ABSTRACT: In the present work design of an economical, non toxic, cement based grouts using different activators, superplastisizer and slag, OPC has been carried out. The grout mix was developed using 75% Ground Granulated Blast Furnace Slag + 25% Ordinary Portland Cement and different concentration of activators and various water cement ratio 0.8, 2 and 5. Various physical properties and strength properties were determined using the tests like specific gravity, pH test, Gel time, Marsh cone viscosity. The unconfined compressive strength has been increased for raw grout samples as well as grouted sand samples as time of curing increases for various grout mix. Permeability of grouted sand samples also carried out by Adherent washout test. From this study is shown that NaF activated grout mix is the best grout with respect to the unconfined compressive strength and viscosity compared to the other activated grout mix.

1. INTRODUCTION
Grouting is one of the excellent ground improvement techniques which are applied to relatively weak and permeable foundation. The development in the field of grouting technology has brought Microfine cement as an innovative grout material which is an inorganic grouting material composed of ultrafine ground calcareous particles that allow penetrating into fine sands that ordinary Portland cement cannot penetrate and as a grout it has excellent permeability, strength and durability. It also eliminates presence of toxic hazards which observed in chemical grout. It is also used for stabilizing of all types of soil and foundations especially permanent structures such as tunnels and dams.

Microfine cement as novel grout material which can penetrate into fine sand and has found increasing acceptance over chemical injection agents which are inferior in strength, more expensive and cause pollution in ground water. Microfine cement is blast furnace slag based cements composed of ultra fine particles and is designed for injection into loose soils, rock and concrete. Microfine cement grout has excellent penetrability, strength and durability. The use of such blended cements has resulted in significant fuel economy and increase in cement production.

2. CHEMICAL COMPOSITION OF SLAG
Slag normally is not hydraulic at room temperature. In slag, the glass content controls the rate of hydration and varies from one slag to another. It requires activation to initiate hydration process and the activators are commonly used are ordinary Portland cement and other alkaline activators such as sodium carbonate and sodium silicate. Alkali activated slag cement has excellent properties over ordinary Portland cement such as rapid strength, durability high resistance to chemical attack, denser microstructure, low production cost.

The GBFS constituent shall conform to the following composition:
\[
\frac{\text{CaO} + \text{MgO} + \frac{4}{3} \text{Al}_2\text{O}_3}{\text{SiO}_2 + \frac{2}{3} \text{Al}_2\text{O}_3} \geq 1.0
\]

<table>
<thead>
<tr>
<th>Composition</th>
<th>Usual range</th>
<th>Typical range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon Dioxide (SiO₂)</td>
<td>30–45</td>
<td>36</td>
</tr>
<tr>
<td>Aluminum Oxide (Al₂O₃)</td>
<td>8–20</td>
<td>16.0</td>
</tr>
<tr>
<td>Calcium Oxide (CaO)</td>
<td>35–50</td>
<td>43.3</td>
</tr>
<tr>
<td>Magnesium Oxide (MgO)</td>
<td>0–20</td>
<td>7</td>
</tr>
<tr>
<td>Ferrous Oxide (FeO)</td>
<td>0–1.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Sulfide sulfur (S)</td>
<td>0–2</td>
<td>1.5</td>
</tr>
<tr>
<td>Manganese Oxide (Mn₃O₅)</td>
<td>0–2.5</td>
<td>&lt; 0.1</td>
</tr>
</tbody>
</table>

As the glass phase content constitutes one of the essential features of slag, various methods have been proposed for measuring the degree of crystallinity. Owing to stress...
Chemically Activated Microfine Slag Cement Grouts

birefringence, it is difficult to distinguish between the crystalline phase and the stressed glassy phase. From SEM, it is found that potassium and sulphur are localized mainly in the glass and that distribution of the elements is revealed. Figure 1 gives the field covered by basic blast furnace slag with 10% MgO weight content, in the quaternary system CaO-SiO2-Al2O3-MgO. With reference to crystalline phases, it has recently been shown that the richer the slag is in akermanite, the less readily it hydrates.

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Because of these cementitious properties, GGBFS can be used as a supplementary cementitious material either by premixing the slag with Portland cement or hydrated lime to produce a blended cement (during the cement production process) or by adding the slag to Portland cement concrete as a mineral admixture.

3. EXPERIMENTAL STUDY

In the present study of the Rheology of Microfine slag cement grout, by employing the INDORMA Slag having fineness 5000 cm²/gm mixed with ordinary Portland cement and churned in the mechanically operated ball mill to achieve fineness in the range of 8800 to 8850 cm²/gm is carried out. This mix consists of 75% slag and 25% cement by weight. Activators commonly used for the activation of slag in presence of water are Portland cement, NaOH, sodium silicate, sodium sulphate, calcium sulphate and KOH.

Table 2: Chemical Composition of GGBFS

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass content</td>
<td>97</td>
</tr>
<tr>
<td>Lime (CaO)</td>
<td>36.81</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>33.65</td>
</tr>
<tr>
<td>Alumina (Al₂O₃)</td>
<td>15.23</td>
</tr>
<tr>
<td>Iron Oxide (Fe₂O₃)</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Prior research work carried out using INDORAMA slag and 2% SMFR (by weight of slag) as dispersing agent and activators i.e. sodium carbonate (Na₂CO₃), potassium carbonate (K₂CO₃), sodium fluoride (NaF), potassium fluoride (KF), sodium sulphide (Na₂S) with its optimum dose of selected chemicals is 0.1% by weight of slag, however this could be due to the work been performed for range above this. Therefore to confirm and find the actual optimum dosage and effect of OPC in the grout mix, the present study has been carried out below the 0.1% i.e. 0.02%, 0.06% and 0.1% (by weight of slag) concentration.

Effect of concentration on gel time, time-viscosity and UCS using different concentration of reactants in MC grouts i.e. 0.02%, 0.06% and 0.1% by weight of slag for all reactants with w/c = 2 was done for deciding the optimum dose of the activators. Physical properties, Flow properties and Strength properties at all concentrations i.e. 0.02%, 0.06% and 0.1% of reactants using w/c = 2 were studied. To study Physical properties, Flow properties and Strength properties using optimum concentration of reactant with w/c = 0.8 and 5 in MC grouts.

4. RESULTS

Followings are the results of the various experiments are done on different grout mixes. From that experiment we obtained physical, viscosity and strength properties which are in form of graphs.
Figure 1 shows Physical properties (specific gravity, gel time, bleeding). Figure 2 shows Flow properties (yield value and viscosity) and Figures 3, 4, 5, 6 show Strength properties (UCS for raw and sand grouted samples, flexural strength, washout strength).
Chemically Activated Microfine Slag Cement Grouts

Fig. 2: Flow Properties (Viscosity and Yield Value)

Fig. 3: Strength Properties for Raw Grout Samples

Fig. 4: Strength Properties for Grouted Sand Samples

Fig. 5: Flexural Strength

Fig. 6 contd.
5. CONCLUSIONS

As w/c ratio increases 0.8 to 2 and 2 to 5, specific gravity decreases for all grout mixes and gel time increases and bleeding potential also increases. In this Na2S activated grout mix take less time compared the other mix. The yield value increases with increase in time for any w/c ratio.

Sodium fluoride (NaF) gives the lowest initial viscosity at time t = 1 min in comparison to other activators at all w/c ratios (i.e. 0.8, 2 and 5). So considering viscosity, NaF proves to be the best grout. Potassium fluoride (KF) also gives low viscosity but it is little higher than NaF. Sodium sulphide (Na2S) gives the highest initial viscosity. Grout mix with 0.1% KF gives maximum strength for 3- days UCS at w/c = 2 for raw grout samples and least value of strength given by 0.06% Na2S at 90 days among all the activators. Also NaF gives nearer value to KF. Grout mix with 0.06% Na2S gives maximum at 3 days UCS whereas 0.1% NaF and 0.1% KF gives maximum strength at 90 days compared to other activators for grouted sand samples. So, with respect to strength, NaF and KF can be considered as the best reactant.

Beam test is performed for w/c = 2 at optimum dose of activators for 90 days curing. The flexural strength is highest for slag cement grout with NaF and lowest with Na2S. Adherent washout strength is found maximum for Sodium silicate for permeability and turbidity. From all the results obtained, it is proved that NaF and KF with 0.1% concentration are appropriate reactants and NaF and KF activated grout mix are the best with respect to gel time, viscosity and strength. Unconfined compressive strength obtained with this activator is highest compared to that with other activators. Initial viscosity is lowest for this grout mix. So, this grout can be considered as the best grout. Na2S gives minimum strength and highest initial viscosity, so in comparison with other mix, it is considered as poor grout.

REFERENCES


