Analyzing the effect of filler on the Shear strength of Grouted sand

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Abstract - *The scarcity of land for construction purposes nowadays demand the use of economical techniques such as grouting for strengthening the available soils especially loose sandy soils. Conventional material adopted for suspension grouting is OPC which is not much cost effective. So the use of certain additives as partial replacement to cement is gaining more importance. Therefore, the present study focusses on the use of metakaolin as a partial replacement to cement as it is a good pozzolonic material. Here metakaolin is added at about 5%, 10% and 15% by dry weight of cement. The shear parameters of the grouted specimen are studied for different water binder ratios of 9:1, 8:2 and 7:3. The results indicated that the cohesion and angle of internal friction increases with increase in water binder ratio. Cement grout with 10% metakaolin was obtained as optimum percentage for water binder ratio of 9:1 and 8:2 due to its higher ability to improve the shear parameters. The best result were obtained for water binder ratio 8:2.*

Key Words: Grouting, Metakaolin, Portland pozzolonic cement, Shear strength

1. INTRODUCTION

The constructional activities in the coastal belt of our country often demand deep foundations because of the poor engineering properties and the related problem arising from weak soil at shallow depths. The very low shearing resistance of the foundation bed causes local as well as punching shear failure. Hence the structures built on these soils may suffer from excessive settlements. Strengthening of these loose sandy soils at shallow depth through economical techniques such as grouting is a possible solution. Grouting often has to serve the primary purpose of filling the voids or replacing the existing fluids in voids with a view to improve engineering properties of the grouted medium.

Cement grouting can be profitably used for improving the shear strength of foundation beds. The shear strength parameters, c and ϕ, shows phenomenal increase when grouted with cement. The cement-water ratio of the grout act as a key parameter in the control of strength gain of sandy soils [Glory et al., 2001][3].Several experimental studies conducted on sand have been devoted to the increase of the strength due to cement grouting. The grouted material remains a frictional one, the strength of which is correctly modelled by Mohr-Coulomb criterion. Grouting is mainly responsible for the gain in cohesion by the material and only marginally affects the friction angle. The cohesion linearly varies with cement content, the magnitude of the cohesion gained by grouting and also the friction angle is a slightly increasing function of cement content. The increase in angle of friction is negligible with respect to cohesion [Maalej et al., 2007][5].

Introduction of a cementing agent into sand produces a material with two components of strength that due to the cement itself and that due to friction. The friction angle of cemented sand is similar to that of uncemented sands. Weakly cemented sand shows a brittle failure mode at low confining pressures with transition to ductile failure at higher confining pressures. For brittle type cementing agents, the cementation bonds are broken at very low strains while the friction component is mobilized at large strains. Density, grain size distribution, grain shapes and grain arrangements all have a significant effect on the behaviour of cemented sand [Clough et al., 1981][2].

Investigation on soil cemented with Portland cement, gypsum and lime were also performed. For low cement contents and low confining pressures the highest shear strength of cemented soils belongs to the soil cemented with Portland cement. Increasing the confining stress, the shear strength of soil cemented with Portland cement drops lower than the shear strength of the soil cemented with gypsum. However, it is still higher than the shear strength of soil cemented with lime. When cement content increases to 4.5% the shear strength of the soil cemented with Portland cement is always higher than the shear strength of the soil cemented with gypsum and lime [Haeri et al., 2006][4].

The addition of a cementing agent to a cohesionless soil with uniform size distribution produces a material with two strengths components that due to cementation or true cohesion and that due to friction. The angle of internal friction for the treated sands is not much different from that of the untreated sand. Peak strength as well as initial tangent modulus values, increase with an increase in curing period, confining pressure, cement content and density [Aiban, 1994][1].

2. MATERIALS

2.1 Sand

The sand used in this study is collected locally from Neyyatinkara, Thiruvananthapuram district. The properties of the soil are studied using standard procedures and the results are tabulated in table 1. 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 (cm/s)	4.25×10^{-3}
Void ratio, e	0.504
Bulk density, (g/cc)	1.627
Porosity, n	0.335
Angle of internal friction, ϕ	39.11
Cohesion (kg/cm2)	0.2
Classification (IS)	SP

2.2 Cement

Portland pozzolonic cement of grade 33 conforming to IS 1498 is used for preparing grout. It was collected from a local supplier. 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

2.3 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 .

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

3. METHODOLOGY

The sand specimen to be tested is mixed with cement and required amount of water for different water binder ratios of 9:1, 8:2 and 7:3. The mixture is placed in the standard shear box and direct shear test conforming to IS: 2720 (Part 13) was performed to determine cohesion and angle of internal friction values. Then samples are prepared by mixing sand with cement and metakaolin, added at 5%, 10% and 15% of dry weight of cement for water binder ratios of 9:1, 8:2 and 7:3. Shear test is performed as earlier after curing for a day. The variation in cohesion and angle of internal friction with the addition of metakaolin are noted.

4. RESULTS AND DISCUSSIONS

The result obtained from the test shows that the shear strength was found to increase more for sand sample with cement added with 5%, 10% and 15% metakaolin for all the three water binder ratios than for samples with cement alone. The increase in shear parameters is contributed by the pozzolonic activity of metakaolin additive.

Both c value and ϕ value increases with metakaolin addition from 5% to 10% and then at 15% addition a slight reduction is observed. This decrease is due to the higher surface area of metakaolin which demand more water to complete the pozzolonic reaction. Thus the optimum amount of filler material was obtained as 10% for different water binder ratios. The most suitable water binder ratio to be adopted was obtained as 8:2. The chart1 and chart2 shows the variation of shear parameters for different percentage addition of metakaolin.

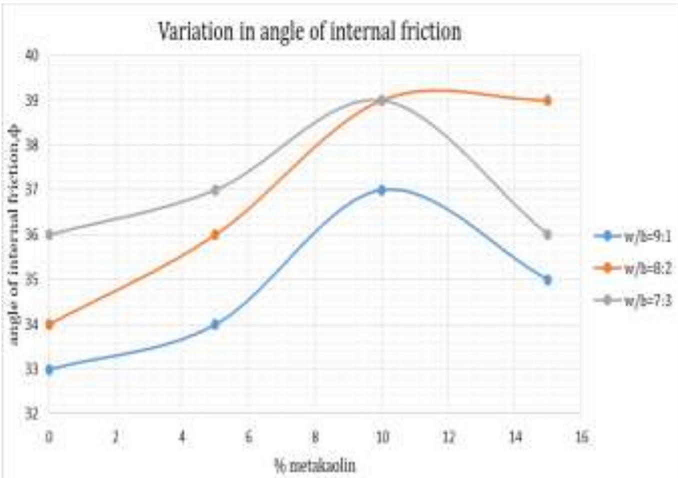

Chart -1: Variation of angle of internal friction

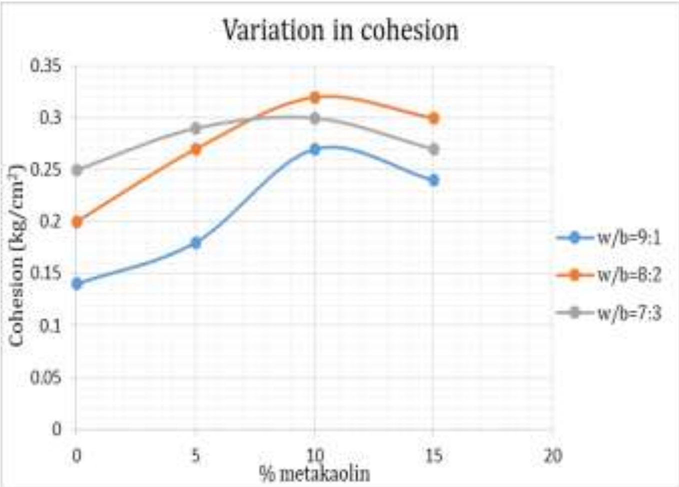

Chart -2: Variation of cohesion

5. CONCLUSIONS

Based on the study the followings conclusions were obtained:

- Shear strength parameters found to increase with increase in percentage addition of metakaolin for all the three water binder ratios.
- The variation in shear parameters obtained was more for metakaolin- cement added samples than for the cement alone added samples.
- The optimum percentage addition of metakaolin was found to be 10% for all the three water binder ratios.
- The effective water binder ratio was found to be 8:2.
- Thus metakaolin was found to be a most effective partial replacement for cement in the process of grouting sand mediums.

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