International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:5, No:10, 2011

Soil Improvement using Cement Dust Mixture

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***Abstract*—**Day by day technology increases and problems associated with this technology also increase. Several researches were carried out to investigate the deployment of such material safely in geotechnical engineering in particular and civil engineering in general. However, different types of waste material have such as cement duct, fly ash and slag been proven to be suitable in several applications. In this research cement dust mixed with different percentages of sand will be used in some civil engineering application as will be explained later in this paper throughout filed and laboratory test. The used mixer (waste material with sand) prove high performance, durability to environmental condition, low cost and high benefits. At higher cement dust ratio, small cement ratio is valuable for compressive strength and permeability. Also at small cement dust ratio higher cement ratio is valuable for compressive strength.

***Keywords*—**cement dust, cement, soil improvement, permeability

I. Introduction

GROUND improvement can be defined as the process of increasing shear strength parameters and decreasing the permeability of the soil [1]. Geotechnical parameters of the soil were improved by using cement dust and cement.

II. Materials

A. Cement Dust

Cement manufacturing is one of the largest industries operating in Egypt. Cement consists principally of limestone and shale, in addition to other materials such as AL2O3, Fe2O3 and sand. Cement is a mixture of Calcium oxide (CaO) (62% - 66%), Silicon oxide (SiO2) (19% - 22%), Aluminum tri-oxide (AL2O3) (4%-8%), Ferric oxide (Fe2O3) (2% - 5%), Magnesium oxide (MgO) (1% - 2%) and other impurities [2]. The production of cement in Egypt reaches to 48 million tons annually. In Egypt, cement industry discard about 3 million tons per year of cement dust, this huge quantity of dust generates continuous problems for both cement makers and governments in addition to significant financial losses to these industrial. It contains chlorides, sulphates, alkalies and calcium oxides that can contain from 8 to 61 % total Cao, and from zero to 37 % free lime, varying by cement kiln. Free lime is the amount of lime that is available for reactions, and is a good indicator of how reactive a cement kiln dust will be. This lime content makes it attractive for use as a neutralization/precipitation agent (mackie et al. 2010).

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B. Sand

Used in this study is local sand, which is typically used as a construction material in concrete and mortar production. Grain size distribution test was preformed in accordance with the ASTM-D422 test method for particle size analysis of soils [3]. Sand characteristics are extracted such as effective diameter (D10), coefficient of uniformity (Cu), coefficient of curvature (Cc), percentage passing Sieve No. 200, theses characteristics are classified according to the Unified Soil Classification System (USCS) (test method for classification of soils for engineering purposes).

C. Cement

The term cement is also commonly used to refer more specifically to powdered materials which develop strong adhesive qualities when combined with water [4]. These materials are more properly known as hydraulic cements. Local Portland cement produced in Egypt was used.

III. Experimental Program

To change the sand from cohesion less soil to cemented soil, to get high dry density with low Optimum moisture contents (OMC), to get good compressive strength, and to get low permeability, the above materials have to be mix together with different ratios. An artificial cemented sand samples at almost maximum dray density and consequently optimum moisture content were prepared in the laboratory. The properties of these samples were controlled by applying the following criteria:

A. Specific Gravity
B. Grain Size Distribution
C. Compaction
D. Unconfined Compressive Strength
E. Permeability

IV. Experimental Results And Discussion

A. *Specific Gravity*:
The Specific Gravity of sand and cement dust are 2.72 and 3.11 respectively

B. *Grain Size Distribution*

1. *Sand*

As shown in Fig.1, the SAND considered as fine to medium sand. This type of sand has medium void ratios, and low dry density. To change the characteristic of this sand we have to add cement dust.

2. *Cement Dust*

The size of cement dust considered as silt size . With the above classification, good compatible mixture materials can

be expected to achieve good values of compactions, permeability, and unconfined compressive strength properties.

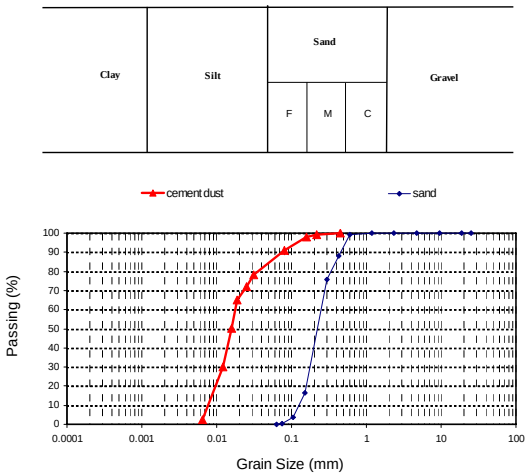

Fig. 1 Grain size distribution for the used materials

C. *Compaction Test Results*

This is the important experimental work to evaluate the compaction ability of soil to improve [5]. The modified compaction test is applied, five layers and 25 blows for every layer. Three times of test are carried out for each material and the average of the results are evaluated. The mixtures are also made by mixing all the materials of sands, and cement dust together with different ratios. This test was used to get the maximum dry density and the corresponding optimum moisture content (OMC) of the sand only and the sand-cement dust mixtures.

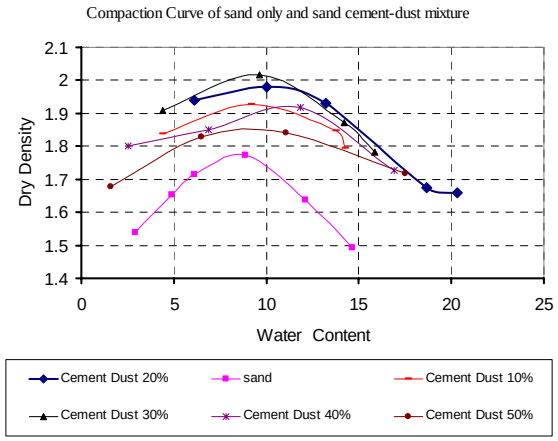

Fig. 2 compaction test results of sand only and sand-cement dust mixtures

1. *Sand Only*

Comparison was made between sand only, and sand with other mixtures. The maximum dry density of 1.77 g/cm3 was obtained with the OMC of 8.84% as shown in Fig. 2. To increases the dry density of the sand some other material has to be added.

2. *Sand and Cement-Dust Mixtures*

As shown in Fig.2 the cement dust is effective for compaction where the dry density increases. The cement dust should be used more than 10% to obtain higher value of dry density. Increasing the cement dust ratio more than 30% is not preferable. More cement dust ratio than 30% less of dry density of the mixture. From Fig.2 it is concluded that the mixture having a high dry density equal 2.01 g/cm3 and OMC equal 9.6 % was obtained from sand 70% mixed with cement dust 30%. By analysing this result, the authors concluded that until 10 % cement dust the voids between the sand grains still, by increasing the cement dust ratio more than 30% most of the voids are full and no need for more cement dust to fill this voids.

D. *Compressive Strength*

Compressive strength is very important for the cement works and soil improvement technology [6]. The compressive strength comes in some cases as first priority or second priority with permeability. Many things affect on the compressive strength like cement and cement dust ratios with sand. We will discus every point separately.

1. *Sand-Cement Dust Mixtures*

Fig. 3 Show that the relation between compressive strength of sand-cement dust mixtures at different time. It is noticed that an increase of cement dust ratio increases of the compressive strength. More of cement dust more of compressive strength of the mixture. The maximum compressive strength at 7, 28, 90, 180 days were obtained from mixture contains sand, 50% cement dust where qu (kg/cm2) were 1.0, 2.1, 4.3, 3.9 respectively. The minimum compressive strength at 7, 28, 90, 180 days were obtained from mixture contains sand, 20% cement dust where qu (kg/cm2) were 0.4, 0.6, 1.2, 1.1 respectively. It is noticed that the maximum compressive strength of the mixtures are at 90 days, more time than 90 days leads to less of the compressive strength. Slightly decreases of the compressive strength with the time more than 90 days.

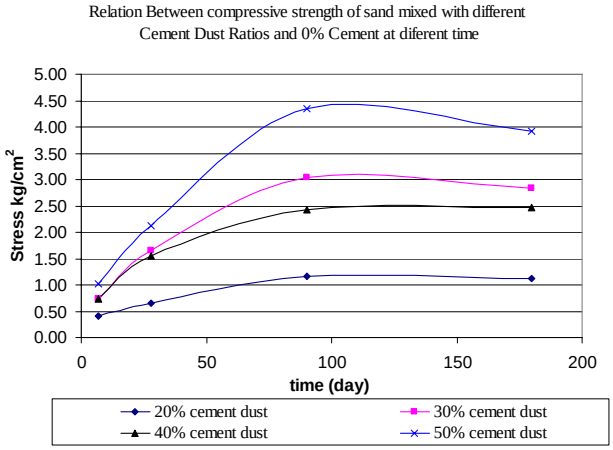

Fig. 3 compressive strength of sand with different cement dust ratios at (0%) cement at deferent time

2. *Sand, Cement and Cement- Dust Mixtures*

Fig. 4 and 5 show that the relation between compressive strength of sand-cement dust mixtures and different cement ratio at different time. It is noticed that an increase of cement dust ratio increases the compressive strength of the mixture at the same cement ratio. More of cement dust more of compressive strength of the mixture. The maximum compressive strength were obtained at 180 days from mixture contains sand, 50% cement dust, 6% cement, where qu is 7.8kg/cm2. From fig.4,5 it is clear that the effect of the cement increase slightly affects on the compressive strength of the mixture. Cement ratio from 3% to 6% gives very small increase in the compressive strength of the mixture. it is recommend economically to small cement percentage with higher percentage of cement dust, for example sand with 50% cement dust and 3%cement. Higher percentage of cement dust with smaller percentage of cement would gain higher compressive strength with time. From Fig. 3, 4 &5 it can be concluded that at cement dust percentage of 20, 30 and 40% there are no significant change in compressive strength. In case of cement dust ratio equal to 50% mixed with cement and sand it is more stable than mixture contains cement dust equal to 50% mixed with sand only.

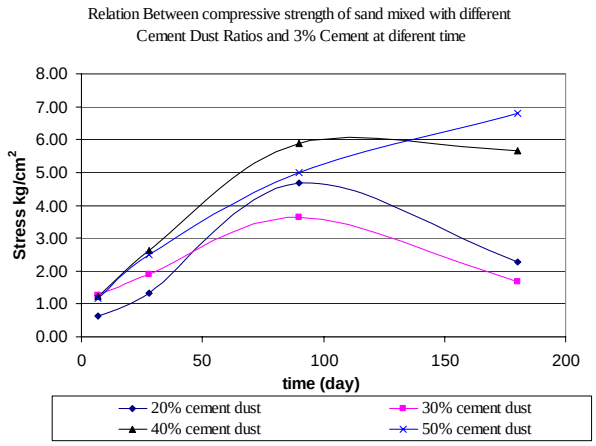

Fig. 4 compressive strength of sand with different cement dust ratios at (3%) cement at deferent time

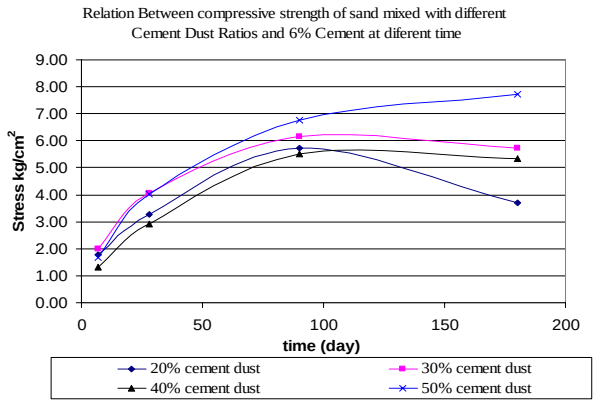

Fig. 5 compressive strength of sand with different cement dust ratios at (6%) cement at deferent time

Fig.6 and 7 show the variation in compressive strength of sand-cement dust mixtures with time using different cement ratio. It is noticed that for the same cement dust content, compressive strength of the mixture increase with time till a certain value (peak) then tend to decrease again. More of cement dust less of compressive strength of the mixture. The maximum compressive strength of the mixtures is at 90 days with cement dust 20% and cement ratio 12%. We conclude that at the same cement dust ratio more cement ratio gives higher compressive strength. To get good compressive strength, stable, and economy, we have to use cement dust with 40% with cement ratio equal 9% and sand.

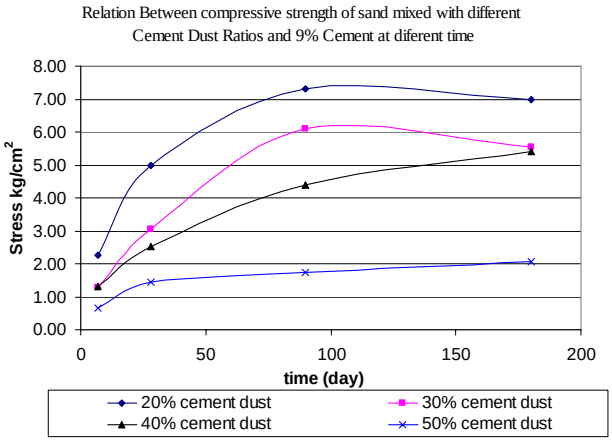

Fig. 6 compressive strength of sand with different cement dust ratios at (9%) cement at deferent time

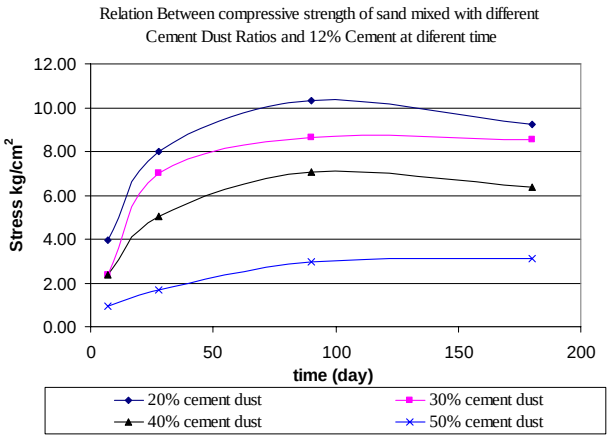

Fig. 7 compressive strength of sand with different cement dust ratios at (12%) cement at deferent time

Comparing results from Fig. 3,4,5,6,7 we found that mixtures with or without cement are not stable except two mixture first one mixture contains 3% cement and 50% cement dust with sand, second one mixture contains 9% cement and 40% cement dust with sand. At higher cement dust ratio, small cement ratio is valuable. But at small cement dust ratio higher cement ratio is valuable. To get economic, stable mixture we have to use small cement ratio with higher cement dust ratio.

E. *Permeability of the Mixture*

A permeability property is very important in the soil improvement especially cut off wall. Low permeability is preferred for all the soil improvement work with good compressive strength [7]. The permeability of the used sand only is $3.74*10^{-3}$ which considered as very high permeability. To achieve low permeability of this sand we have to add cement dust, and cement. Cement dust decrease the permeability of materials by decreasing the voids ratio. In this work sand, cement dust, and cement were used to decrease the permeability factor of the mixture. We get the permeability of the mixtures after 24 hours from mixing.

Fig. 8 and 9 show that the relation between permeability of sand-cement dust mixtures and different cement ratio. It is noticed that an increase of cement dust ratio from 10% to 40% decreases the permeability of the mixtures at same cement dust ratio. More of cement dust from 40% to 50% increases the permeability of the mixtures.

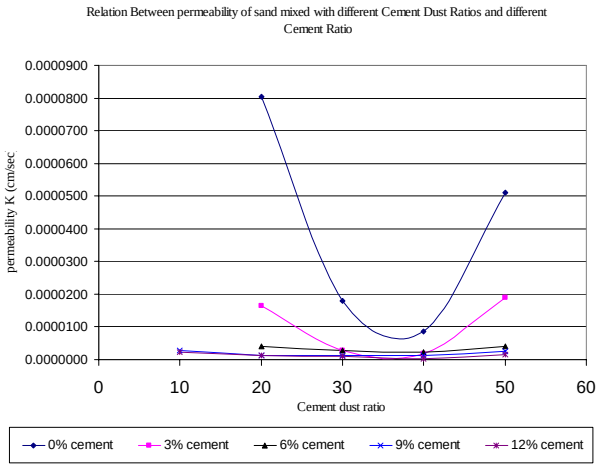

Fig. 8 permeability of sand with different cement, cement-dust ratios

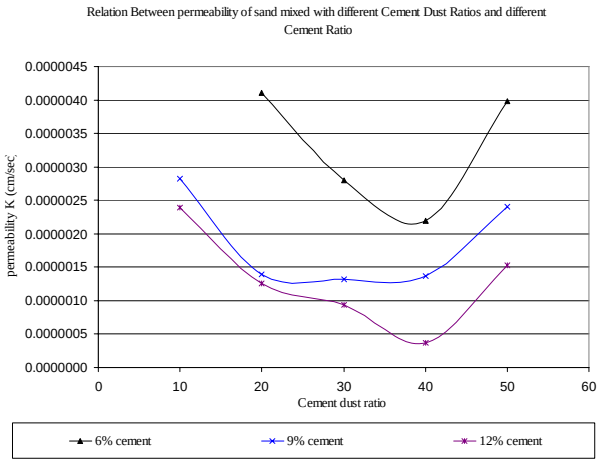

Fig. 9 permeability of sand with different cement, cement-dust ratios

Also an increase of cement ratio of the mixtures decreases the permeability. It can be concluded that when cement or cement dust increases in the mixtures these leads to decreases of the voids ratio, increases of the bulk density, and increases the cementing ability. After a limited ratio from cement dust which is 40% an increase of cement dust ratio increase the voids ratio and increases the permeability. The good permeability of the mixtures comes from mixtures contains cement dust ratios from 30% to 40% and cement ratios from 3% to 12%, which are vary from 3.73E-07 cm/sec to 2.83E-06 cm/sec. The minimum permeability of the mixtures is 3.73E-07 which comes from mixtures contains cement dust 40% and cement ratio 12%.

V. Conclusion

The compaction characteristic of the sand was improved by cement dust. Considering the seepage control, compressive strength, cement dust was approved to have more pronounced effect on the reduction of the sand permeability and enhance of the compressive strength of sand.

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