Dyala, Wasit and Messan governorates. These dunes consist of Sandy Clay dunes.
2) Middle sand strip: this formation extends between Euphrates and Alluvial plain on the west and Tigris on the east. This formation includes Babylon, Wasit, AL-Muthana, AL-Qadisyah and Thiqar governorates. These dunes consist of Fine Sandy Clay dunes.
3) Western sand strip: this formation extends western of Euphrates in the western desert on the west to the south. This formation includes AL-Anbar, Karbala, and Najaf, AL-Muthana, Thiqar and Basrah governorates. These dunes consist of silica (Quartaz – SiO_2) Sand dunes .[6,8]

4- Wind Velocity and drifting:

Sand dune drifting represent a main environmentally problem facing most of countries located within dry and semi-dry regions, drifting with time will cause degradation of soil and sand dunes formation. Sand drifting or Minimal wind threshold velocity can be defined as environmentally dynamic phenomena, creeping or movement of granular sand above dunes surfaces when the wind velocity reach to (5.5 meter per second) .[9]

5- Shear Strength - resistance-parameters (c, ϕ)- drained shear strength of Soil:

The property that enables a material to remain in equilibrium when its surface is not level is known as its shear strength . Soil in liquid forms have virtually no shear strengths of relatively small magnitudes compared with those exhibited by steel or concrete. [10]

The direct shear test were applied to find the shear strength parameters according the (ASTM D3080) method , This test method covers the determination of the drained shear strength of a soil material in direct shear. The test is performed by deforming a specimen at a controlled strain rate on or near a single shear plane determined by the configuration of the apparatus. Generally, three or more specimens are tested, each under a different normal load, to determine the effects upon shear resistance and displacement, and strength properties such as Mohr strength envelopes. The strength of a soil depends of its resistance to shearing stresses. It is made up of basically the components;

1. Frictional – due to friction between individual particles.
2. Cohesive - due to adhesion between the soil particles

The two components are combined in Colulomb's shear strength equation,

$$\tau f = c + \sigma_f \tan ø \qquad \ldots\ldots (1)$$

Where,
τf = shearing strength- resistance- of soil at failure .
c = apparent cohesion of soil .
σf = total normal stress on failure plane .
ø = angle of shearing resistance of soil (angle of internal friction). [11]

6- Penetration resistance of Soil

The property that resist the vertical direct forces , its obtained by using (cone pentrometer) (ELE) Company apparatus according to the method (BS 1377 part 2:1990) . It consists of metallic cone with half angle of (30o) and (30.5)mm coned length. It will be fixed at the end of a metallic rod with a disc at the top of the rod so as to have a total sliding weight of 148 grams. The total rod shall pass through two guides. (to ensure vertical movement) fixed to a stand, Suitable provision will be made for clamping the vertical rod at any desired height above the surface of the paste in the trough. A metal cup , approximately 55 mm in diameter and 40 mm deep is filled with the sample and the surface struck off level , the cone of mass 80 grams , is next placed at the center of the smoothed soil surface and level with it . the cone is released so that it penetrates into the soil(sample) and the amount of penetration, over a time period of 5 seconds , is measured. [12]

Soil Stabilization

There are many soil stabilization methods such as mechanical methods which includes (soil ducks, leveling and covering) ,biological methods which includes (vegetation and planting) , stabilizing using chemicals (oil, polymers..). [13]

A wide variety of stabilizer methods (chemical/mechanical) have been used, such as:

1-Mechanical stabilization:

Under this category, soil stabilization can be achieved through physical process by altering the physical nature of native soil particles by either induced vibration or compaction or by incorporating other physical properties such as barriers and nailing. Mechanical stabilization is not the main subject of this review and will not be further discussed.

2-Chemical Stabilization:

Chemical methods of soil stabilization are a wider group, as there are many different applications. The major advantage of this approach is that there is likely a chemical soil stabilization solution designed for any specific environment you may require, so performance is likely to be high. Polymer based *methods of soil stabilization* are the most modern, and offer a number of advantages over more traditional procedures. They involve combining the soil with non-reactive, environmentally neutral polymer based filler material. One of the biggest advantages of polymer based methods of soil stabilization is that they do not negatively impact the environment whilst creating a waterproof. [14]

Chemical stabilization of sand forms a binding surface crust that conserves soil water beneath the crust, prevents or impedes wind erosion, and stabilizes the sand. Depending on their chemical properties, sand stabilizers can form three types of binding crust: a rigid crust, a flexible crust, or an elastic crust. All these crusts have smooth surfaces that protect the sand surface from direct erosion by wind. The combination of several sand control measures, including chemical treatments, biological measures, semi-buried sand fences, and upright sand fences, can effectively control damage from blowing sand. Ideal chemical sand stabilizers should offer good adhesion and rapid infiltration of the sand. In general, interstitial spaces about 8 microns in diameter exist between the particles of aeolian sand. When a liquid stabilizer is sprayed on the sand surface, droplets smaller than 8 microns seep into the sand and bind its particles together, whereas droplets larger than 8 microns remain on the sand surface to form a coat and stabilize the sand after consolidation. In addition to simple mechanical adhesive action, the inter-particle binding may involve other complex processes.

In the 1950s, American scientists conducted dust control experiments using an emulsion of oil resins called Coherex in the areas surrounding Edwards Air Force Base in the Mojave Desert of California and the Mercury Nuclear Testing Base in Nevada . Scientists from the Weitrman Institute and Cyanidiamide Company developed sand stabilizers such as urea-formaldehyde, urea-dicyandiamide, and polyacrylamide . American soil scientists have also tested more than 30 kinds of organic and inorganic materials to control wind erosion. In the 1960s, scientists tested dune stabilization using asphalt emulsions, and using Curasol, Unisol 91, Coherex, Rohagit, and Askar polymer emulsions. Other countries, including Germany, Iran, Libya, Algeria, Saudi Arabia, and Iraq, have also conducted dune stabilization experiments using oil and oil products. Since 1980, Chinese scientists have tested dune stabilization using asphalt emulsions, sodium silicate at the Shapotou Desert Research and Experiment Station of the Chinese Academy of Sciences. [15]

Chemical stabilization is concerned with looking at soil on the molecular level, and methods of stabilization could be summarized into four categories:

1-Treating the soil with a chemical compound having a stronger bond to the surface of the soil particles than that of the water such that the water sensitivity is eliminated. The additive displaces the water molecules from the grain surface and prohibits the bondage of new water molecules, hence rendering the soil non-wetting. Such an effect can be achieved by treating the soil with Methehyl Cholorosilane gas.

2-Adding non-hydrated positive charge ions attached to the surfaces of a generally negative charge, and substituting other ions. The sensitivity of the soil to water is then decreased and after drying, the soil cannot be wetted again. This treatment can be achieved by adding Ammonium Salts.

3-Treating the soil with large molecule type ionic compounds with which the molecular chains connect the soil particles with electrostatic and polar forces such that the soil becomes porous but remains impermeable and structurally stable.

4-The interaction between water and soil can be modified by separating the polyvalent cations bound to the surfaces of the soil particles. In the presence of free water, the solvated water layer may increase and the treated soil can be compacted and made water impermeable or easily processed even at extremely low water content since its contraction with water will be very small. [16]

7- Objective

The objective of this work is to improve the sand dune Characteristics by adding optimum dose of locally Iraqi materials , silica gel (sodium silicate) and cement kiln dust (CKD) .

8- Materials

1) Sand Dune (SD)

The Sand samples were brought from the Western desert of Iraq, about (70 Km) west of AL-Rutba city. The sand was tested in the laboratory to obtain the engineering properties of the sand before mixing, Figure (4) shows the grain size distribution which obtained by sieve analysis according to the (ASTM D422) method, The physical and chemical tests are obtained according to (ASTM) , C 128 -93 method, which shown in table (2) .[17]

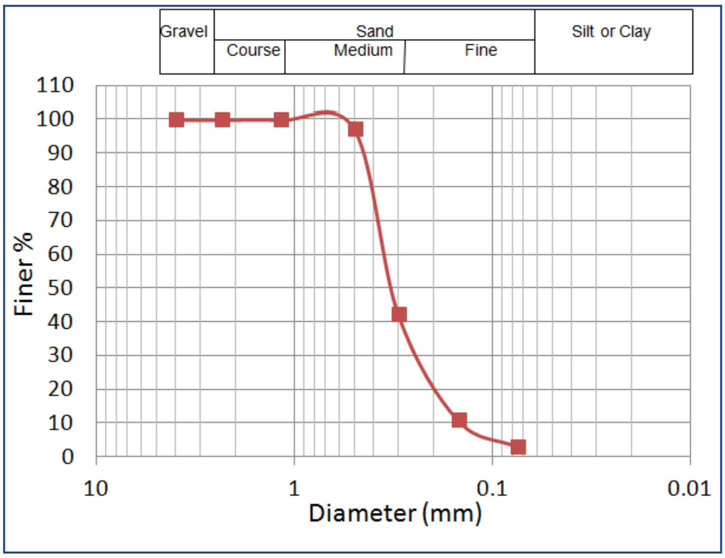

Figure 4: Grain size distribution of sand dune

Table 2: Physical and chemical properties of sand dunes

Parameters	VALUE
(Sulfate) SO_3 %	0.11
Water content (w.c) %	0.45
pH	7.85
Total Dissolved Salts Ratio %	1.475
(Chloride)Cl^{-1} %	0.011
Specific Gravity	2.56
Coefficient of Uniform (CU)	3.6

2) Silica Gel (SG)

In this study we dissolved Sodium Silicate solution (Silica Gel) or (Silica Gum) in Liquid State which is produced by General Company of Glass and ceramic industrial in Ramadi City by wet method.

Silica gel represents one of the dissolved polymers . The polymer silicate ions consist of many chain series or three-dimensional chain .The Chemical formula of silica gel is (Na_2O. SiO_3.$5H_2O$). The chemical analysis was done to this material by Glass Factory and the chemical analysis was as following in the table (3).[18,19]

Table 3: Liquid State Specifications of Sodium Silicate (Silica Gel)

Liquid State Specifications of Sodium Silicate(Silica Gel)	
Chemical Composition	**Composition**
Specific Gravity	**1.5±0.05**
SiO_2	**32±6%**
Na_2O	**14±2%**
Ratio(SiO_2/Na_2O)	**2.4±0.4**

3) Cement kiln Dust (CKD)

In this study Cement kiln Dust in Solid State brings from Fallujah Cement Factory. Fig (5) shows the grain size distribution of (CKD) , table (4) shows the physical and chemical properties of (CKD), (CKD) may be viewed as waste , it is essentially an intermediate product makes direct return to the kiln, or recycling. (CKD) may be useful in a variety of applications, including construction, stabilization, waste treatment and agricultural.[20]

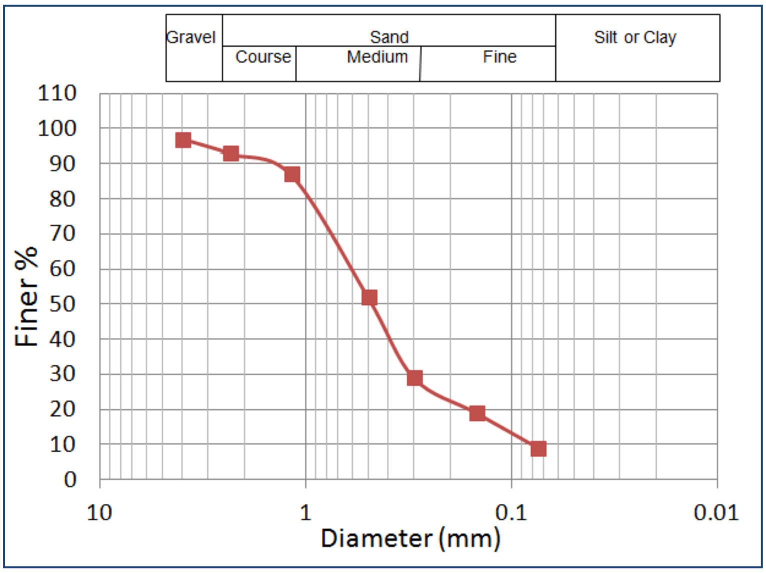

Figure 5: Grain size distribution of CKD.[20]

Table 4: Physical and Chemical Properties of (CKD) .[20]

Components (wt%)	value
CaO	49.7
AL_2O_3	5.0
SiO_2	17.1
Fe_2O_3	0.3
MgO	1.4
SO_3	6.6
Na_2O	0.9
K_2O	1.1
Bulk Density (gm/l)	800 - 850
pH	10.5 - 13

9- Methodology

This research includes stabilization of sand dunes with locally materials, silica gel and cement kiln dust , the research is done by the following order :

1- Determine the engineering, physical and chemical properties, grain size distribution (G.S.D) of sand dunes and cement kiln dust (CKD), chemical composition of sand dune , silica gel and cement kiln dust (CKD).

2- Make three experimental mixtures contains sand with (2.5% , 5% and 7.5% weight) of silica gel solution , these solutions spry to the sand dunes molds .These mixtures denoted by the symbol (m1, m2 and m3) respectively, then mixtures aging for (7, 14 and 28) days .

3- Determine the engineering characteristics of mixtures , such as sand drifting, drained shear strength-resistance- parameters (c , ø),which determined by the direct shear test to obtain the shear strength-resistance at failure (τf) and penetration after (7, 14 and 28) days for three mixtures.

4- Determine the optimum mixture (best result) of engineering characteristics for mixtures .

5- Make three experimental mixture contains consist of optimum mixture with (2.5%, 5% and 7.5% weight) of CKD (fourth mixture), the silica gel

6- solution will mixed with CKD then spry to the sand dunes molds , this Mixture denoted by the symbol (m4).

7- Determine the engineering characteristics of mixtures , sand drifting, , drained shear strength-resistance- parameters (c , ø),which determined by the direct shear test to obtain the shear strength-resistance at failure (τf) and penetration after (7, 14 and 28) days for the mixture(m4).

8- Determine the optimum mixture (best result) of engineering characteristics for mixtures , figure (6) shows flow chart of methodology .

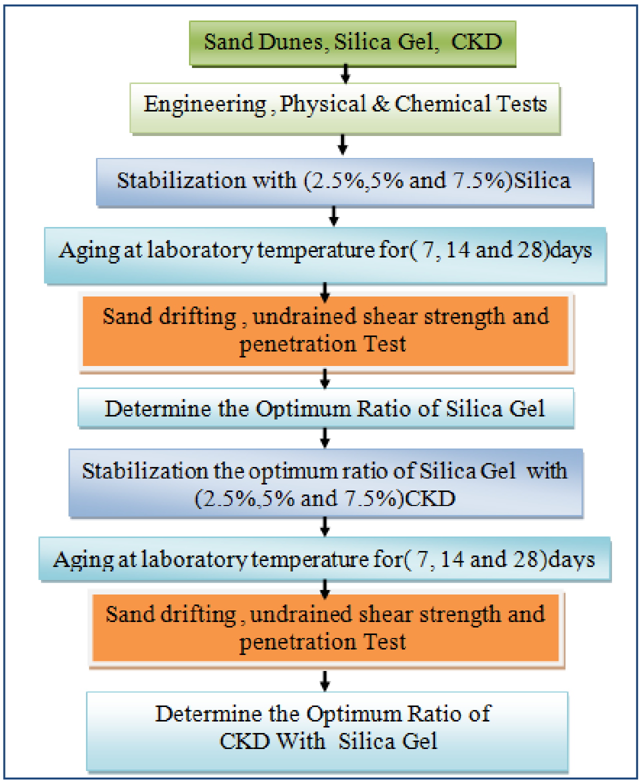

Figure 6: Flow chart of methodology

10 Results and Discussion

This research includes stabilization of sand dunes using silica gel and (CKD) ,sand dunes grain size distribution . Table (2) shows some chemical and physical properties of silica sand, The specific gravity is (2.56). The chlorides and sulfate were obtained according to the specification(BS1377 test No.9) are (0.011% and 0.11%) respectively .The hydrogen ion concentration (pH-value) is (7.85) , also the coefficient of uniform (CU) is 3.6 , Figure.(4), shows that the sand dunes is classify as sandy (97.09% sand and 2.91% clay) .

Table (3) shows the chemical analysis of silica gel represent one of the dissolved polymers. The polymer silicate ions consist of many chain series or three-dimensional chain .The chemical formula of silica gel is ($Na_2O.\ SiO_3.5H_2O$).

Figure.(5) show the grain size distribution of CKD , which show that (75%) is smaller than (10 microns) , and the bulk density about (800 - 850) (gram/litter) and the hydrogen ion concentration (pH-value) is between (10.5 - 13) .

Table (5) show the Wind effect or drifting sand velocity , Four velocities (5, 15, 30 and 45) meter per second by using blower motor to apply air (wind) on the sand dunes surfaces to detect the initial velocity which can effect on the sand surfaces, and Anemometer apparatus used to measure air velocity .The results show that the drifting sand happen at (5 m/s) for pure sand dune, (30 m/s) required to drifting sand occur for (m1) at (7 days age) and (45 m/s) required to drifting sand occur for (m1) at (all ages), while drifting sand not occur for (m1) at (28 days age). drifting sand not occur for (m2) at (all ages). drifting sand not occur for (m3) until velocity (45 m/s) for (all ages).

The results show that adding silica gel is increasing sand resistance to drift (erosion), and the best result is adding (5%) of silica gel to sand dunes , which denoted by mixture (m2).

Table 5: Wind effect or drifting Sand velocity

Mixture	Drifting at wind velocity (5 m/s) for Ages			Drifting at wind velocity(15 m/s) for Ages			Drifting at wind velocity(30 m/s) for Ages			Drifting at wind velocity(45 m/s) for Ages		
	7 day	14 days	28 days	7 day	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28 days
Sand Dune	+	+	+	+	+	+	+	+	+	+	+	+
m_1	-	-	-	-	-	-	+	+	-	+	+	+
m_2	-	-	-	-	-	-	-	-	-	-	-	-
m_3	-	-	-	-	-	-	-	-	-	+	+	+
- : No Effect (No Drifting) , + : Effect (Drifting)												

Table (6) and figures (7, 8 and 9) show the shear strength- resistance- , cohesion and penetration properties for (m1, m2 and m3) mixtures, The results show that adding silica gel increase the shear strength, stability and decrease the penetration .The shear strength Increased by (72%, 74% and 71%) for (m1, m2 and m3) at age (28 days) respectively. The cohesion increased by (125%, 150% and 50%) for (m1, m2 and m3) at age (28 days) respectively.

The penetration decreased by (56%, 66% and 63%) for (m1, m2 and m3) at age (28 days) respectively.

When adding silica gel in different ratios in aging case, silica gel work as jointing between sand particles and filler, silica gel attend to modify with aging.

The results show that adding silica gel is increasing sand dune shear strength - resistance- , cohesion , decreasing penetration and resistance to drift (erosion), and the best result is for mixture (m2).

Table (7) show the wind effect or drifting sand velocity for adding (2.5%, 5% and 7.5%) of CKD to the best mixture (m2), Four velocities (5, 15, 30 and 45) meter per second by using blower motor to apply air (wind) on the sand dunes surfaces to detect the initial velocity which can effect on the sand surfaces, and Anemometer apparatus used to measure Air velocity .The results show that the drifting sand doesn't happen at all velocities for (all ages).

Table (8) and figures (10, 11 and 12) show the shear strength - resistance- , cohesion and penetration properties for (adding (2.5%, 5% and 7.5%) of CKD to the best mixture (m2), The results show that adding CKD increase the shear strength, stability and decrease the penetration, the shear strength increased proportional to mixture (m2) by (4.4%, 10.1% and 7.6%) for (m41, m42 and m43) at age (28 days) respectively. The cohesion increased proportional to mixture (m2) (18.1%, 27.2% and 5.4%) for (m41, m42 and m43) at age (28 days) respectively.

The penetration decreased proportional to mixture (m2) by (62.8%, 70.7% and 69.0%) for (m41, m42 and m43) at age (28 days) respectively.

The results show that adding (5%) of CKD to (m2) mixture, which denoted by mixture (m42) gave the best results.

Table 6: Shear Strength, Cohesion and Penetration Properties for mixtures

Mixture	Shear Strength - resistance- for Ages (KPa)			Cohesion for Ages (KPa)			Penetration for Ages (mm)		
	7 days	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28 days
Sand	13	13	13	4	4	4	18.8		
m_1	10	32.9	46.4	5	6	9	16.1	13.8	12
m_2	20.3	34.2	50.1	7	9	10	13.1	12.5	11.3
m_3	10.9	24.8	45.1	1	4	6	12.5	11.8	11.5

Table 7: Wind effect or drifting Sand velocity For (m2 and m4s) mixtures

Mixture	Drifting at wind velocity (5 m/s) for Ages			Drifting at wind velocity(15 m/s) for Ages			Drifting at wind velocity(30 m/s) for Ages			Drifting at wind velocity(45 m/s) for Ages		
	7 days	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28 days
Sand Dune	+	+	+	+	+	+	+	+	+	+	+	+
m_2	-	-	-	-	-	-	-	-	-	-	-	-
m_{41}	-	-	-	-	-	-	-	-	-	-	-	-
m_{42}	-	-	-	-	-	-	-	-	-	-	-	-
m_{43}	-	-	-	-	-	-	-	-	-	-	-	-
- : No Effect (No Drifting) , + : Effect (Drifting)												

Table 8: Shear Strength, Cohesion and Penetration for (m2 and m4s) mixtures Properties

Mixture	Shear Strength - resistance- for Ages (KPa)			Cohesion for Ages (KPa)			penetration for Ages (mm)		
	7 days	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28 days
Sand	13	13	13	4	4	4	18.8	18.8	18.8
m_2	20.3	34.2	50.1	7	9	11	13.1	12.5	11.3
m_{41}	20.8	36.5	52.3	10	11	13	8.3	7.2	4.2
m_{42}	21.1	36.9	55.2	10	12	14	7.2	6.6	3.3
m_{43}	21.7	35.6	53.9	9	10	11	7.4	7.0	3.5

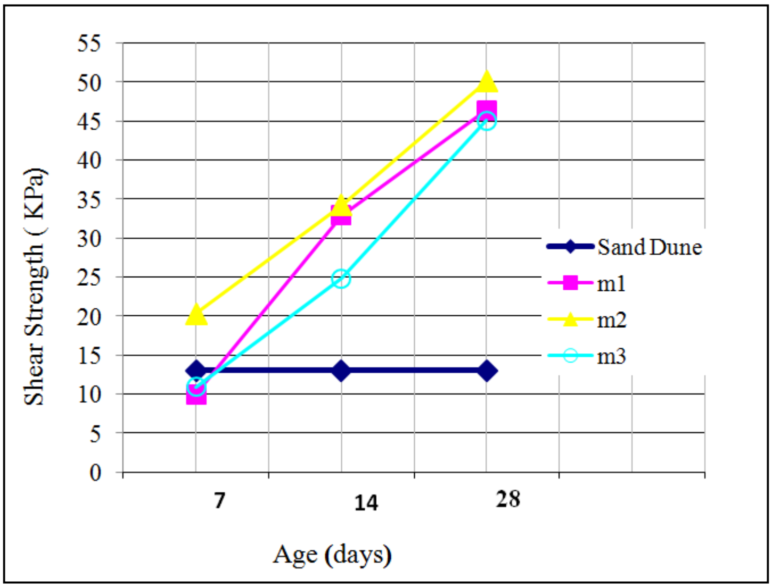

Figure 7: Shear strength and Age for Mixtures (m1, m2 and m3)

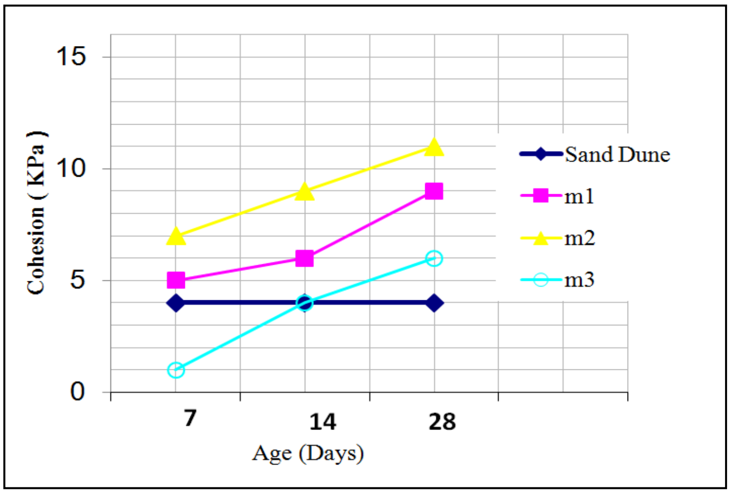

Figure 8: Cohesion and Aging Relation for Mixtures (m1, m2 and m3)

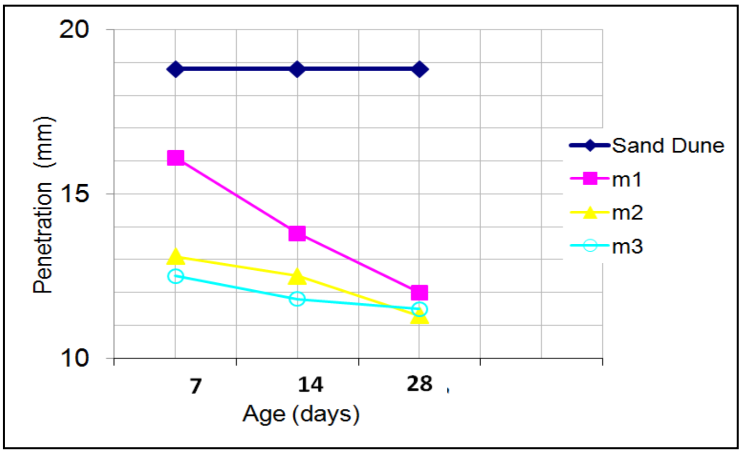

Figure 9: Penetration and Age for Mixtures (m1, m2 and m3)

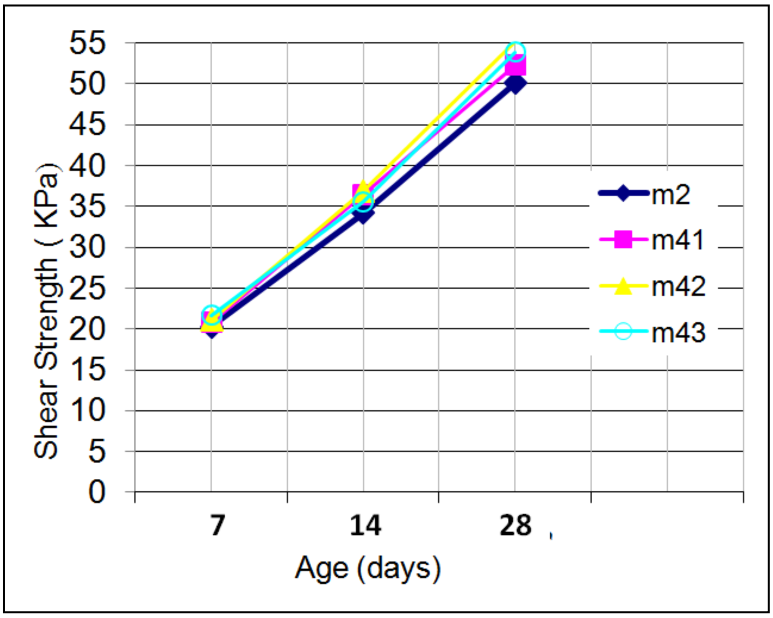

Figure 10: Shear strength and Age for Mixtures (m2, m41, m42 and m43)

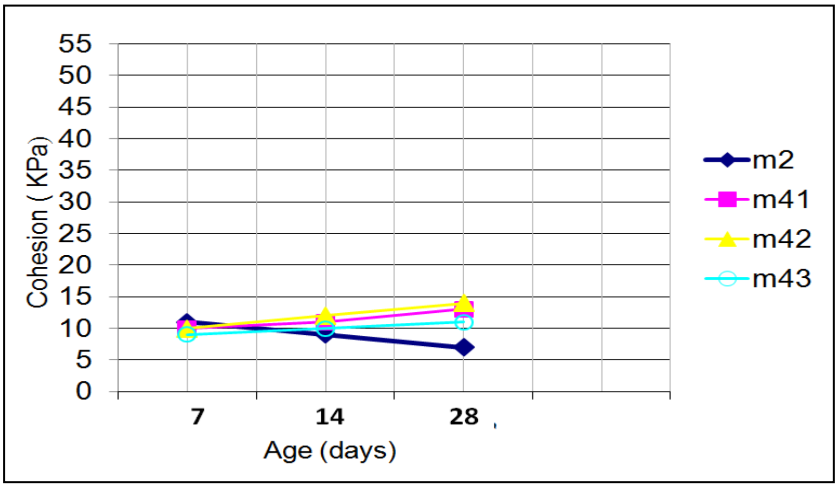

Figure 11: Cohesion and Age for Mixtures (m2, m41, m42 and m43)

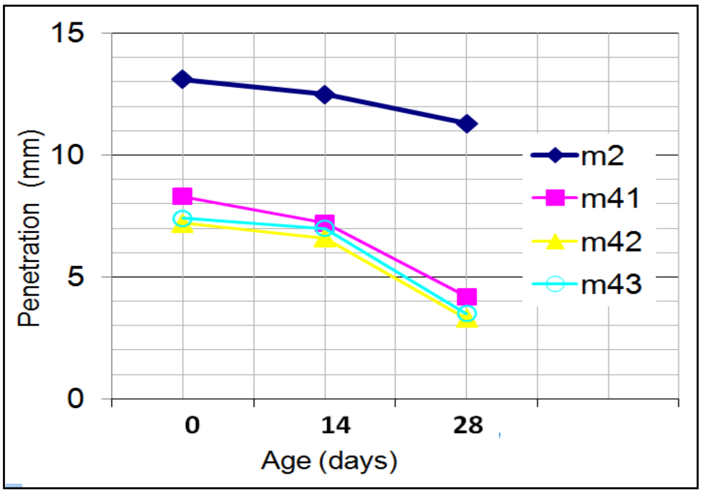

Figure 12: Penetration and Age for Mixtures (m2, m41, m42 and m43)

11 Conclusions:

1- Silica gel and (CKD) can be used to Stabilize and improve Sand dunes .

2- The Shear Strength and Cohesion of sand dunes increased and penetration decreased by adding Silica gel and (CKD) to the sand dunes .

3- Adding (5%) of Silica gel to the sand dunes (mixture m2) will increase Shear Strength and Cohesion of sand dunes by (74% and 150.0%) at age of (28 days) respectively , and decrease the penetration by(66%) at age of (28 days) ,and adding (5%) of (CKD) to the (mixture m2) – (mixture m42) - will increase Shear Strength and Cohesion of sand dunes by (10.1% and 27.2%) at age of (28 days) respectively , and decrease the penetration by(70.7%) at age of (28 days) m which give better result than other mixture ratio.

13- Suggestions:

1- Study the ability of using other local materials as additives to improve sand dunes.

2- Study the effect of long term time on sand dunes.

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تثبيت الكثبان الرملية باستخدام صمغ السيليكا وغبار أفران الأسمنت

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الخلاصة:

تضمنت هذه الدراسة امكانية استخدام كل من صمغ السيليكا وغبار افران الاسمنت كمواد محلية عراقية متوفرة و اقتصادية كمثبتات للكثبان الرملية ومحسن لخواصها ، أجريت التجارب المختبرية للفترة من (حزيران – تشرين الثاني) لعام 2013 .

تم تحديد الخصائص الفيزياوية والكيمياوية لكل من الكثبان الرملية ، صمغ السيليكا وغبار أفران الاسمنت . تم تقسيم العمل الى مرحلتين ، تضمنت المرحلة الاولى عمل اربعة خلطات مختبريه اضيف الى ثلاث منها صمغ السيليكا الى الماء لتكوين محلول بتركيز وزني (2.5%، 5% و 7.5%) وتم الاشارة اليها بالخلطات (m1, m2, m3) على التوالي وكذلك خلطة مرجعية (كثبان رملية- رمل)، تم حفظها بدرجة حرارة المختبر لمدة (7 ،14 و 28) يوم .

أجريت بعض الفحوصات الهندسية على الخلطات الثلاثة لتحديد تاثير سرعة الرياح على الأنسياق الرملي ، وقوة مقاومة القص ، قوة التماسك و الاختراق .

تضمنت المرحلة الثانية تحديد الخلطة الافضل (الأمثل)من الخلطات الثلاث السابقة من خلال مقارنة النتائج . تم بعدها اضافة (2.5% ,5% و 7.5%) من غبار افران الاسمنت الى محلول صمغ السيليكا للخلطة الافضل وتم الاشارة اليها بالخلطات (m41 m42 ,m43) على التوالي ، تم حفظها بدرجة حرارة المختبر لمدة (7 ، 14 و 28) يوم .

أجريت بعض الفحوصات الهندسية على الخلطات الثلاثة لتحديد كل من قيمة الأنسياق الرملي، وقوة مقاومة القص، قوة التماسك و الاختراق .

عموماً أظهرت النتائج تحسن كبير في خصائص الكثبان الرملية بعد اضافة كل من صمغ السيليكا وغبار أفران الاسمنت ، وهذا يعني امكانية استخدامهما كمثبتات للكثبان الرملية ومحسنين لخواصها ، لتوفر صمغ السيليكا وغبار أفران الاسمنت ورخص ثمنهما .

الكلمات المفتاحية : تثبيت ، الكثبان ، الرملية ، غبار ، السيليكا .