"Application of Microfine cement grouts to improve carrying capacity of model pile foundation"

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▪ Abstract

This paper focuses on the improvement of load carrying capacity of model pile group founded in sandy soil by injecting Microfine cement grout with water cement ratio 5:1 and 2:1.Grout is injected through perforated pipe having pointed end with constant pressure at bottom and around the model pile group. After 7 days of injection, pile load test is performed on model pile group embedded in grouted foundation sand formation and ultimate load is determined from load vs. settlement curves. It is seen improvement of carrying capacity.

KEY WORDS: Microfine cement grout, carrying capacity, pile foundation

▪ Introduction

Generally, particulate grouts are prepared with Ordinary cement. Such grouts injectable into gravels and coarse sand. Newtonian grouts can easily penetrable in fine sands and coarse silts, but Newtonian or chemical grouts are costly, toxic and harmful to health. As a substitution of such costly and toxic grout Microfine cement grouts with different water cement ratio can be used.

MC500 was the first Microfine cement available in market, manufactured by Onoda Cement Corporation in Japan. Grouts prepared with ordinary cement have limited applications for grouting in fine sand and coarse silt due to its larger particle size makes injectability difficult. Because of that reason Microfine cement grouts satisfy this requirement of having very fine particle size for grouting.

While grouting with Microfine cement, reaction between water and fine cement particles are very fast and get stiffen quickly. Due to which pumping of grout prepared with Microfine cement becomes difficult. To resolve this problem, dispersing agent is to be added in grout to increase its flow ability. Amount of dispersing agent to be added in grout ranges from 1to 5% of cement by weight. In this study, sodium naphthalene formaldehyde (SNF) is used as dispersing agent. Dispersive agent is used to prevent quick stiffness of grout, to reduce Interparticle attractive force between particles and to reduce the bleeding.

▪ Materials

The materials used in this research work were Microfine cement with dispersing agent and sand.

a) Sand:

As mentioned, sand with relative density 51% was used as grouting medium for this study grain size distribution curves of sand used is shown in Figure 1.properties of sand used for research work are shown in table 1.

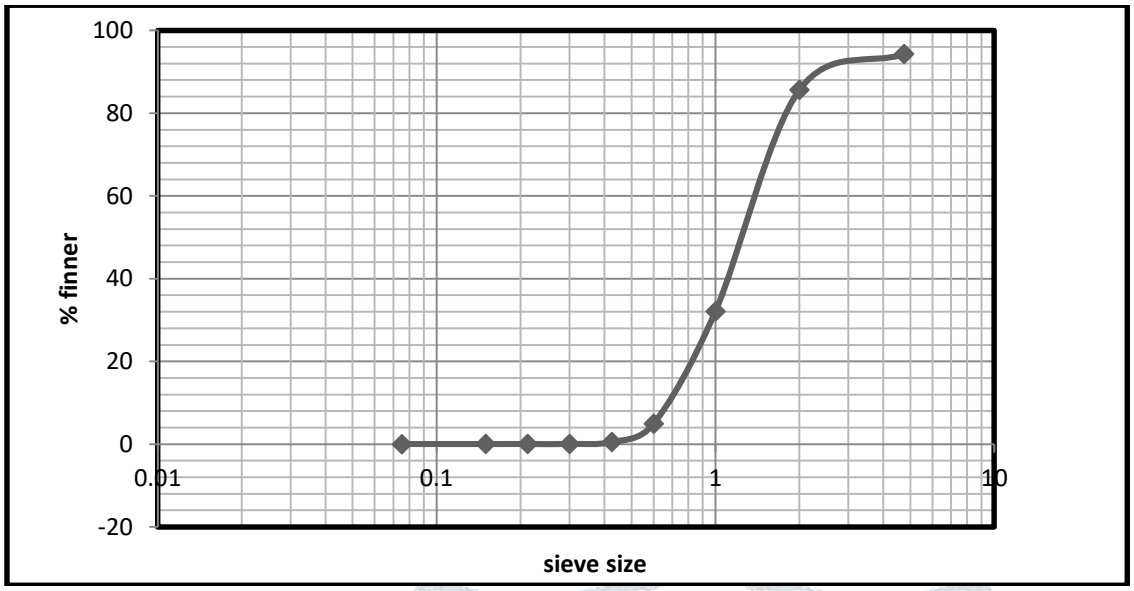

Figure 1: particle size distribution curve

Table 1: properties of sand

Specific gravity	**2.65**
Minimum density	**1.45 g/cc**
Maximum density	**1.90 g/cc**
Field density	**1.65g/cc**
Relative density	**51%**
C_u	**<3**
C_c	**<1**
D_{10}	**0.685mm**
D_{15}	**0.76mm**
D_{30}	**0.97mm**
D_{60}	**1.4mm**
D_{85}	**1.2mm**
Sand classified	**SP**

b) Microfine cement:

Alccofine 1108SR grade Microfine cement was used for preparation of grout to inject. Chemical composition and Properties of Microfine cement used in research are given in table 2 and table 3 respectively.

Table 2: chemical composition of Microfine cement

Chemical constitutes	
CaO	61.10%
MgO	2.71
Al2O3	9.23

SiO2	24.64
FeO	2.62
SO3	2.90%
LOI	2.10%
IR	0.88%

Table 3: properties of Microfine cement

Property	Value
Form	Dry fine powder
Component	Single
Particle size d_{95}	< 11.5 Microns
Blaine Fineness	> 9000 cm^2/gm
Marsh Cone Viscosity[1]	35 to 55 seconds
Compressive strength[2]	> 30 MPa at 7 days > 45 MPa at 28 days

▪ Methodology:

In this research work, sand was filled in tank of size 60cm × 60cm × 80cm in three layers. Each three layer were subjected to vibration of 60second with surface vibration shown in figure 2. After vibration top layer of sand, saturated whole sand mass before injection of grouting. Then after model pile group (2 × 2) show in figure 3 having shafts or piles of 18 cm long was driven into sand mass which is filled in tank.

Figure 2: surface vibrator used in research

Figure 3: Model pile group

Grout of desired proportion was prepared uniformly by mixing properly in mixer shown in figure 4 for few minutes. Prepared grout pumped and injected at bottom as well as around the of pile group by grout pump shown in figure 5 through perforated pipe having conical tip at end as shown in figure 6.setup of grouting foundation sand bed is shown in figure 7. After grout has been injected, it was kept in humid environment for 7 day to strengthen the grouted mass. Load-settlement test was conducted after 7 days to determine ultimate carrying capacity of model pile group in grouted soil mass. Test set up is shown in figure 8 below.

Figure 4: grout mixer used in research

Figure 5: grout pump used in research

figure 6: perforated pipe

Figure 7: setup for grouting foundation sand mass

Figure 8: pile load test setup

As shown in figure 8, jack of capacity 2 tones is given to exert load on pile group, proving ring is for measuring load and dial gauges are provided to measure settlement of pile group. Some grouted foundation sand mass were extracted from tank after pile load test and shown below in figure 9.

Figure 9: grouted foundation sand formations extracted after pile load test

- **Pile load test results and discussion**

1) **Load vs. settlement curve for soil with or without grouting for w/c=5:1 is given below**

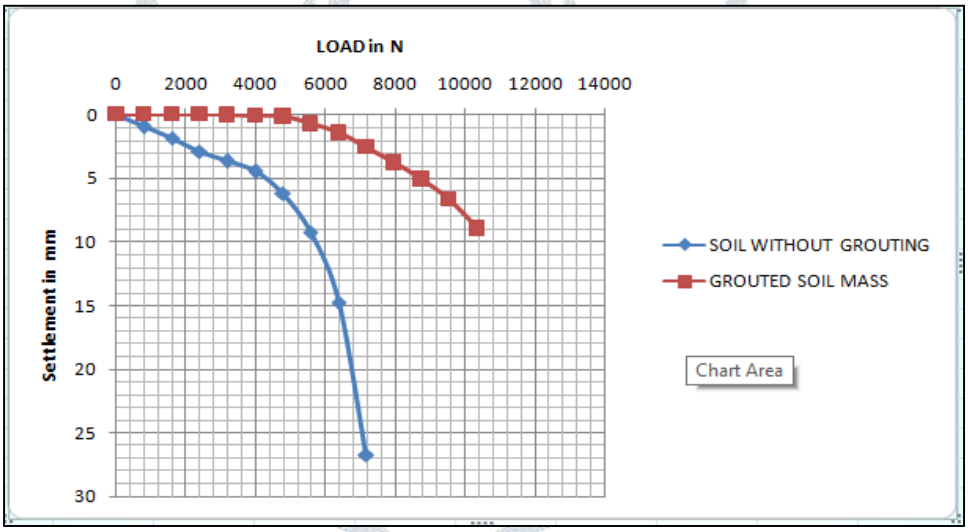

Figure 10: load v/s settlement curves for model pile group embedded in ungrouted foundation sand bed and grouted sand bed (grouting at both bottom of pile group and around the pile shaft) with w/c=5:1

It is seen in figure 10 that load carrying capacity of model pile group is more in grouted soil mass than that of virgin soil. Grout of (w/c=5:1) predetermined quantity prepared with Microfine cement is injected at bottom of pile group and sides of pile shaft by hand pump. Volume of grout to be injected is determined from volume of voids in volume of sandmass to be grouted. Injected Microfine cement grout into sand increases cohesion of sand and Interparticle bond hence increase in compressive strength and settlement is also less in grouted sandy soil in which model pile group in founded.

2) Load vs. settlement curve for soil with or without grouting for w/c=2:1 is given below.

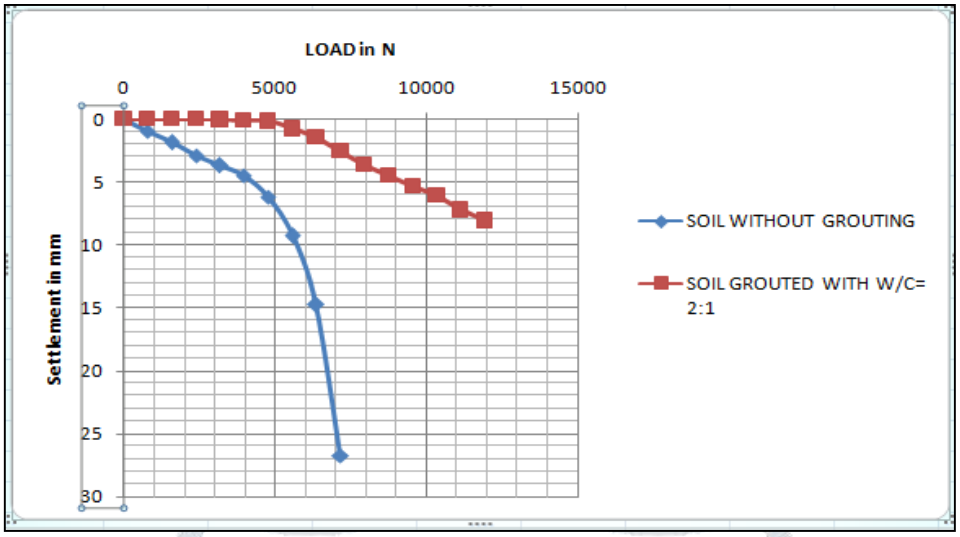

Figure 11: load v/s settlement curves for model pile group embedded in ungrouted foundation sand bed and grouted sand bed (grouting at both bottom of pile group and around the pile shaft) with w/c=2:1

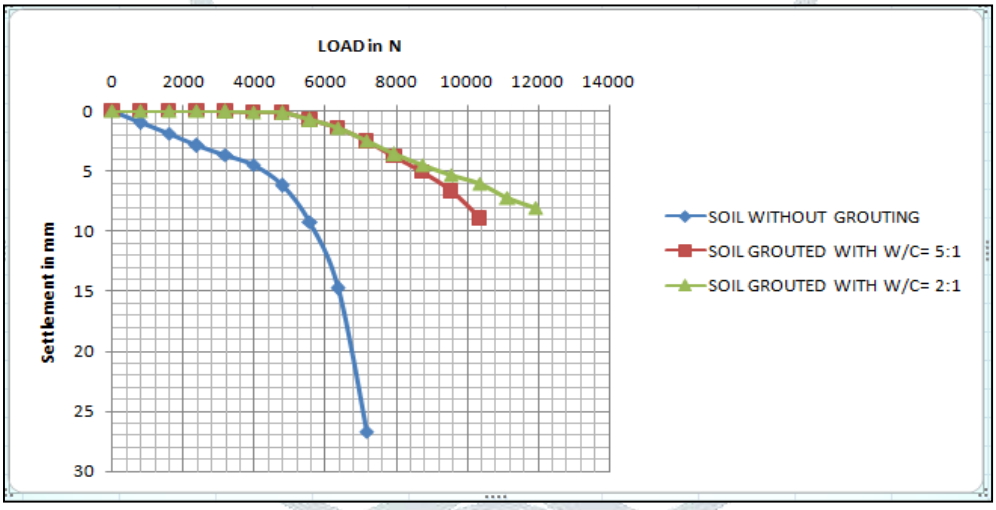

Figure 12: combined graphs for all three conditions

From figures 11 and 12 given above, we can conclude that ultimate load carrying capacity of grouted foundation sand formation increases with decreasing w/c ratio. As we can see ultimate load carrying capacity of foundation sand formation grouted with w/c ratio 5:1 is around 8100 N where as ultimate load carrying capacity of foundation sand formation grouted with w/c ratio 2:1 is around 9000 N and settlement is also less than that of 5:1 ratio as shown in figure 12. Permeability of grouted sand is very less compare to ungrouted sand mass

▪ Conclusion:

a. Microfine cement grouts are injectable into fine sands where grouts prepared with ordinary cements are impenetrable and chemical grouts are proven uneconomic and toxic.
b. Bleeding is less in case of Microfine cement grout compare to OPC cement grout.
c. Bearing capacity of sand (Cohesionless soil) can be increased with proper injection of Microfine cement grout. Thus load carrying capacity of model pile group also can be improved by injection of

well proportioned Microfine cement grout at bottom of shaft up to depth of twice width of pile cap.

d. Microfine cement also can be use where moisture or ground water is prone to raise and enter the foundation. Microfine cement grouts reduce the permeability of grout.
e. Ultimate load carrying capacity of model pile increases with decrease in water cement ratio as Microfine cement increase the cohesion of soil and Interparticle bond.
f. This research is applicable in field where foundation sand formation has been weaken or water table has been risen in foundation after some time of construction.

▪ References:

1. Vipulanandan, C. and S. Shenoy. 1992. Properties of cement grouts and grouted sands with additives. In: Grouting, Soil Improvement and Geosynthetics. Borden, R. H., Holtz, R. O., and Juran, I. (eds.), New Orleans, Louisiana, USA, 500–511.

2. Zebovitz, S., R. J. Krizek, and D. K. Atmatzidis. 1989. Injection of fine sands with very fine cement grout. J. Geotech. Eng. 115: 1717–1733

3. Murat Mollamahmutoglu and Yuksel Yilmaz. Engineering Properties of Medium-to-Fine Sands Injected with Microfine Cement Grout.

4. Grouting technology in tunneling and Dam construction by Dr. A. V. Shroff and Dr. D. L. Shah.

5. Hatem, Mohammed, Knutsson, Hellström" Rheological Properties of Cement-Based Grouts Determined by Different techniques" Science Research Engineering, 2014, 6, 217-229

6. "Bearing Capacity Improvement of Loose Sandy Foundation Soils through grouting" by Santhosh Kumar; Benny Mathews Abraham; A.Sridharan and Babu. T. Jose.