



## Stabilization of Medium Dense Sand with Microfine Cement Grout with Various Proportions of Sodium Silicate

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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 rockfill dams. Grouting becomes very much essential for stabilizing loosely packed sandy soils with either zero (0%) fines or fines <10 % subjected to dynamic forces. The paper focuses on the rheological properties of raw cement grout prepared from microfine cement having fineness of 6000cm<sup>2</sup>/gm and it was used to stabilize loosely packed sandy soil using sodium silicate as an additive. The various parameters viz. fluidity, bleeding potential, unconfined compression strength of raw grout are determined. From the overall results it was concluded that MFC grouts with sodium silicate provides considerable improvement in strength and penetrability characteristics of grouted sand that improves the resistance in liquefaction.

**KEYWORDS**

*MFC grouts, rheological grout properties, UCS.*

**INTRODUCTION**

The modification of soil and rock properties by filling voids and cracks is two centuries old technique. Grouting can be defined as a method of injecting a special liquid or chemical or slurry material called grout into the ground for the purpose of improving the soil or rock. Grouting can be effectively used to modify strength and permeability of grouted mass and also to prevent Collapse of granular soils, Settlement under adjacent foundations, Groundwater movement, Utilities damage, Tunnel run-ins etc.. Grouting is effective and economical ground improvement technique for the major infrastructures like earthdams, rockfill dams ,metro rail, mono rail, fly over bridges, foot over bridges, jetties, etc. as the foundations of these structures are often subjected to static loads in addition to the most important dynamic loads. The concept of Microfine cement grouting was first developed in Japan. In India this concept is new and still under development and research. The development in the field of grouting technology has brought Micro-fine cement as an innovative grout material for the replacement of costly chemical grouts. The main objective of this paper is to find the Rheological properties of raw grout cement i.e. fluidity, bleeding potential and gellification time and also to know the unconfined compressive strength of Microfine cement grout for the stabilization of medium dense sand.

**MATERIALS**

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

**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. Finally their unconfined compressive strength is obtained for stabilization of medium dense sand.

**DETERMINATION OF OPTIMUM GROUT MIX**

The optimum raw grout can be defined as a grout in which the combined action of all the ingredients provide sound grout properties like fluidity, bleeding potential, setting time,

penetrability and strength. The optimum grout also provides a good water tightness and impermeability.

From the results of all the raw grout property tests and unconfined compressive strength test of all the raw grout mixes, it was decided to use the optimum grout mix which contains **1 w/c ratio and 2.5 % sodium silicate.**

**RHEOLOGICAL PROPERTIES OF OPTIMUM RAW GROUT:**

w/c ratio	1
Sodium silicate	2.5%
Afflux time	88 sec
Gel time	53 sec
Bleeding Potential	0.2%
UCS (21 days)	2064 (kPa)

**Unconfined compression strength test:**

**Procedure for specimen preparation:**

Moulds are prepared from the PVC pipes by cutting these pipes into equal parts (height = 9.5cm,diameter = 4.5 cm). These are then provided with an adhesive tape 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. The Unconfined strength test was performed according to IS 2720 (part 10): 1991. It is the load per unit area at which an unconfined cylindrical specimen of soil will fail in the axial compression. All raw grout samples are tested on strain controlled unconfined compression machine at strain rate of 2.15 mm/min after 21 days of curing. 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 1/8<sup>th</sup> of the specimen diameter.

**GRADATION OF SAND TO PREPARE THE GROUTED SAND SAMPLE AS PER IS:2720 (PART-IV):**

For a sand-cement grout mix, evenly graded sand(ranges between 75 micron - 4 mm) should be used. The sand should be evenly garded means it is desired to have the values of Cu >= 6 and Cc = 1 to 3. For this purpose, number of sieve analysis tests are carried out. After number of sieve analysis tests and by adopting some trial and error methods, the obtained values of Cu and Cc are 6.25and 1respectively.

**RELATIVE DENSITY (IS-2720 PART 14):(D<sub>r</sub>) or (I<sub>d</sub>)**

The most important index aggregate property of cohesionless soil is its relative density. The relative density of medium dense sand should be between 35% to 65%.It can be calculated from the equation given below.

$$I_d \text{ (or } D_r) = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100$$

Where,

- e=void ratio in the natural state
- e<sub>max</sub>=void ratio in the loosest state
- e<sub>min</sub>= void ratio in the densest state

**Determination of volume of grout for 40% relative density**

Volume of Grout should be equal to volume of voids in the soil sample. Which can be calculated from the following steps.

- Step1:Find the total volume of the mould.(V)
- Step2:Find the maximum void ratio and minimum dry density in the loosest condition(e<sub>max</sub>)
- Step3:Find (e<sub>min</sub>)for relative density of 40% .
- Step4: Calculate mass of soil required at various relative density i.e 40% .
- Step5:Find the volume of solids of natural soil (V<sub>s</sub>)
- Step6: Find volume of voids (V<sub>v</sub>)
- Step7: Find volume of air and volume of water
- Step8: Find final volume of grout required for relative density.

From the above steps it was calculated that for the relative density of **40%** the mass of soil sample required was **246 gms**. And the volume of grout required was **51 ml**.

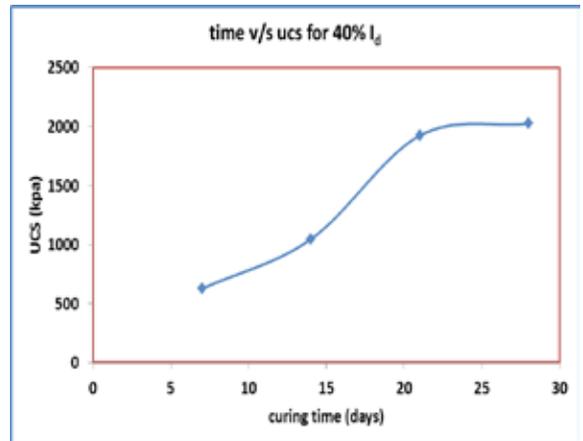
**INJECTING GROUT IN THE SOIL SAMPLE:**

The grout was injected in the soil sample by the special lab injection technique. An injection of 60 ml capacity provided with a needle of 3.1 mm internal diameter at the other end. A pressure gauge of 10kg/cm<sup>2</sup> is provided at the middle. The mixture of grout is filled in a syringe. Then the grout is injected with manual pressure and allowed to pass through a PVC pipe and then from needle which is kept in the mould. Pressure gauge kept at the middle measures the pressure applied at time of application of injection of grout.

**UNCONFINED COMPRESSION TEST ON THE GROUTED SOIL SPECIMEN**



**Compressive Strength v/s Curing Time of MFC Grouted Sand**



**CONCLUSIONS:**

- Effect of Sodium Silicate on the Rheological properties of Raw Grout
- As the sodium silicate proportion increases the afflux time of the grout slurry decreases. When sodium silicate increases from 0.5 % to 3%,the afflux time decreases by 12.1%, 17.6%, 27.2%, 46.6% and 47.8% respectively For a constant w/c 1. As the amount of sodium silicate increases the inter particle bond gets weaker which reduces the afflux time.
- As the percentage of sodium silicate increases, the Gel time of the grout slurry increases. When sodium silicate increases from 0.5 % to 3% by 22.2%, 31.7%, 41.6%, 47.1%, 45.1% respectively with the same w/c ratio. When sodium silicate reacts with cement, the particles get clogged and thereby reducing the flow ability of the grout particle.
- As the sodium silicate proportion increases the unconfined compressive strength of the grout slurry increases. When sodium silicate increases from 0.5 % to 3 %,the unconfined compressive strength increases by 21.9%, 0.87%, 16.6%, 28.6% and 26.1% respectively For a constant w/c 1. As the amount of sodium silicate increases the inter particle bond gets weaker which reduces the afflux time.

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