A COMPREHENSIVE STUDY ON COLLOIDAL SILICA BASE GROUT USING DIFFERENT REAGENT

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Abstract. To improve stability and mechanical Properties of soil, there are several methods being used by engineers since time immemorial. In this study, colloidal silica based grout has selected for the experiment to improve soil properties. The Colloidal Silica (CS), which is a silicon-based chemical grout, possesses no health hazard, it is chemically and biologically inert, has excellent durability characteristics. Colloidal silica based grouting being used widely across the globe for its intended purpose. In this paper experiments carried out to develop colloidal silica based grouts, to determine the Physical, Rheological and Strength parameters with different neutral inorganic salts (reagents) and analyze the best suitable design grout that can impart good strength to the grouting system. Various tests conducted to measure the Gel time, pH Value, Viscosity and UCS (unconfined compressive strength) in laboratory using different reagents like $Cacl_2$, $Mgcl_2$, KCl, CaO and cement. On increment of doses of reagents, found that UCS, pH and Viscosity increase whereas the Gel time decreases. After performing above tests with different reagents, we finally concluded that calcium oxide gave better strength compare to other reagents at optimal doses.

Keywords: Soil, Colloidal silica, unconfined strength, Gel time.

1 Introduction

1.1 Colloidal Silica

Ground improvement problem, a civil engineer will probably examine use of grouting as one of the possible solution. Pressure grouting or injection may be defined as the process of injecting suitable cementitious slurries, suspensions or similar material in to inaccessible places, such as underlying formation of foundations of structures for the purpose of sealing seams, cracks and fissures of filling voids. Though the principal use of the process is to fill openings in a mass and to render it impervious to percolating water, it is also used to improve strength and elastic properties of the material in which it is injected. The success of the grouting will depend on the selection and type of grouting materials and suitable grouting techniques.

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, pH, time-viscosity and Unconfined Compressive Strength using different concentration of reagent i.e. 0.1%,0.5%,1.0%,and 2.5% of total grout for all reagent(Calcium Chloride, Magnesium Chloride, Potassium Chloride, Calcium Oxide, and ordinary Portland cement) with w/cs =1 for deciding the Maximum dose of the reagent. Using Maximum dose of reagent, detailed study is carried out on physical properties, flow properties and strength properties with w/cs=1. Further study on Physical properties, Flow properties and Strength properties is carried out using 2.5% CaO with w/ cs =0.5, 1.and 2.To develop better colloidal silica grout an effort has been made using above reagent.

2 Material Used for Investigation

The basic grout materials used in this investigation were Colloidal Silica, water, sand and reagents such as $Cacl_2$,$Mgcl_2$, KCl, CaO and cement. Properties of colloidal silica has been shown in table.

Table 1 Properties of Colloidal Silica

Test Grade	*CILICOL 30 AK*
Concentration of SiO_2	30-31 Wt %
Concentration of Na_2O	0.3-0.5 Wt %
pH	9.5-10.5
Particle Size	10-20 nm

Viscosity (cps)at 25E	<5
Sp Gravity at 20	1.20-1.22
Appearance	Clear to Opalescent
Stability	Semi Permanent
Manufacturing Company	STERLING CHEMICALS

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

4 Result and Analysis

Physical Characteristics

Gel Time

Fig.1 shows effect of different concentration of reagent on gel time. It can be seen that for all reagents gel time decreases with percentage concentration of reagent increases. Table 1.shows value of gel time for different concentration of reagents.

Table2. Gel time for different % concentration of reagent (w/cs= 1)

% concentration of reagent	Gel time (min) (w/c= 1)			
	0.1%	0.5%	1	2.5
$CaCl_2$	20	7	6	3
CaO	-	60	5	3
KCl	-	-	120	35
$MgCl_2$	25	7	5	4
Cement	-	-	-	3

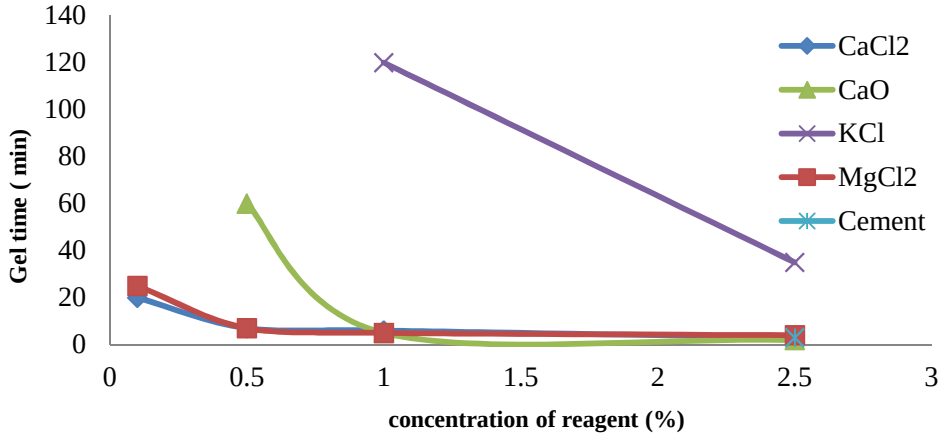

Fig. 1. Effects of Different Concentrations of Various Reagent on Gel Time for Raw Colloidal Silica Grout (w/cs = 1)

pH Value

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

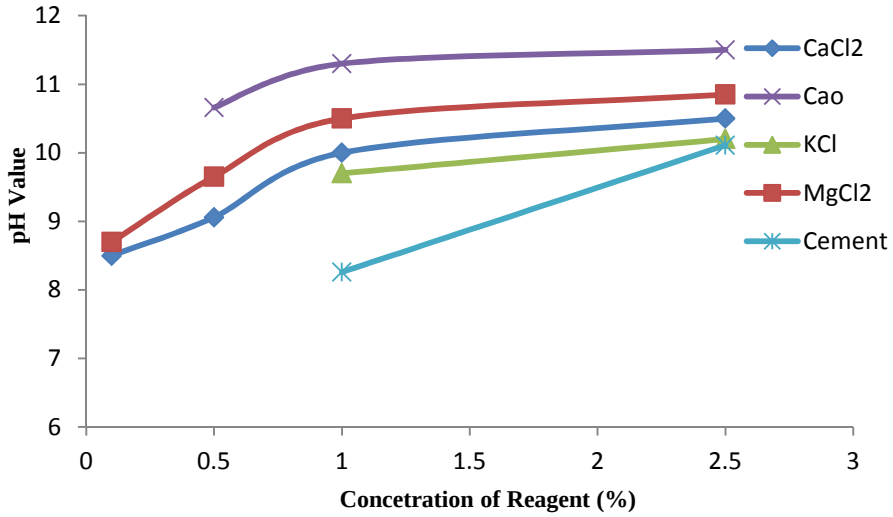

Fig.2. Effect of concentration of Various Reagent on pH (w/cs = 1)

Rheological Characteristics

Flow Curves at Different Time Intervals

Fig. 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.

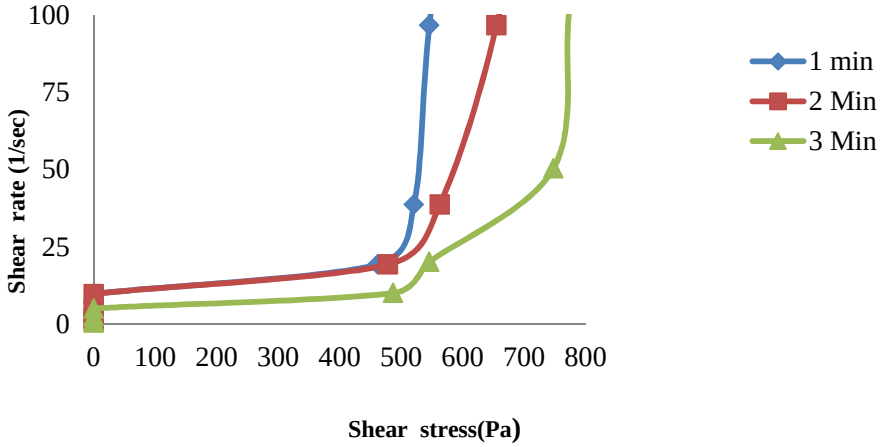

Fig.3. Flow curves for CaO = 2.5%, w/cs = 1

Time -Viscosity Characteristics

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

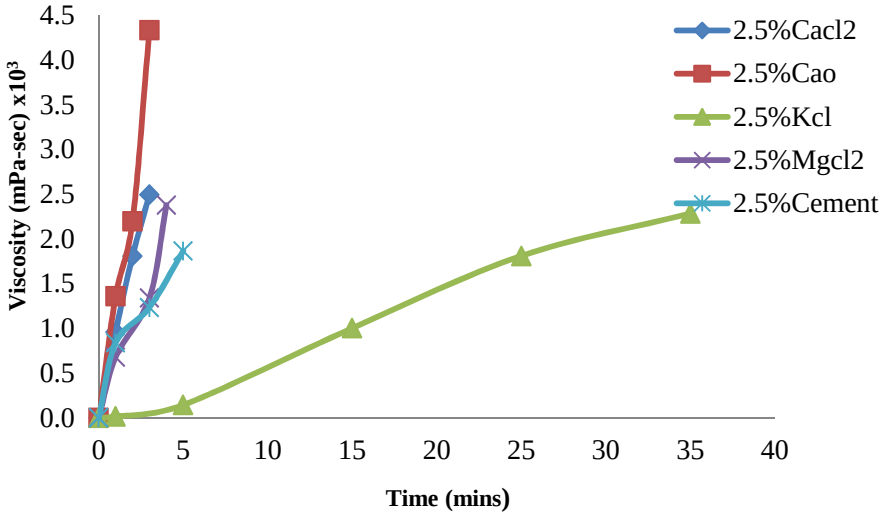

Fig. 4. Time- viscosity characteristics for colloidal silica grouts (w/cs= 1)

Yield Value (τo) of Colloidal silica Grouts

Fig. 5. Shows the variation of yield stress with time for colloidal silica grouts. For the chemical grout yield stress is zero initially.

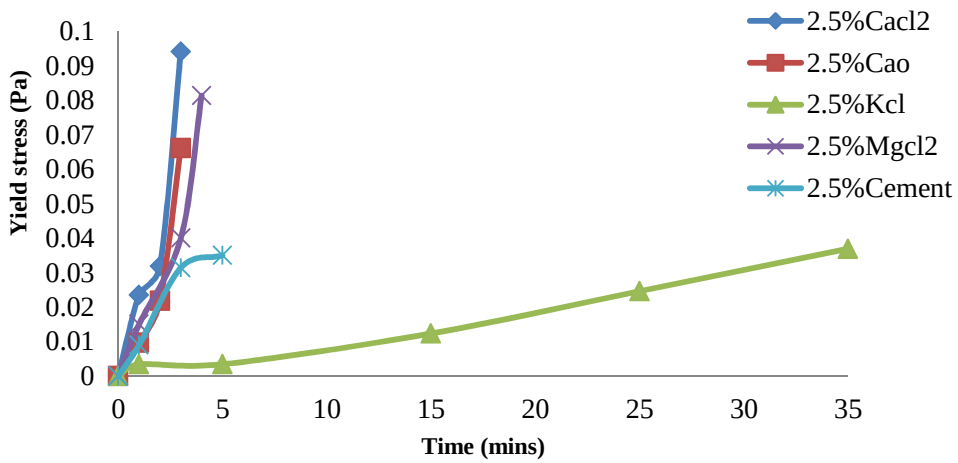

Fig. 5. Yield stress v/s time for colloidal silica grouts (w/cs= 1)

Time Strength Characteristics

Needle Penetration Resistance of Colloidal Silica Row Grout

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

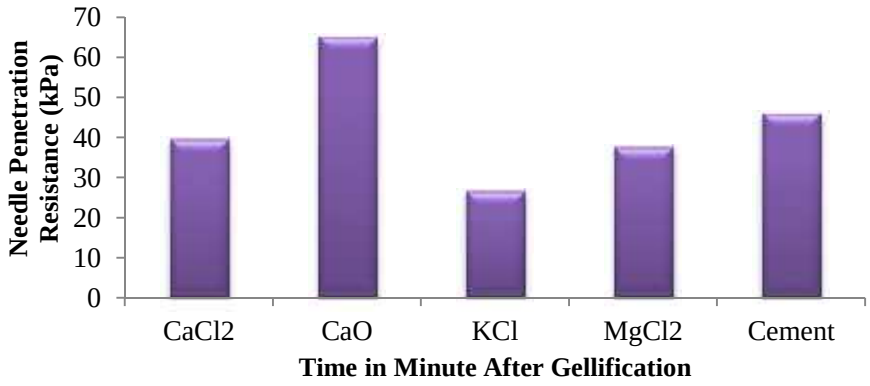

Fig. 6. NPR of Raw Colloidal Silica Grout with Concentration - 2.5 %, (W/CS = 1.0)

Vane Shear Test

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

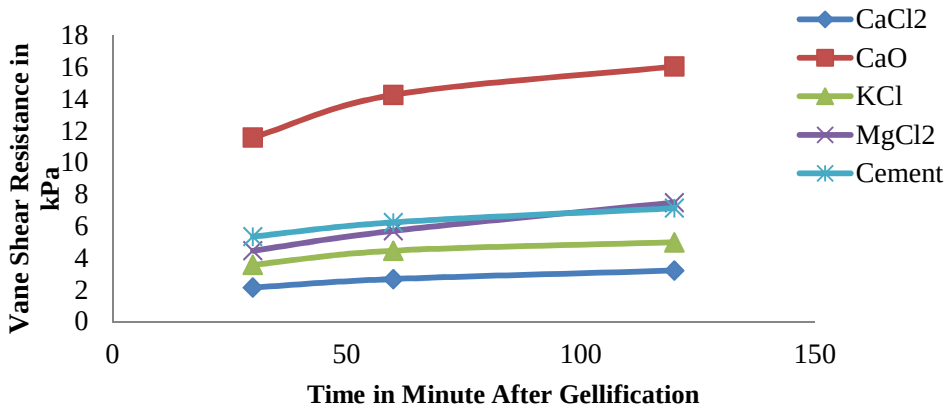

Fig. 7.Vane Shear Resistance versus time of Raw Colloidal Silica Grout with Optimum Dose of Reagent (2.5%) (w/cs = 1.0)

Time UCS Characteristics of Raw Gel for colloidal silica Grouts

Fig.8. Shows stress- strain curves for raw grout dry cured at w/cs= 1 for Maximum does of reagent. Fig.9. Shows UCS v/s curing time. From the figures, 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.

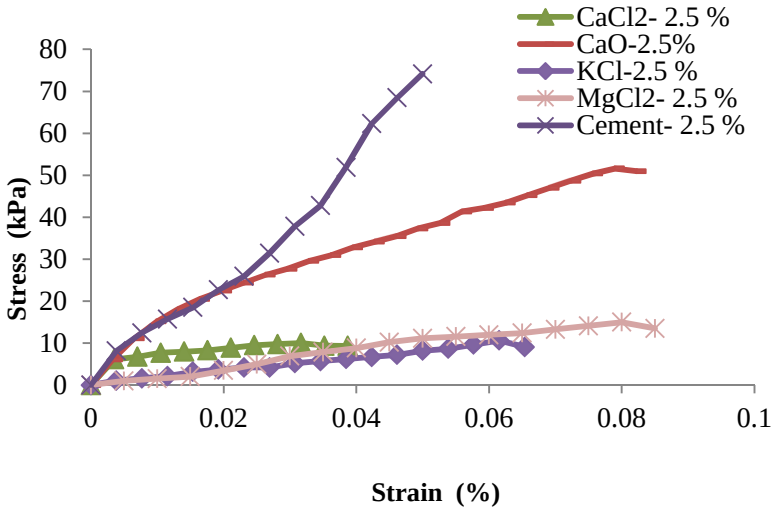

Fig. 8. 90- Days Stress- Strain Curve of Various Reagents for Raw Grout in Dry Cured (W/CS = 1)

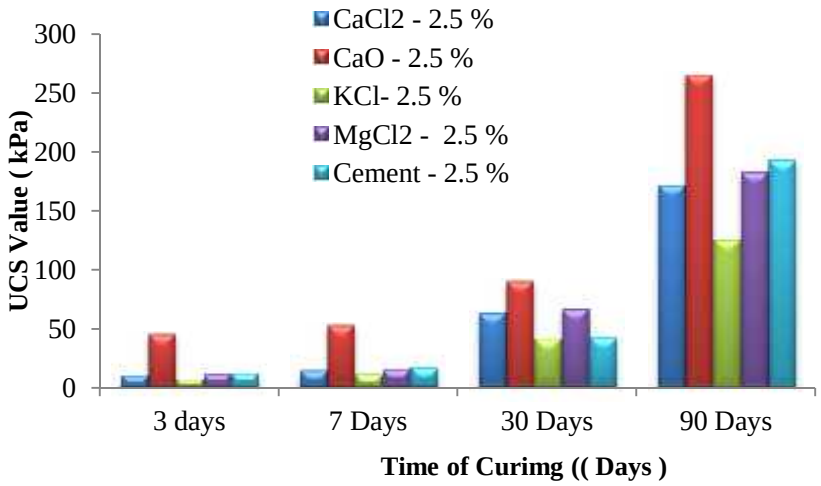

Fig. 9. UCS V/s Time of Curing, for Raw Grout Dry Cured (w/ cs = 1.0)

5 CONCLUSION

Physical Properties

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

Time- 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= 1min in comparison to other reagents 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. 2.5 % CaO, the needle penetration value decreases with increase in water to colloidal silica ratio.
2. The Vane shear resistance of colloidal silica grout increase with time after Gellification and decrease in water to colloidal ratio.
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 and decreases in w/cs for different concentration of reagent.

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