Effect of Sodium Silicate on the Rheological Properties of Microfine Cement Raw Grout

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Abstract— Grouting technology is versatile accepted soil improvement technique mostly used in India either for restoration problems to increase special soil parameters and to stop leakage in earthen and rock fill dams. The use of Microfine cement grout along with sodium silicate can easily deal with the problems associated with ground improvement, toxicity & costliness of chemical grouts. The aim of the present research is to develop proper grout mix design using various water cement ratios and various percentage of sodium silicate along with Microfine cement (fineness = 6000 cm2/gm). This paper focuses the effect of sodium silicate on rheological properties of MFC grout.

Key words: Microfine cement grouting (MFC); rheological properties of grout; raw grout design

I. Introduction

Grouting can control ground water seepage through and below the structure and can increase the stability of soils/ rocks against any structural load during and after construction while, compaction grouting can densify surrounding weak mass and/or uplifting the settled structure. Grouting technology is versatile accepted soil improvement technique mostly used in India either for restoration problems to increase special soil parameters and to stop leakage in earthen and rock fill dams. Grouting becomes very much essential for stabilizing loosely packed sandy soils with either zero percent silt or clay fines or fines less than 10 % subjected to dynamic forces. The aim of present research study is to propose a proper grout mix design using microfine cement (fineness 6000cm^2/gm, according to ALCCOFINE Ltd., Bombay) to stabilized loosely packed sandy soil using sodium silicate as an additive. The addition of sodium silicate as an additive in the cement based grout can improve the mechanical properties of the raw grout. Therefore, it is important to study the effects of such grout materials on the physical and mechanical properties of grout to provide a cost effective design. The various parameters viz. fluidity, bleeding potential, gellification, unconfined compression is determined.

II. Objective

The main objective of this paper is to find out the optimum ratio of grout mix by measuring the unconfined compressive strength of various grout mixes.

III. Materials

The materials used in this research work are Microfine cement (ALLOFINE-1101-MF) and Sodium silicate.

IV. Importance of Microfine cement as grouting material

Before we proceed to the properties of Microfine cement, it is important to know why Microfine cement is chosen. The concept of Microfine cement grouting was first developed in Japan. In India this concept is new and still under development and research. Suspension grouts, prepared conventionally with ordinary Portland cement, can be successfully injected into gravels and coarse sands. Chemical grouts can permeate fine sands and coarse silts, but they are expensive and pose environmental and health problems. As an alternative to chemical grouting of fine and medium grained sands, the use of grouts prepared with microfine cements has been proposed. Its penetration capability is comparable to any chemical grouts with high strength and durability. Microfine cement is advantageous over Ordinary Portland cement as it can provide a larger specific surface area.**[**4**]** Due to this larger specific surface area, the grout with Microfine cement may provide better grout properties than the grouts with Ordinary Portland Cement. Due to its high fineness, the cement has extremely good retention when used for purpose of grouting in both-the micro-cracks in concrete or rocks or voids in soil. It provides better penetration in tight joints, fissures & pore spaces. Due to better penetration there is good water tightness. The greater fineness allows penetrating in to fine sands and finely cracked rocks. The MFC provides faster setting than normal cements. It also provides sound durability. After curing by hydration, the MFC grout achieves good impermeability. So, MFC can be effectively used in ground water control problems and tunnel construction works so that the time duration between two activities can be reduced. Pulverization of the ordinary cements to produce microfine cements has a detrimental effect on apparent viscosity Which increased by an average of 500%, It improves bleeding. It has a positive effect on setting times, rate of early strength Development and 28-day unconfined compression strength, extends the range of groutable sands to ‘‘medium-to-fine” and yields very satisfactory unconfined compression strength of grouted sands.

A. *Properties of Microfine Cement:*

The type of MFC used in this project is ALCCOFINE-1101 MF supplied by Alccofine Ltd., Bombay. The properties of MFC are given below.

Fineness(cm^2/gm)	6000
Specific gravity	3.1
Bulk density (kg/m^3)	700-800
PSD (D50)	<9
PSD (D95)	<22

Table 1: Physical properties of Microfine cement

PSD= Particle size distribution (μm)

Initial setting time (min)	Final setting time (max)
1 hour	10 hours

Table 2: Setting time of Microfine cement

At 1:1 water / ALCCOFINE 1101-MF ratio (by weight) at standard temperature 27±2 degree Celsius

Constituent	%
IR(max)	4.0
MgO(max)	6.0
SO3(max)	3.0
LOI(max)	5.0
Cl-(max)	0.05

Table 3: Chemical properties of Microfine cement

1) *Marsh Cone Flow:*

At 1:1 water / ALCCOFINE 1101-MF ratio (by weight) at standard temperature 27 ± 2 degree Celsius with 2% Power flow 2230 admixture.

Marsh Cone Flow
27-38 sec

Table 4: Marsh cone flow

Constituent	%
SiO2	28.49
Na2O	8.5
SiO2:Na2O	3.35
Specific gravity	1.4

Table 5: Properties of sodium silicate

Water used for grouting shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugars, organic materials or other substances that may be deleterious.

V. EXPERIMENTAL PROCEDURE

There are three methods for raw grout design: Frame work approach, conceptual frame work approach and equivalent weight approach. For cement based grouts frame work approach is used; for chemical based grouts other two approaches are used. (Dr. A. V. Shroff and Prof. D.L.Shah, MSU, 1987). The raw grout solutions were prepared with various water to cement ratios (1%,1.5%,2%,2.5%) along with various percentages of sodium silicate (0.5%,1%,1.5%,2%,2.5%). For each proportion of water to cement ratio and sodium silicate, the grout properties like fluidity, gel time, bleeding potential, etc. are measured. Then these grout mixes are subjected to an unconfined compression strength test. An ideal grout system should be uniform stable mix that has a viscosity sufficient low to be easily pumped into the soil or rock, replacing ground water and occupying the full space of voids or cracks and which can solidify in sufficient time and producing desirable set strength.

A. *Mixing Mechanism of Raw Grout:*

Mixing of raw grout material is one of the important steps for homogeneous raw grout mixing. For preparation of grout mix, cement, water and sodium silicate were taken by weight. Percentage of sodium silicate (SiO2:Na2O) were selected on the basis of total weight of material taken with respect to water cement ratio. For example; for w/c ratio 1, 500 gm cement and 500 gm water was required to make the grout of 1 liter quantity. For this 1000 gm grout mix 1% of sodium silicate means 10 gm was added to the mix. Mixing mechanism was done by first adding sodium silicate into the water and then it was added to the known weight of cement. All these ingredients were thoroughly mixed by using a mechanical mixture in such a way that there is no segregation of the particles. The mixing time of grout was maximum 3 to 5 minutes and mixing speed was kept constant at 2000 rpm for preparation of all samples throughout the experimental work.

Fig. 1: Mixing Mechanism of raw grout material

The mechanical mixture is shown into the above photograph. The following table 6 shows the specifications of the mechanical mixture:

Motor Detail	1/16 HP, 220/230 Volts, 50 cycles. A.C. Power Supply
Type of rotor	12.5 mm diameter, 55 mm long three bladed propeller of 65mm sweep made up stainless steel
Maximum speed	0 to 8000 rpm
Stirring capacity	2 liters

Table 6: Specifications of the Mechanical mixture

VI. RHEOLOGICAL PROPERTIES OF RAW GROUT

A. *Marsh Cone Test:*

Grout workability can be characterized by the Marsh cone test, according to ASTM C939-02. Based on this standard the measurement of flow time is connected to the grout fluidity, meaning that the longer the flow time, the lower is the grout fluidity. This test enables a grout design regarding several factors, like admixture and additives dosage for instance, since it gives an idea of the maximum dosage of each grout component in order to obtain a favorable behavior that permits its injection at low pressure. Thus, the Marsh cone test was used to optimize the amount of sodium silicate used. A volume of1000 ml of grout was placed into the cone and the flow time (expressed in seconds) required for grout to flow out was measured.

Fig. 2: Set up for Marsh Cone Test

The design of marsh cone was derived from the Hagen Poisevillers law which state that afflux time (seconds) of a fixed volume (1000 cc) through a capillary (4.75mm) is proportional to the viscosity of the fluid.

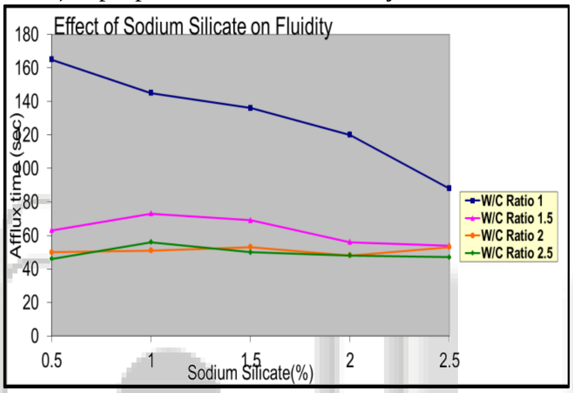

Fig. 3: Sodium Silicate v/s Afflux time

Graph shows the results of Marsh cone test.

The above fig. 3 shows the effects of sodium silicate on the time of Afflux or fluidity. The graph shows that as the amount of sodium silicate increases, the afflux time or fluidity decreases. The graph also shows that for water to cement ratio equal to 1, the graph is stable and gradually decreasing curve. There is noticeable difference in the results for water to cement ratio equal to 1. For water to cement ratio equal to1.5, there is a little fluctuation in the graph. The graph initially increases, reaches to a peak value, then slightly decreases at 1.5% amount of sodium silicate. The same without much more difference in the afflux time.

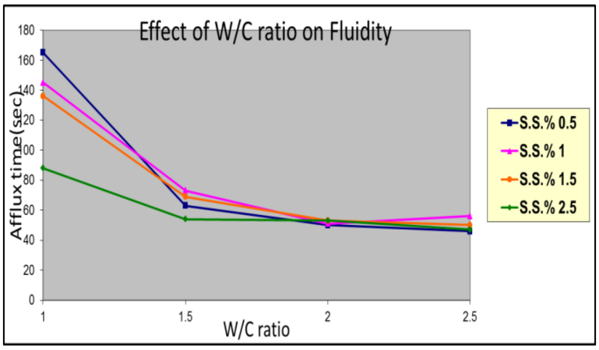

Fig. 4: W/C ratio v/s Fluidity

The above fig. 4 shows the effect of water to cement ratio on Afflux time of Microfine cement grout with varying proportion of sodium silicate (0.5 to 2.5%). The graph shows that as the water to cement ratio increases the fluidity or time of Afflux decreases. It also shows that as the proportion of sodium silicate increases the time of Afflux or fluidity also decreases.

The graph also indicates that the water to cement ratio equal to 1 is an optimum Afflux time for particular percentage of Sodium Silicate.

B. Bleeding Potential Test:

According to European Standard EN 12715, a suspension is characterized as ‘stable’’ if it has a bleed capacity of up to 5% after120 min from preparation. It is considered good practice to use stable suspensions because unstable suspensions may provide only a partial filling of soil voids due to bleeding. This test measures the stability of grout. Stability is measured by holding 1000 cc of suspension of grout in a container of given dimension and determination of the clear water above the setting particles.

1) Bleeding tests should be carried out for grout because of the following reasons:

During bleeding, the upflow of water from grout mixture leads to the formation of channel paths inside the grout mix. These channels act as potential paths for aggressive materials to pass through as these channels would not be closed during further hydration of the grout. The loss in volume by bleeding generates voids inside the grout mix which affects the properties and performance of the grout. Moreover, it increases the chance of corrosion of steel elements protected by the grout.

Fig. 5: Bleeding Potential test

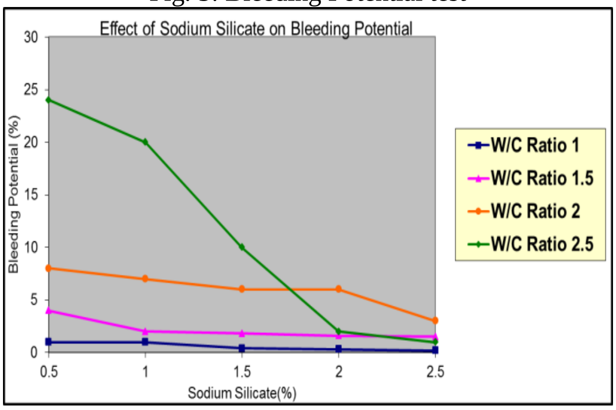

Fig. 6: S.S v/s Bleeding Potential

The fig. 6 shows the effect of sodium silicate on the bleeding potential of Microfine cement grout. The graph shows that as the amount of sodium silicate increases in the grout the bleeding potential decreases. It also indicates that as the water to cement ratio increases the bleeding potential increases.

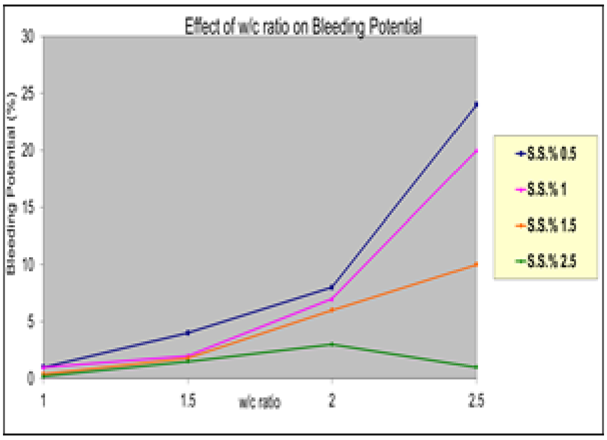

Fig. 7: W/C v/s Bleeding potential

The fig. 6 shows the effect of water to cement ratio on the bleeding potential of Microfine cement grout. The graph shows that as the water to cement ratio increases the bleeding potential increases. It also shows that as the proportion of sodium silicate increases the bleeding potential decreases. The results show that the grout prepared with Sodium Silicate 2.5% is a stable grout.

C. Gellification Time Test:

Gellification time is that time at which the grout has acquired sufficient physical-chemical bond so that there is no any deformation. In any grout the gel time can be varied to some extent by varying its ingredients like precipitant, activator, accelerator and retarder. The time of gelation is measured by the conventional method as standardized by Barbadette (1955) by the deformation of 100 cc grout in a cup of 50 mm diameter placed in three position-horizontal, inclined and inverted to access the time for partial and full gelation

Fig. 8: Gellification time test

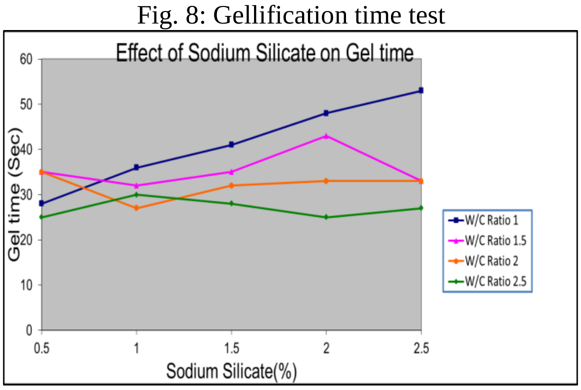

Fig. 9: Sodium Silicate v/s Gel time

The above fig. 9 shows the effects of sodium silicate on the time of gelation. The graph shows that as the amount of sodium silicate increases, the gelation time also increases. The graph for w/c ratio 1 is gradually increasing with increase in the percentage of Sodium Silicate.

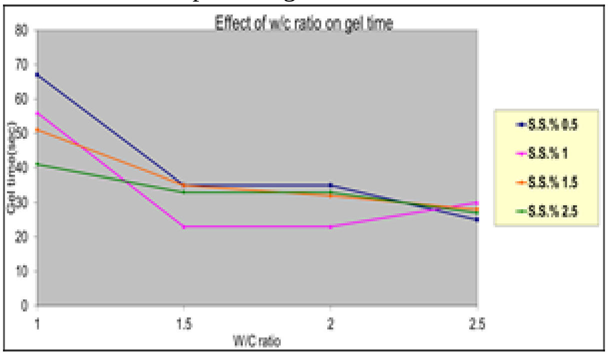

Fig. 10: W/C v/s Gel time

The above fig. 10 shows the effect of water to cement ratio on Gellification time of Microfine cement grout with varying proportion of sodium silicate (0.5to2.5%). The graph shows that as the water to cement ratio increases the time of gelation decreases. It also shows that as the proportion of sodium silicate increases the time of gelation also decreases. The graph also indicates that the water to cement ratio equal to 1 is an optimum water to cement ratio.

D. Unconfined Compressive Strength Test:

1) Procedure for Specimen Preparation:

The following fig. 11 shows the process of preparation of mould and specimen. Moulds are prepared from the PVC pipes by cutting these pipes into equal parts (height = 10.5 cm, Diameter = 4.2 cm). These are then provided with a tape as shown into the figure so that the grout slurry can be easily filled. They are also provided with a vertical cut so that the grout specimen can be easily removed whenever required. These specimens are kept for curing for 21 days and then they are subjected to an Unconfined Compression test.

Fig. 11: PVC mould covered with cello tape for UCS specimen

The sample was prepared as per IS:2720 part10.The specimen for the test shall have a minimum diameter of 38 mm and the largest particle contained within the test specimen shall be smaller than l/8 of the specimen diameter. If after completion of test on undisturbed sample, it is found that larger particles than permitted for the particular specimen size tested are present, it shall be noted in the report of test data under remarks. The height to diameter ratio shall be within 2 to 2.5.Measurements of height and diameter shall be made with verniercallipers or any other suitable measuring device to the nearest 0.1mm.

Fig. 12: Unconfined Compressive Strength test

The fig. 13 shows the effect of sodium silicate on compressive strength of grout mix sample. The graph shows that as the amount of sodium silicate increases the compressive strength of grout sample also increases for w/c ratio equal to 1. For other w/c ratio there is decrease in unconfined compressive strength as the percentage of sodium silicate increases.

The Unconfined Compressive Strength is maximum for the amount of sodium silicate 2.5% at the water to cement ratio equal to 1.

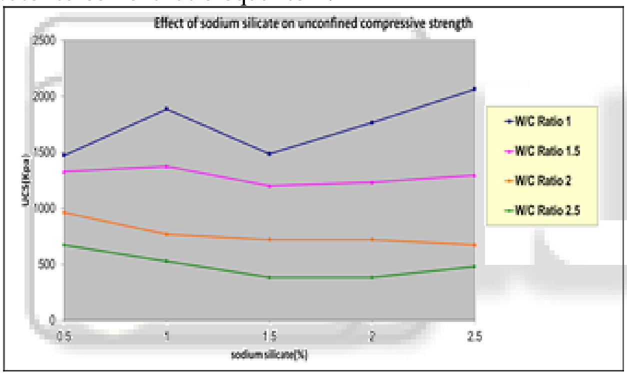

Fig. 13: Sodium Silicate v/s UCS

The figure 14 shows the graph between unconfined compressive strength and water to cement ratio of the grout mix sample. The graph shows that as the water to cement ratio increases the unconfined compressive strength decreases. The graph also shows that at the water to cement ratio equal to1 with the proportion of sodium silicate equal to 2.5, the value of unconfined compressive strength is high.

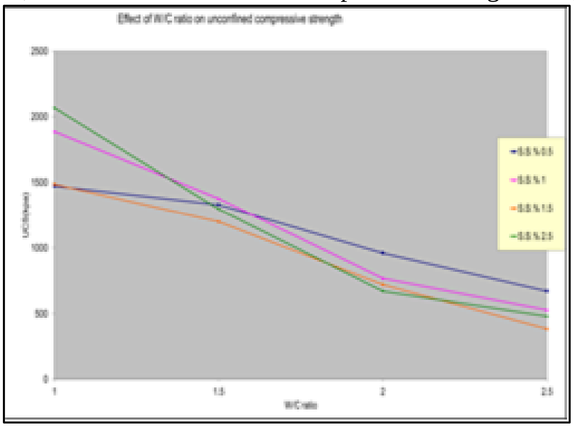

Fig. 14: W/C ratio v/s UCS

VII. Conclusion

From the above experimental work it can be concluded that

- The optimum raw grout mix contains water to cement ratio equal to 1 and the amount of sodium silicate is 2.5 %.
- As the amount of sodium silicate increases in the grout the bleeding potential decreases.
- As the amount of sodium silicate increases, the afflux time or fluidity decreases.

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