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Geotechnical Evaluation of Fines Content Effect in Gravelly Sand Replacement Soil

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Abstract

The compacted soil replacement procedure has been widely used in Egypt for Overcoming the unfavorable actions of some problematic soils, such as expansive, Collapsing soils and ground fill. Compaction of the replacement soil is necessary for stabilizing it and improving its performance. The supporting capacity of a replacement soil increases with the increase of its dry density. Therefore, the density of the replacement layer is the major factor controlling its behavior under the effect if external stresses. Compacted sand and gravelly sand are preferred materials when used for soil replacement. They tend to have better engineering properties, if they are placed according to the standard specifications. Gravelly-sand soil, which consists of gravel, sand and fines, is widely used as replacement soil in the field. The effect of fines content on possibly achieved density of such soil is experimentally investigated. Another experimental stage of the effect of fines on the bearing capacity of circular footings on gravelly-sand with different percentages of fines was performed. It was found that a fines content of 10 % gives highest dry density, if the soil is compacted according to modified proctor specifications and with the addition of fines, settlement increases and the ultimate bearing carrying capacity decreases.

1 – Introduction

A compacted composite soil mixture technique is recommended in many applications in geotechnical engineering fields. Singh and Alam [1] stated that the structure of a compacted soil depends on the

relative proportions of the coarse particles and the fines. Shelley and Daniel [2] recommended the usage of clayey gravels soil (GC SOIL) for the homogeneous embankments, cores of dams and compacted earth linings.

The ASTM designation gave the specification of materials for soil-aggregate sub base, base and surface road covers the quality and grading of materials for use in the construction of these roads. It mentioned that, fine aggregate mixtures consisting of natural or crushed sand have particles passing the No. 200 sieve ranging from 6 % to 15 % by weight. The fraction passing the No. 200 sieve shall not be greater than two thirds of the fraction passing the No. 40 sieve.

Further, the presence of fines in sand has an influence on the bearing capacity. The problem of bearing capacity of shallow foundations on granular soils has been studied for many years [3-7]. However, an accurate solution capable of predicting peak load carrying capacity for a wide range of soil relative densities, effective stress conditions and foundation shapes within a practical context remains elusive owing to the presence of fines. There are many investigations in the literature on the role of fines on stress strain behavior of silty sand [8-10]. It is difficult to anticipate why the behavior of silty sand is contractile. The basis for deformations, whether silty sand would be contractile or dilative and what kind of stress strain behavior is to be expected compared with that of clean sand needs further explanation. The factor that controls the behavior of confined silty sands is a matter to be investigated. The natural sands contain varying amount of fines, whereas the current knowledge of its engineering behavior is primarily based on clean sands [11, 12].

Navac [13] reported the coarse-grained, granular well-graded soils with less than 4 % passing No. 200 sieve, are insensitive to compaction moisture content. The Egyptian Code for Soil Mechanics and Foundation Design and practice [14] defined the grained soil that has no cohesion or has permeability with low percentage of fines. This fine percentage with 0.06-mm diameter is less than 10 %. The vanayagam [15] stated that, for silty sand soil with a fines content in the range of 20 % - 30 %, the relative density (D_r) increases. This relative density (D_r) could be as high as 80 % - 90 %. At higher fines content greater than about 30 %, silty sand may behave in a similar manner to that of the host fine-grained soil. Pitman et al. [16] indicate that, as the fines content increases, initially the steady-state strength at the same void ratio decrease, followed by an increase in shear strength with a further increase in fines content beyond about 30 %. Reyad and Salem [17] stated that a well-compacted mixture of 35 % sand and 65 % gravel produces very satisfactory soil replacement for practical purposes

2 – Experimental work

a) Compaction test

The used soil in this study was a gravelly-sand soil obtained from a site on The Cairo-Suez Desert Road. The used soil is a mixture of fine, medium, and coarse particles. The grain size distribution of the soil is shown in Fig. (1). The specific gravity G_s was determined by the pycnometer and it was found to be 2.65. The scoop and the funnel methods were followed for determining the minimum dry density ($\gamma_{d \min}$) for the tested soil in the laboratory, and the minimum density was found to be 1.50 gm/cm³. To find out the most effective percentage of fines (F_{eff}) added to the soil, to be used as a good compacted soil replacement. Six Standard proctor tests were performed for the tested sample. These samples were mixed with different percentage of fines, which were passing sieve No. 200. The standard proctor tests were performed on samples of 0 % fines, 5 % fines, 8 % fines, 10 % fines, 12 % fines, 15 % fines.

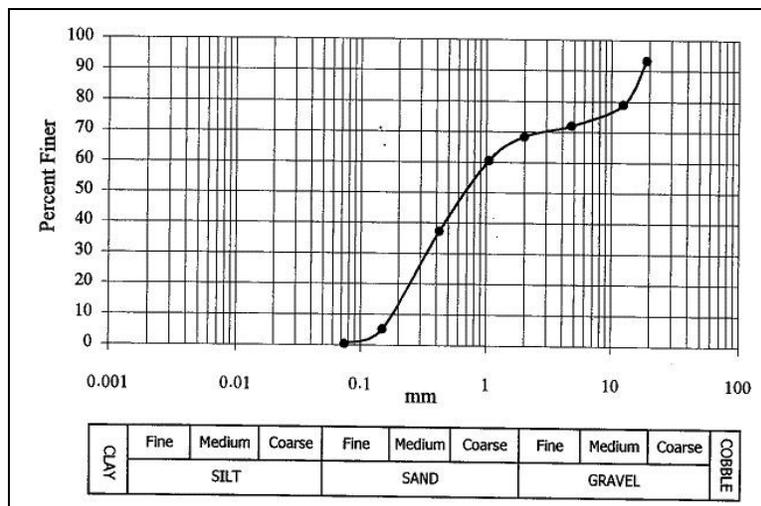


Figure (1): Grain size distribution of the tested soil

b) Plate load test

Six series of plate loading tests were conducted in a special bricked tank that was built and lined with bricks and cement mortar. The net dimensions of the test tank were 1.5 m x 1.5 m and 0.75 m deep as shown in Figure (2). The reason for choosing these dimensions was that, the plate test must be developed on an excavated pit of size not less than five times the size of the plate and the depth of the pit not less than twice of the plate size as stated in Bowles [18]. The used plate diameter is 30 cm. A huge steel frame was constructed around the built tank to resist the hydraulic jack reaction. The tested soil was placed in the tank under the predetermined five compaction conditions with the same fine contents. A mechanical vibrating hammer used in the compaction process of the tested soil. The footing plate was placed in position and the load was applied in increments by the hydraulic jack. Each load increment was maintained constant until the footing settlement is less than 0.02 mm/hour. The settlement of the footing was measured using two dial gauges placed on opposite sides of the footing.



Figure (2): Plate loading test setup

3 – Results and Discussions

a) *Fine content effect on compaction*

From the results obtained from the standard proctor tests which performed on samples of 0 % fines, 5 % fines, 8 % fines, 10 % fines, 12 % fines, 15 % fines. The relations between the dry densities and the water contents of the compacted samples were plotted as shown in Figure (3). The relationship between the fine percentages for the tested samples and the optimum moisture contents (OMC) as well as the maximum dry density were plotted against fine percentages as shown in Figs. (4) and (5) respectively.

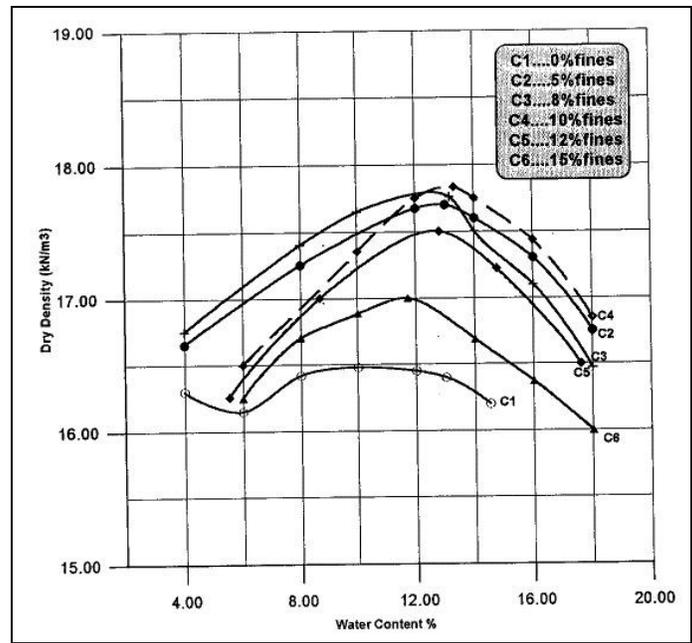


Figure (3): Effect of fines content on the moisture-density relation

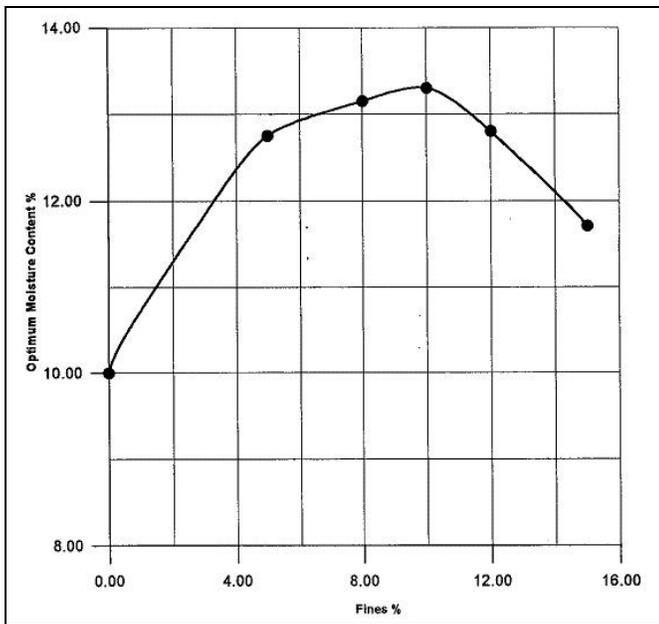


Figure (4): Effect of fines content on the OMC

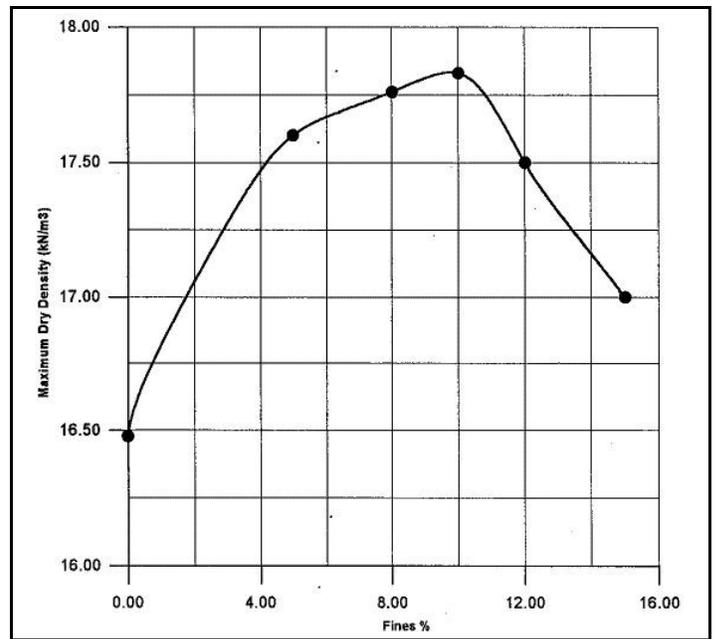


Figure (5): Effect of fines content on the maximum dry density

Figure (3) showed that considerable increase in the value of the maximum dry density of the tested soil is observed at fine percentage of 10 percent. Fig (4) and Fig (5) may explain this result as it indicates the effect of fines on optimum moisture content. When 5 % of fines is mixed with the sample, the optimum moisture content increased by 30 % and the maximum dry density increased with 7.4 %. This increase is due to the reduction of the air voids (e), which were filled by the effect of both the fines and the increase of the moisture content. By increasing the percentage of fines from 5 % to 8 and 10 %, a small change Occurred in the maximum dry density, this change was found to be about 0.73 % Increase. Also, the change in the optimum moisture content was small, it was about 2.3 % increase. However, by increasing the fine percentage to 12 %, the maximum dry density was reduced by 1.85 % and 3.76 % reduction in the optimum moisture content. Also, by increasing the fine percentage to 15 %, the maximum dry density was reduced by 2.86 percent, and the optimum moisture content was reduced by 8.5 percent.

b) Fine content effect on bearing capacity

In order to analyze the effect of fines, a series of tests was carried out with all parameters were kept constant except the percentage of fines content. Figure (6) shows the variation of bearing capacity with different percentage of fines content with the settlement ratio (S/d) where d is the plate diameter. It is clear that increasing the percentage of fines, the bearing capacity decreases. It is due to the fact that as we increase the proportions of fine content, the density increases along with the compressibility. The effect of compressibility offsets the effect of increase in density. In other words, with the addition of fines, settlement increases and the

ultimate bearing carrying capacity decrease. Hence, in the presence of fines, the failure criterion is governed by allowable settlement and the bearing capacity of the footing decreases.

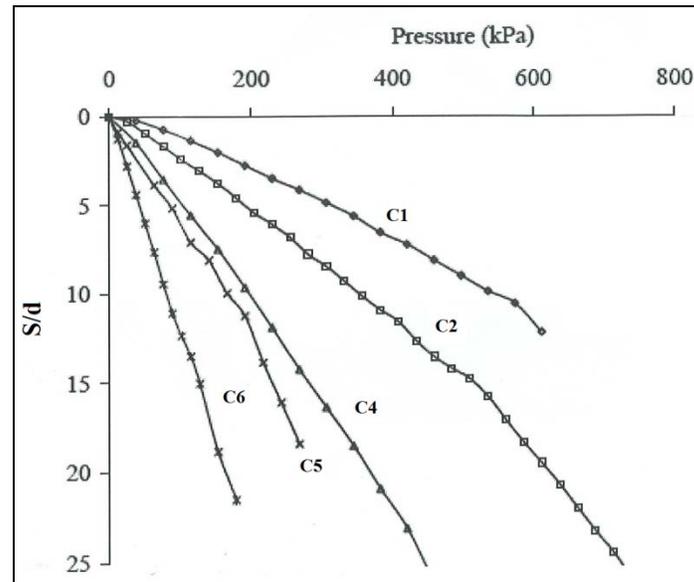


Figure (6): Effect of fines content on bearing capacity

Conclusions

Based on experimental study, the following conclusions are drawn.

- The increase in the maximum dry density depends on the air voids reduction caused by fines and water content together. The increase of fines content causes the optimum moisture contents to increase because of, decreasing the specific gravity (G_s), changing in the shape of soil grains, and reduction in air void ratio. The increase of fines content causes the increase of maximum dry density until a limit value of fines percentage. And after that limit the maximum dry density begins to decrease because fines grains move to the voids between sand grains producing higher density until a certain limit value of the fines content. This limit of fine percentages differs according to the differences between the tested soils. It was found that some improvements in the maximum dry density occurred if fine percentage was 10%. So, the effective percentage of fines $F_{eff} = 10\%$.
- The experimental plate load test program proved that the bearing capacity of circular footings on gravelly sand soils decreases with the increase in their fines proportions as the failure criterion is governed by allowable settlement which is with the addition of fines, the settlement increases and the ultimate bearing carrying capacity decreases.

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