Strength improvement of Gandhinagar soil using microfine cement as grout

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Grouting technology is a widely accepted soil improvement technique for improving soil parameters like c and ϕ value. The use of Micro fine cement grout along with sodium silicate can easily deal with the problems associated with ground improvement, toxicity & costliness of chemical grouts. Grout is injected under pressure into the material to be grouted until it fills the desired void or until the maximum specified pressure is attained and a specific minimum grout flow is reached. The purpose of this study is to investigate the proper grout mix using micro fine cement (whose specific area is greater than the normal cement) and silica used in grouting. An attempt has been made to find the optimum grout mix design at various water content (10% and 20%) and cement content (5%, 10%, 15%, 20% and 25%). The paper discusses about strength improvement of loose sandy soil and silty clay soil. The results shows that with the increase in micro fine cement content, the strength of soil will increase and with the increase in the water content, strength of soil decreases. In this study direct shear test was performed to find shear strength of loose sandy soil. The grouting properties of microfine grout was found to be better as compared to the conventional grout.

Keywords: Micro-fine Cement, Grouting, Shear Strength, Direct Shear Test, Sandy soil.

1 Introduction

The building of structures on the ground with less structural stability often requires the soil to be improved in order to ensure the safety and the sub structure stability of surrounding buildings [1]. Collapses and seepage of water are common phenomenon during the construction of tunnels and other underground works which is caused by soil having poor shear strength or permeability capacity. Phenomenon of Liquefaction of soil can be observed during the events of earthquake due to the insufficient shear and bearing capacity of the soil [2].

Different methods like external vibration, vibro-flotation, compaction piles, compaction with explosives, replacement of soil, grouting etc. can be used as the ground improvement techniques for the soil. Grouting is the method with several applications in the field of civil engineering, previously was not widely accepted as it required high skill and efficiency of labors to pursue the tasks. Grouting is a method in which the material is injected under pressure into the cavity until the desired volume of material around the hole is filled or until the maximum specified pressure is attained and a specific minimum grout flow is reached. Various grout slurries like cement-based grout slurry such as cement slurry and cement-sodium silicate slurry to chemical slurry such as lignin, acrylic, and urea or epoxy resins can be used according to the requirements of the project.

As an alternative to chemical grouting of fine and medium grained sands, the use of grouts prepared with micro-fine cements has been proposed. Micro-fine cement is advantageous over Ordinary Portland cement as it can provide a larger specific surface area [3]. Due to this larger specific surface area, the grout with Micro-fine 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.

The grouting reduces pore size while filling the voids in the material and also create bond between soil particles, thereby improving the engineering properties such as strength, stiffness and reduction of permeability. In this paper an attempt is made to study the improvement in the strength of grouted loose sand by using microfine cement as grout.

2 Materials Used:

The Basic material used for soil testing are Water, Micro fine cement (MFC) and Sandy soil. MFC is similar to cement which when combined with water exhibits cohesive and adhesive properties that help in holding soil particle together to form a soil mass. Most of the case the micro fine cement are available in slurry (cement + water) form and also available in powder form. Micro fine cement particle is finer than normal cement particle and use to improve soil shear strength. The microfine cement used in this experimental program has following properties: Fineness=6000cm^2/gm, specific gravity=3.1, bulk density=700-800kg/m^3, Particle size D_{50}<9μm and D_{95}<22μm[5]. The soil used here is basically sand and have following properties.

Table.1. Properties of the soil used in this experimental program.

Properties	**Values**
Grain size D_{10}	0.17mm
Grain size D_{30}	0.22mm
Grain size D_{60}	0.3mm
Uniformity Coefficient(C_u)	1.76
Coefficient of Curvature, (C_c)	0.95
Specific gravity(G_s)	2.62

3 Test Methodology and Results

3.1 Test of Micro fine Cement (MFC)

The initial and final setting time of the micro-fine cement slurry were found out by the vicat apparatus and the results have been shown in Table.1.

For finding Initial Setting Time, immediately place the test block with the non-porous resting plate, under the rod bearing the initial setting needle. Then lower the needle and quickly release allowing it to penetrate in to the mould. In the beginning the needle will completely pierce the mould and after certain repetition of this procedure over a period of time the needle fails to pierce the mould for 5 + 0.5mm. Record the period elapsed between the time of adding water to the cement to the time when needle fails to pierce the mould by 5 + 0.5mm as the initial setting time.For finding Final Setting Time replace the needle of the vicat apparatus by the needle with an annular ring and lower the ring and quickly release. This process is repeated until the annular ring does not make an impression on the mould. Record the period elapsed between the time of adding water to the cement to the time when the annular ring fails to make the impression on the mould as the final setting time.

For the given soil with different water-cement ratio the initial and final setting time obtained is given below in Table.2.

Table.2. Initial and Final setting time for different water cement ratio.

W/C ratio	Initial Setting Time(min)	Final Setting Time(min)
0.5	190	265
0.67	220	295
1	290	362
1.3	335	416
1.5	380	460
2	452	590

3.2 Direct Shear test of MFC and Soil Mixture

Direct Shear test has been performed to determine Shear Strength of soil and done so, using direct shear apparatus. The initial tests were performed on pure soil and the shear strength was found out. The results obtained were compared with the shear strength of micro-fine cement silica grouted soil. The direct shear test on soil samples having different proportions of MFC and different water-cement ratio is given below.

A. Direct shear test on soil sample having 5% and 25% MFC Content (Variation of Initial water content)

1. An attempt has been made to find out the Optimum Moisture Content for obtaining Maximum Shear Strength of the soil mixture through Direct Shear Test. Here the 5% and 25% of MFC content is mixed with soil and direct shear test is done on 7 Days and 28 days of curing period. The obtained result of shear strength for 5% and 25% MFC content is given below in the Fig.1.a and Fig.1.b respectively. These results are for 100kN/m^2 Normal load applied in the direct shear test. The 25% MFC content is the optimum mix of our study of improvement of soil. For both the cases of MFC content of 5% and 25%, there is a decrease in shear strength with increase of the water content and for both the cases there is a general increase in shear strength with increase in the curing period. Here for 5% MFC content the shear strength decreases from 142kN/m^2 to 110kN/m^2 for 28 days of curing and for 7 days of curing the trend is not very clear and this can be attributed to not gaining sufficient strength in such a short period of time. For 25% MFC content shear strength decreases from 932kN/m^2 to 815kN/m^2 for 28 days of curing and from 525kN/m^2 to 403kN/m^2 for 7 days of curing. So the 7 days curing period give a clearer trend for 25% MFC content compared to 5% MFC content.

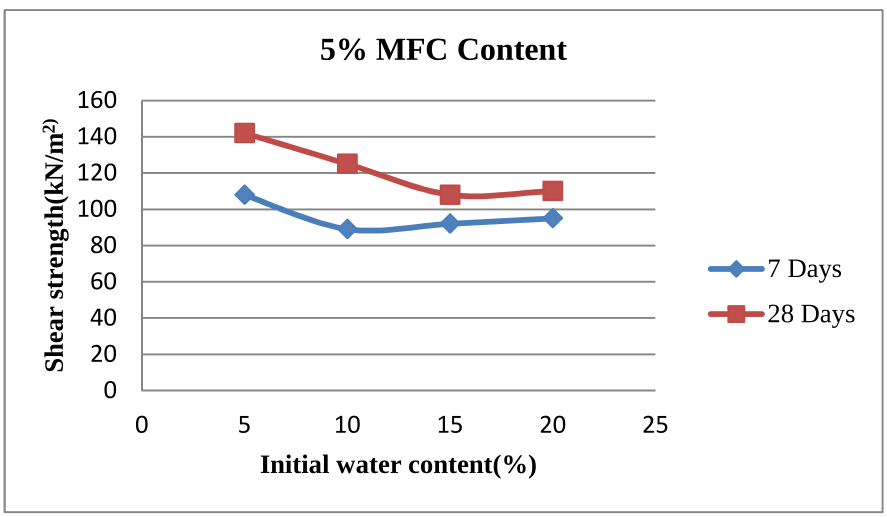

Fig 1.a. Graph showing Shear strength v/s Initial water content at 5% MFC content.

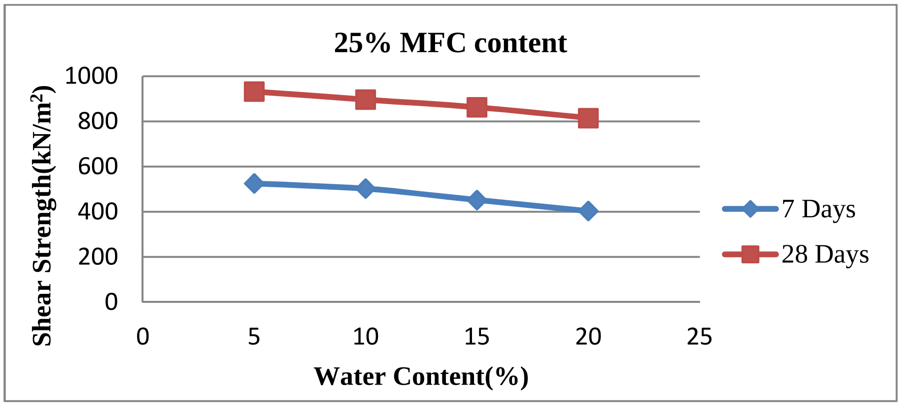

Fig 1.b. Graph showing Shear strength v/s Initial water content at 25% MFC content.

B. **Direct shear test on soil sample having 20% Initial water Content (Variation of MFC content)**

This graph (Fig.2) shows the results of the direct shear tests conducted on soil mixture of different MFC content with variation from 0 to 25%, while keeping the water content at 20%. This Graph shows the variation of shear strength of soil sample on 7 days and 28 days for different MFC content. This test results is for applied normal load of 100 kN/m^2. The increase in shear strength is steeper in case of 28 days curing (82 kN/m^2 to 815 kN/m^2) for different MFC content compared to 7 days curing (82 kN/m^2 to 403 kN/m^2) and this can be attributed to the higher molecular bonding strength with the increase in curing period.

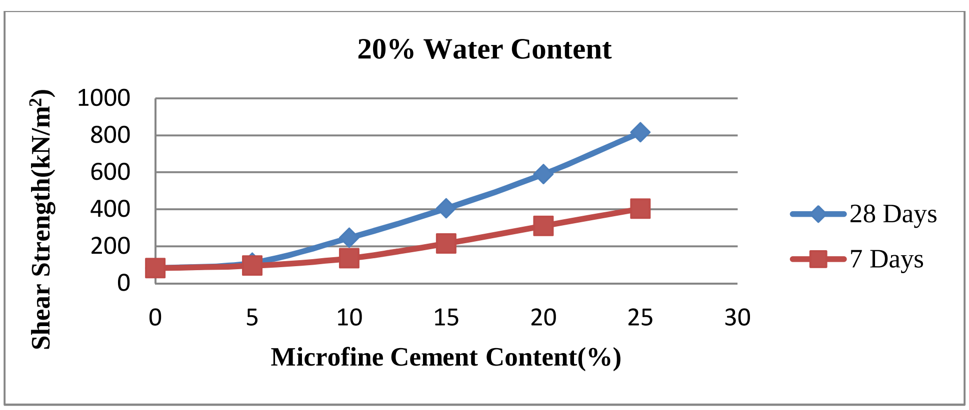

Fig 2. Graph showing Shear strength v/s MFC content at 20% water content.

C. **Direct shear test on soil samples after curing period of 28 days and for 20% Initial water Content (Variation of applied normal load)**

In this case the Graph (Fig.3) shows the relative variation between Shear strength and MFC content for applied normal load of 50, 100 and 150 kN/m^2. This direct shear test is conducted on mixed soil sample after 28 days of curing keeping the water content at 20%. The shear test is conducted for normal stress of 50, 100 and 150 kN/m^2. The graph clearly shows that the strength increment is steeper (82kN/m2 to 625kN/m2 for 50kN/m2 normal stress and 105kN/m^2 to 952 kN/m^2 for 150kN/m^2 normal stress) as the normal stress applied increased.

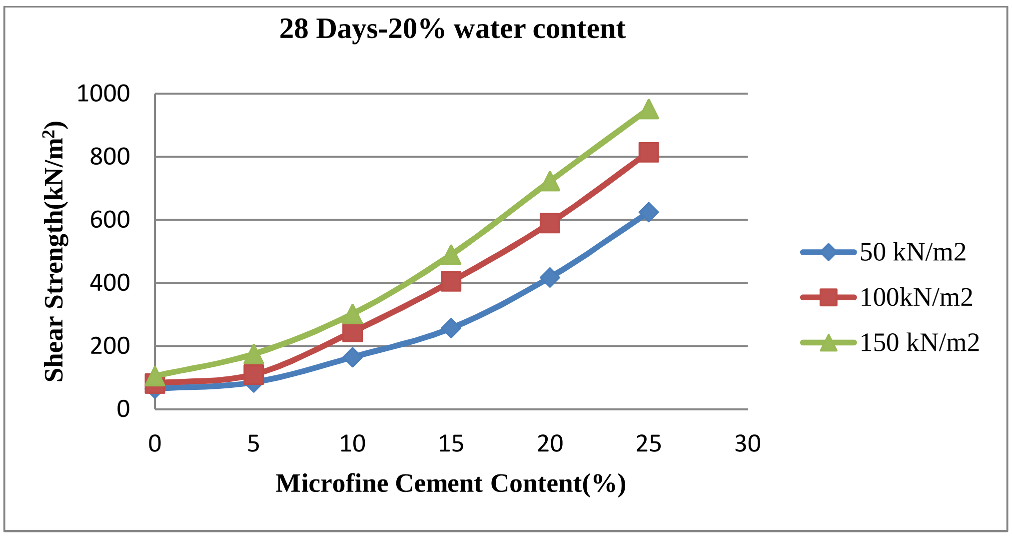

Fig 3.Graph of Shear strength v/s MFC (%) at 20% water content and 28 days.

D. In Direct Shear Test, Variation of Shear Stress vs Shear Strain for soil samples with different MFC content (5% to 25%)

This figure(Fig.4) shows the graph of Shear stress Vs Shear strain obtained from direct shear test conducted on soil samples having different micro fine cement contents (5% to 25%) and water content of 5%. All the direct shear test conducted here is for the normal stress of 100kN/m^2. The Graph indicates the shear stress failure point for various MFC content; starting from 110kN/m^2 at 5% MFC content to 815kN/m^2 at 25% MFC content. It is also quite clear that with increase in MFC content, maximum shear strength is achieved at lesser shear strain.

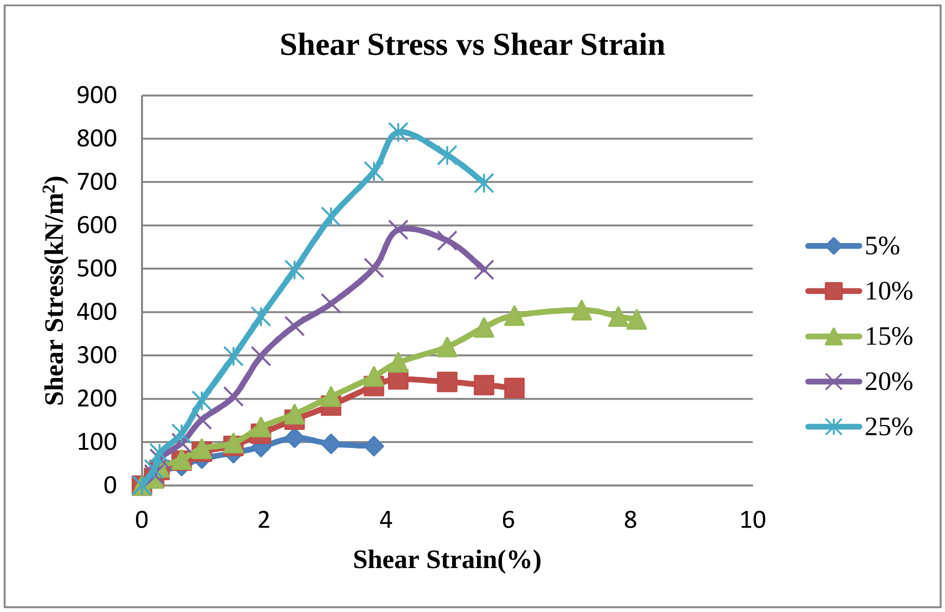

Fig 4. Graph of Shear strength v/s Shear strain (%) at different percentage of MFC content.

CONCLUSIONS

The broad conclusion based on the analysis of the experimental results are given in this section. There is an over 8 times increase in the shear strength can be seen at the age of 28 days by 25% replacement of soil by micro fine cement at a specified W/C ratio. Micro fine Cement content is directly proportional with the shear strength of the soil (maximum shear strength at 25% MFC). For both the cases of MFC content of 5% and 25%, there is a general trend of decrease in shear strength with increase of the water content and in both the cases there is a general increase in shear strength with increase in the curing period. The increase in shear strength is steeper in case of 28 days curing for different MFC content compared to 7 days curing.

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