EXPERIMENTAL STUDY ON THE COMPRESSION STRENGTH OF GROUTED SAND COLUMN

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ABSTRACT: An attempt is made in the present investigation to get the compressive strength of sand stabilized with various water cement ratio. From the Direct shear test conducted the results shows increase in cohesion property and decrease in angle of internal friction with respect to cement content. Experiments were conducted on grouted sand column with water cement ratio of 1.5, 2 and 2.5 and addition of 2% Sulphonated Naphthalene Formaldehyde (SNF). The experimental results revealed that at lower water cement ratio higher compressive strength was observed. It was also observed the compressive strength increases with curing period. The ratio of UCC strength at a given water cement ratio to UCC strength at water cement ratio of 1.5 decreases from 0.29 to 0.58 for 7, 14 and 28 days curing for specimens grouted only with cement. For samples grouted with cement plus 2% SNF 0.18 to 0.49 for 7, 14 and 28 days curing.

1. INTRODUCTION

Grouting is a special technique developed in recent years with many applications. It is a procedure which involves grout injection into voids, fissures and cavities in soil or rock formation in order to improve their properties, specifically to reduce permeability, to increase strength and durability or to lessen deformability of the formations. Grouting has a wide application in modern civil engineering world (Nonveiller, 1989). More specifically, it is applied to:

(a) Reduce permeability of a ground mass formation in order to control seepage and loss of stored water in a dam reservoir
(b) Mitigate the soil liquefaction in structures for the protection of environment; control uplift on a structure, or to prevent the danger of erosion of soil from the foundation
(c) Increase the strength and reduce the deformability of soil material under the foundation
(d) Stabilize the ground around cutting face and to control the settlement of ground surface during the opening of a tunnel (Fransson, 2001)
(e) Fix reinforcing elements (e.g., cables) in pre-cast and pre-stressed concrete structures
(f) Fix rock pre-stressing anchors
(g) Lift and erect leaning structures and buildings
(h) Fill voids between rock and tunnel linings (Yesilnacar, 2003);
(i) Rehabilitate and reinforce old defective masonry on historical buildings (Yeon & Han, 1997).

Various materials are used for grouting depending on the purpose of grouting and the properties of the grouted rock or soil (Cambefort, 1977). They may range from plastic mortars, thick or liquid suspensions of cement and other compounds and additives in water (Ohama, 1984), chemical solutions (Karol, 1982), resins (Anagnostopoulos & Hadjispyrou, 2004), artificial foams, to hot bitumens and bitumen emulsions. Chemical admixtures such as super plasticizers, accelerators, antifreeze agents and many others are used to modify the grout properties and protect it from the environmental conditions.

2. MATERIALS AND ITS PROPERTIES

2.1 Soil

The sand required for the study was collected from Palar river bed. Figure 1 presents the grain size distribution curve of sand.

![Grain size Distribution Curve for Sand](image)
Table 1 summarises various index properties of sand.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Specific Gravity (G)</td>
<td>2.62</td>
</tr>
<tr>
<td>2.</td>
<td>Coarse Sand (%)</td>
<td>20</td>
</tr>
<tr>
<td>3.</td>
<td>Medium Sand (%)</td>
<td>65</td>
</tr>
<tr>
<td>4.</td>
<td>Fine Sand (%)</td>
<td>15</td>
</tr>
<tr>
<td>5.</td>
<td>Effective Size $D_{10}$ (mm)</td>
<td>0.4</td>
</tr>
<tr>
<td>6.</td>
<td>Coefficient of Uniformity $C_u$</td>
<td>1.75</td>
</tr>
<tr>
<td>7.</td>
<td>Coefficient of Curvature $C_c$</td>
<td>0.89</td>
</tr>
<tr>
<td>8.</td>
<td>IS Classification – Poorly Graded Sand (SP)</td>
<td></td>
</tr>
</tbody>
</table>

### 2.2 Properties of Cement

The cement used in the study is of 53 grade ordinary Portland cement. Table 2 presents the properties of cement. The specific gravity of the cement is 3.15. It has initial setting time of 30 minutes and final setting time of 600 minutes.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Properties</th>
<th>Characteristic value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Initial setting time</td>
<td>30 min</td>
</tr>
<tr>
<td>2.</td>
<td>Final setting time</td>
<td>600 min</td>
</tr>
<tr>
<td>3.</td>
<td>Specific Gravity</td>
<td>3.15</td>
</tr>
</tbody>
</table>

### 2.3 Properties of Sulphonated Naphthalene Formaldehyde

The super plasticizer used in the present study is Sulphonated Naphthalene Formaldehyde. The properties of Sulphonated Naphthalene Formaldehyde (SNF) are presented in Table 3. It has a specific gravity of 1.2. It exists in liquid state and looks brown in color.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Properties</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Specific Gravity</td>
<td>1.2</td>
</tr>
<tr>
<td>2.</td>
<td>Color</td>
<td>Brown</td>
</tr>
<tr>
<td>3.</td>
<td>Chloride contents</td>
<td>Nil</td>
</tr>
<tr>
<td>4.</td>
<td>Nature</td>
<td>Liquid</td>
</tr>
</tbody>
</table>

### 4. RESULTS AND DISCUSSIONS

#### 4.1 Effect of Cement Content on Shear Strength Parameters

##### 4.1.1 Effect of Cement Content on Angle of Internal Friction

Figure 2 plots the variation of angle of internal friction with increase in cement content and water content obtained from direct shear test results conducted immediately after preparation of samples.

It is observed that as the cement content increases angle of internal friction decreases and it is also observed that as the water content increases angle of internal friction decreases. It is also observed that the rate of reduction in angle of internal friction with cement content is higher up to the cement content of 8%. Further addition of cement has decreased the angle of internal friction value at a lower rate as evidenced from Figure 2. It is well known that the strength of sand is mainly contributed by the parameter angle of internal friction. The observed reduction in angle of internal friction with increase in cement content and water content is due to the fact that the cement paste has coated the sand particles and made its angular surface to smoothen surface, hence lead to
the reduction in angle of internal friction upon immediate testing. Perhaps if this sample would have been cured for some period then it would have given higher angle of internal friction because of cementation bonds developed between the particles.

4.1.2 Effect of Cement Content on Cohesion
The variation of cohesion as obtained from direct shear test with increase in cement content and water content is plotted in Figure 3.

From Figure 3 it is observed that as the cement content increases cohesion increases and water content increases cohesion decreases. It is intensity to note that up to 6% cement content the rate of increase in cohesion is gradual and beyond that there is a sudden increase in cohesion. When the cement content is added to the sand and mixed thoroughly with water this cement paste coats the sand particles. Further upto 6% cement content, the cement would not have coated the sand particles completely and the 8% cement addition may be coating the sand particles thoroughly. The coated cement exhibits some cohesion between the sand grains and that is reflected on the above observation of increasing cohesion intercept with increase in cement content.

4.2 Unconfined Compressive Strength of Grouted Sand Column

4.2.1 Effect of Water-Cement Ratio on Compressive Strength
Figure 4 plots the variation of compressive strength of specimens grouted with cement of various water cement ratios and cured for 7, 14 and 28 days.

From Figure 4 it is observed that as the water-cement ratio increases compressive strength decreases. It is also observed that the unconfined compressive strength increases with curing periods. The unconfined compressive strength decreased linearly with increase in water cement ratio for 7 days curing. However for 14 and 28 days of curing, increasing the water cement ratio from 1.5 to 2 decreased the UCC strength drastically and further increase in water cement ratio to 2.5 affected the UCC Strength marginally.

4.2.2 Effect of SNF on UCC Strength of Cement Grouted Sand Sample
Figures 6 to 8 plots the variation of compressive strength with water-cement ratio of specimens grouted with cement alone and cement +2% (SNF) cured for 7, 14 and 28 days.
Experimental Study on the Compressive Strength of Grouted Sand Column

5. SUMMARY AND CONCLUSIONS

Based on the experiments conducted on sand stabilized with cement and cement + Sulphonated Naphthalene Formaldehyde (SNF) the following conclusions are arrived at

1. The angle of internal friction decreases as the cement content increases and it is also observed that as the water content increases angle of internal friction also gets reduced upon immediate testing.

2. The cohesion intercept increases as the cement content increases, but when the water content is increased then there is a reduction of cohesion intercept.

3. In case of grouted sand column, as the water cement ratio increases it is observed that compressive strength decreases for both cement grouting and cement with 2% Sulphonated Naphthalene Formaldehyde (SNF) grouting. But as on addition of 2% Sulphonated Naphthalene Formaldehyde (SNF) results in increase of strength for all water cement ratios compared to the specimens grouted with cement alone.

4. The efficiency of Sulphonated Naphthalene Formaldehyde is more pronounced at lower water cement ratio in case of grouted specimens. From this it can be concluded that Sulphonated Naphthalene Formaldehyde (SNF) is very effective in increasing the workability at lower water contents, which in turn will improve the compressive strength.

REFERENCES


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