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Effect of Metakaolin On the Hydraulic Conductivity of Grouted Sand

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***Abstract*: Grouting is the procedure by which grout is injected into soil formation to fill the voids and thereby improving the engineering properties of the medium. Grouting is effective in reducing the permeability of the medium. The study here presents the use of metakaolin as a partial replacement to cement grout in improving the permeability characteristics of sand medium. Metakaolin was added at three different percentages of 5%, 10% and 15% by dry weight of cement for three different water binder ratios of 9:1, 8:2 and 7:3. A comparison of reduction in permeability was made between plain cement grout and metakaolin added cement grout for all three water binder ratios. The variation in permeability is also studied for curing periods of 7, 14 and 28 days. From the result obtained it is noted that at 10% metakaolin addition coefficient of permeability reduces to 2.13×10^{-6} m/s for water binder ratio of 7:3 at 7 days curing. At a curing period of 14 days the coefficient of permeability again found to decrease to 1.53×10^{-6} m/s. Also the most effective water binder ratio was obtained as 7:3.**

***Keywords*: Curing, Grouting, Metakaolin, Permeability.**

1. Introduction

Hydraulic conductivity defines the capacity of a porous medium to conduct particular fluid, and is a function of both the medium and the fluid. The permeability and strength of grouted sand is strongly influenced by the method of grouting because different mechanism govern the deposition and packing of cement particles within the pore structure. During the injection process, preferential flow paths allow the migration of cement parties into the soil, and microstructural packing undoubtedly varies within the pores of the grouted sand, this is in contrast to the more uniform distribution of particles in hand-mixed specimens (Schwarz und Krizek, 1994).

Pandian et al. (1995) studied the permeability and compressibility behaviour of bentonite-sand/soil mixes, that the bentonite particles due to their very large specific surface form a coating around the courser sand particles, thus preventing direct contact between grains. This results in a decrease in compressibility at the same time the permeability coefficient is of the same order, as bentonite particles coat sand grains with the result that seepage control still affected.

The permeability of stabilized sand may increase remarkably due to flow channels caused by the shear stress increment and that the relationship between the permeability of stabilized sand and the shear stress increment depends upon density, grain size and type of chemical grout. In sands stabilized by silicate grout, the permeability of stabilized sand with large grain size increases remarkably owing to shear deformation, irrespective of density (Mori and Tamura, 1986).

An increase in w/c ratio of grout increased the permeability of soils and decreased the strength of grouted samples (Akbulut and Saglamer, 2002). For grout injected specimens, decreasing the water to cement ratio of the grout and increasing the curing time significantly lowered the permeability and increasing the strength, whereas increasing the distance from the injection point had little effect on the permeability and produced meaningful reductions in strength (Schwarz and Krizek, 1994). The effectiveness of the grouting operation in terms of permeability and strength is controlled, to some extent, by the granulometry of the soil formation, the finer the sand is being grouted, and the larger is the observed increase in strength and decrease in permeability (Zebovitz et al, 1989)

2. Materials and Methodology

A. Soil Properties

Locally available sand collected from Neyyatinkara, Thiruvananthapuram district was used for the study. Table 1 shows the properties of sand. From the test results, the soil can be classified as Poorly Graded Sand according to Indian Standard Classification system.

Table 1
Properties of Sand

Properties	Value
Specific gravity	2.64
Effective size D_{10}, mm	0.3
Uniformity coefficient, Cu	1.53
Coefficient of curvature, Cc	0.992
Coefficient of permeability, k (m/s)	4.25×10^{-5}
Void ratio, e	0.504
Bulk density, (g/cc)	1.627
Porosity, n	0.335
Angle of internal friction, ɸ	39.11
Cohesion (kg/cm^2)	0.2
Classification (IS)	SP

B. Cement

Portland pozzolonic cement of grade 33, collected from a local supplier, conforming to IS 1498 is used for preparing grout. The Table 2 shows the properties of cement used.

Table 2
Properties of Cement

Properties	Value
Grade	33
Fineness (%)	6.5
Standard consistency (%)	28
Initial setting time(min)	85
Final setting time(min)	420

C. Metakaolin

Metakaolin used for the study was collected from English India clay Ltd, Veli. Metakaolin is a pozzolonic material which is obtained from treated kaolinite clay with heat at about 600 to 800°C. This thermal treatment of kaolinite leads to dehydroxylation of the crystalline structure of kaolinite to form Metakaolin.

Table 3
Properties of Metakaolin

Properties	Value
Specific gravity	2.6
Liquid limit (%)	85
Plastic limit (%)	33
Plasticity index	52
Shrinkage limit (%)	21
Clay (%)	80
Silt (%)	12
Sand (%)	8
Classification	CH

D. Test Procedure

Constant head permeability test is conducted for grouted samples. The sand sample to be grouted is prepared inside a PVC mould. The sample is prepared conforming to IS: 2720 (part 17). Porous medium is provided at the bottom and then sand is filled. After grouting the sand medium, a porous medium is again provided at the top. The figure 1 shows the schematic representation of permeability setup. Water is permitted through the sand medium at a constant head of 10cm. The prepared specimens are allowed to cure under saturated condition and discharge measured after the flow attains a steady state. Discharge measurements are taken for different curing periods of 7 days, 14 days and 28 days to study the effect of curing period on the permeability of the grouted sample.

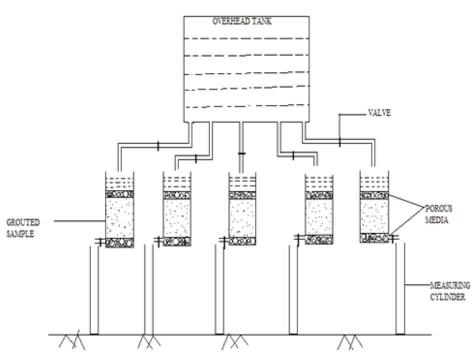

Fig. 1. Schematic representation of permeability setup

The grouting operation was carried out using a grout pump at a grouting pressure of 3kg/cm^2. The grouting setup consist of a grout chamber with air compressor, grouting nozzle and a regulating valve. The grout was prepared using cement with and without metakaolin additive. The metakaolin was added at 5%, 10% and 15% by dry weight of cement. The study was carried out in three different water binder ratios of 9:1, 8:2 and 7:3.

3. Results and discussions

The coefficient of permeability of the virgin sand was obtained as 4.25×10^{-5}. From the test result it was observed that coefficient of permeability was found to decrease with decreasing water binder ratio for plain cement grout and also for metakaolin modified cement grout. The reduction in k value was observed more for metakaolin modified grout. This is because the hydration of cement is enhanced by the addition of metakaolin which result in reducing the interconnectivity of soil voids.

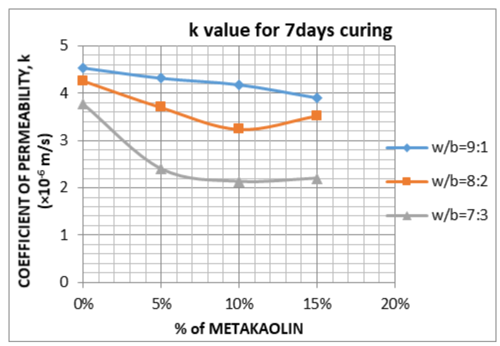

Fig. 2. Variation of k value for 7 days curing

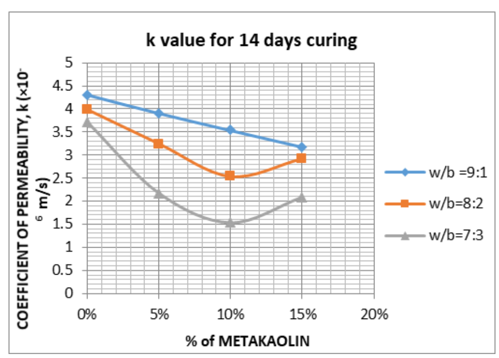

Fig. 3. Variation of k value for 14 days curing

With an increase in percentage of metakaolin from 5% to 15% a reduction in k value was observed for all the three water binder ratios. Lowest value of 2.13×10^{-6} m/s was observed for 10% addition of metakaolin at water binder ratio of 7:3. Further with addition of 15% metakaolin a slight increase in value to 2.2×10^{-6} m/s was observed. This reduction is due to high specific surface area of metakaolin which demands more water to enhance the reaction at low water binder ratios. With an increase in curing period to 14 days k value found to decrease to 1.53× 10^{-6} m/s. No further reduction is observed for 28 days cured sample having 10% metakaolin at water binder ratio of 7:3. Thus the optimum additive was found as 10%. The grout mix of water binder ratio 7:3 is found to be much effective grout in reducing permeability characteristics of grouted sand. Figures 2, 3 and 4 shows the variation in k obtained.

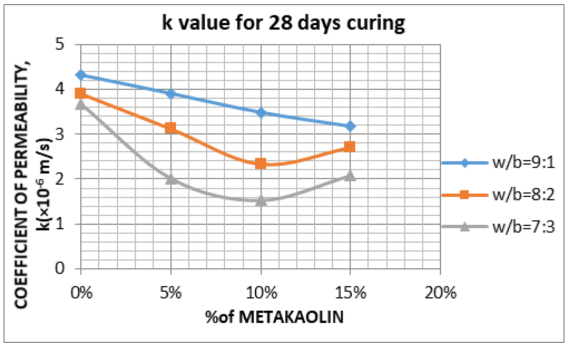

Fig. 4. Variation of k value for 28 days curing

4. Conclusion

The following conclusions are drawn from the study:

- As the water binder ratio decreases coefficient of permeability value decreases.
- The reduction in permeability is observed more for metakaolin modified cement grout than for plain cement grout.
- With an increase in percentage addition of metakaolin to 10% the permeability was found to decrease. Thus 10% addition can be suggested as an optimum value.
- With an increase in curing period permeability is found to decrease.
- The most effective water binder ratio for reducing the hydraulic conductivity of sand sample was found to be 7:3.

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