Development of Colloidal Silica Grout Using Different Reactants

Dave, K.K.  
e-mail: grish4u@gmail.com  
Patel, G.N.  

Joshi, N.H.  
Patel, G.N. Santwani, P.K.  
Assistant Research Officer 
Dept. of Applied Mechanics, Faculty of Technology & Engineering,  
The Maharaja Sayajirao University of Baroda, Vadodara  
1GERI, Race Course, Vadodara

ABSTRACT

The Colloidal Silica (CS), which is a silicon-based chemical grout, possess no health hazard, it is chemically and biologically inert, has excellent durability characteristics. It is commonly used in permeation grouting. In this paper investigation is to develop colloidal silica based grouts examining the Physical, Rheological and Strength parameters with different kinds of neutral inorganic salts and best suitable design grout to be achieved through experimental analysis. A series of Gel time, pH Value, Viscosity and UCS (unconfined compressive strength) test were conducted in laboratory using different reactants like CaCl\(_2\), MgCl\(_2\), KCl, CaO and cement with variation in percentage. The test result shows that UCS strength increases, Gel time decreases pH increases, viscosity increases with increase in percentage of concentration of reactants. The entire above tests were performed with different reactants and from that, we finally concluded that CaO gave better strength compare to other reactants.

1. INTRODUCTION

The Colloidal Silica (CS), which is a silicon-based chemical grout. It poses no health hazard, is unaffected by filtration is chemical and biologically inert, has excellent durability characteristics. Colloidal Silica treatment increase strength reduces hydraulic conductivity and enhances liquefaction resistances of a soil. The colloidal silica has been used for soil treatment in tunnels and dam construction and site stabilization. Colloidal silica is an innovative grout. This is made by extracting alkali from sodium silicate using ion-exchange resin, in the factory. This colloidal silica has an electrical double layer around its surface. After breaking the layers with inorganic salt the colloidal are bonded with siloxane bonds and thus develop a gel network. The size of colloidal silica is about 10 to 100 nm in diameter. The network of this colloidal silica grout is formed by condensation and polymerization of silanol radicals on the surface of the colloidal. Consequently, the structure of colloidal silica grout is considered to be a pile of spherical connected to each other.

The present investigation has been carried out to study gel time, syneresis, pH, time-viscosity and Unconfined Compressive Strength using different concentration of reactants i.e. 0.1%, 0.5%, 1.0%, and 2.5% of total grout for all reactants (Calcium Chloride, Magnesium Chloride, Potassium Chloride, Calcium Oxide, and ordinary Portland cement) with w/cs = 1 for deciding the optimum dose of the reactants. Using optimum dose of reactants, detailed study is carried out on physical properties, flow properties and strength properties with w/cs = 1. To develop better colloidal silica grout an effort has been made using above reactants intermixed applied with w/cs = 2. Their effects are examined on gel time, UCS and pH value.

2. MATERIAL OF INVESTIGATION

The basic grouts materials used in present investigation were Colloidal silica, water, sand and reactants such as CaCl\(_2\), MgCl\(_2\), KCl, CaO and cement. Properties of colloidal silica shown in table.

<table>
<thead>
<tr>
<th>Test Grade</th>
<th>CILICOL 30 AK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration of SiO(_2)</td>
<td>30-31 Wt %</td>
</tr>
<tr>
<td>Concentration of Na(_2)O</td>
<td>0.3-0.5 Wt %</td>
</tr>
<tr>
<td>pH</td>
<td>9.5-10.5</td>
</tr>
<tr>
<td>Particle Size</td>
<td>10-20 nm</td>
</tr>
<tr>
<td>Viscosity (cps) at 25E</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Sp Gravity at 20</td>
<td>1.20-1.22</td>
</tr>
<tr>
<td>Appearance</td>
<td>Clear to Opalescent</td>
</tr>
<tr>
<td>Stability</td>
<td>Semi Permanent</td>
</tr>
<tr>
<td>Manufacturing Company</td>
<td>STERLING CHEMICALS</td>
</tr>
</tbody>
</table>
In the experiment work, Bahadarpur sand was used. The sand passing through 425µ and retained on 75 µ was used for grouted sand sample. The reactants were used experiment studied available commercially.

3. EXPERIMENT STUDIES

The experiment studies were planned to examine as below (1) Gel time measure by beaker pouring method (2) pH measure by pH meter (3) Viscosity measure by Brookfield viscometer (4) Needle Penetration resistance test (5) Vane shear test (6) Unconfined compressive strength measure by uniaxial testing machine (7) Indirect Tensile strength by Brazilian test (8) Adherent wash out test.

4. RESULT & ANALYSIS

Physical Characteristics

**Gel Time**

Figure 1 shows effect of different concentration of reactants on gel time. It can be seen that for all reactants gel time decreases with percentage concentration of reactants increases.

**pH Value**

Figure 2 shows the effect of different concentrations of reactants on pH value of raw colloidal silica gel. The pH Value increases from 8.50 to 11.50 as percentage of concentration reactants increase with w/cs = 1.0.

Rheological Characteristics

**Flow Curves at Different Time Intervals**

Figure 3. shows the plotting of shear rate V/s shear stress it is observed that, as time increases, the curve deflects more towards the shear stress axis at different time intervals.

**Time - Viscosity Characteristics**

Fig.4. shows time viscosity curves for different reactants with colloidal silica grout at w/cs = 1.0 in which CaO shows the maximum viscosity and minimum viscosity observed in KCl.

**Yield Value (τ₀-) of Colloidal Silica Grouts**

Figure 5. shows the variation of yield stress with time for colloidal silica grouts.
**Development of Colloidal Silica Grout Using Different Reactants**

**Time Strength Characteristics**

*Needle Penetration Resistance of Colloidal Silica Raw Grout*

Fig. 6 shows Needle penetration resistance of Colloidal Silica Raw Grout at 2.5% concentration of different reactants at water to colloidal ratio 1.0, in which CaO exhibits maximum NPR Value while KCl having minimum NPR Value.

![Fig. 6: NPR of Raw Colloidal Silica Grout with Concentration - 2.5%, (W/CS = 1.0)](image)

**Vane Shear Test**

Fig.7 shows that as the Vane shear resistance immediately increases after Gellation with progress of time and values increase with increase in concentration.

![Fig. 7: Vane Shear Resistance v/s Time of Raw Colloidal Silica Grout with Optimum Dose of Reactants (2.5%) (w/cs=1)](image)

**Time UCS Characteristics Grouted sand of colloidal silica Grouts**

Fig. 8 shows stress-strain curves for grouted sand dry cured at w/cs=1 for optimum does of reactants. Fig. 9 shows UCS v/s curing time. It is observed that the peak stress is higher for CaO and lower at KCl. The stress-strain curves shows elasto-plastic behavior. The UCS strength increases curing time increases.

![Fig. 8: 90 Days Stress-Strain Curve of Various Reagents for Grouted Sand Wet Condition (W/CS= 1)](image)

![Fig. 9: UCS V/s Time of Curing for Grouted Sand Wet Condition (W: CS = 1.0) ](image)

**Indirect Tensile Strength Characteristics of colloidal silica Grouts**

Fig. 10 shows the variation of tensile strength v/s time of curing (3, 30 and 90 days) for w/cs=1 with concentration of reactant. It is observed that tensile strength increases with time. Comparison of indirect tensile strength with UCS for colloidal silica grouts, we can see that indirect tensile strength is about 5% to 10% of UCS.

![Fig. 10: Indirect Tensile Strength Versus Time of Curing, For Grouted Sand (w/cs=1) ](image)

**5. CONCLUSION**

**Physical Properties**

1. Gel time decreases with percentage concentration of reactant increases in w/cs=1. The gel time decreases from about 120 min to 3 min for different concentration of reactants.
2. The pH Value increases from 8.50 to 11.50 with concentration of reactant increases from 0.1% to 2.5% for all reactants at w/cs = 1.0. The pH is maximum for CaO.

Times- Viscosity Characteristics Including Flow Properties

1. Colloidal silica grouts are pseudo-plastic in nature with deflection of flow curves increasing towards shear stress axis with progress of time. For Colloidal silica grouts the yield stress increases with time, yield value is about zero initially.
2. Calcium oxide gives the highest initial viscosity at time t= 1 min in comparison to other reactants at w/cs =1 and Potassium chloride gives lowest initial viscosity for same w/cs ratio.

Time- Strength Characteristics

1. NPR value for all Colloidal Silica Raw Grouts after 1 hour Gellification is beyond 70 kPa with w/cs=1.
2. The Vane shear resistance of colloidal silica grout increase with time after Gellification
3. The unconfined compressive strength of raw grout and grouted sand dry and wet cured condition increases with increase in curing time from 3 to 90 days. Grouts mix with 2.5% CaO reactant gives max 90-day UCS whereas, 0.1% CaCl₂ gives least strength amongst all reactants. So with respect to strength CaO can be considered as the best reactant.
4. The indirect tensile strength is about 5% to 10% of UCS.
5. The Various combination of reactants tried for strength of colloidal silica grout using w/cs =2, does not give higher strength as compare to 2.5% CaO.
6. Permeability of grouted sand increases as the pressure increases. Turbidity of wash out water increases with increase in hydraulic gradient. Adherent washout strength 343 kPa for 2.5% CaO with w/cs= 1.

REFERENCES