Visakhapatnam Chapter

Proceedings of Indian Geotechnical Conference 2020
December 17-19, 2020, Andhra University, Visakhapatnam

Study on Permeation Grouting with Cement to Improve Load Carrying Capacity of Sandy Soil

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Abstract. Grouting is one of the ground improvement technique used as a soil stabilization method for loose soils or rocks to improve their mechanical strength. The different types of grouting methods include permeation, compaction, hydro fracture, jet, compensation, deep mixing etc. This study includes permeation grouting where pore spaces in soil are grouted without disturbing the formation. The study focuses on the effect of cement grout on the bearing capacity of fine Ganga sand, for that cement grout with different water cement (W/C) ratio (8:1, 7:1, 6:1 and 5:1) was injected in the soil. The tests were conducted in poly-carbide sheet fabricated tank of 15cm x15cm x 15cm and grout material was injected with the help of perforated pipes. The improvement in strength properties of sandy soil were verified by performing plate load test with plate size of 5 cm x 5 cm. The results shows incredible improvement in load carrying capacity as cement portion increases but for W/C ratio below 5:1 increases the viscosity of mix and hence reduces the flow capacity.
Keywords: permeation grouting, water cement ratio, sandy soil, plate load test.

1 Introduction

Grouting is a very old technique, which has been in existence from 200 years. Traditionally grouting materials were clay, pozolan and hydraulic lime and later on Portland cement. The technique was invented by a French engineer Charles Berigny who injected clay and lime grout into a masonry wall. Current grouting techniques are employed to increase the bearing capacity of foundations [1], construction of cut-off curtains, groundwater control, stabilization of slopes and more [2, 3].

Conventionally prepared suspension grouts with ordinary Portland cement can be injected successfully into gravels and coarse sands, but it is very difficult or impossible to injecting these grouts into fine and medium sands. The various chemical grouts have been developed to improve the properties of soils with finer granularity, although these grouts create problems related to toxicity and permanence [4].

The successful permeation of a particulate grouts into any soil formation mainly depends on the relative sizes of the voids available in the soil formation to be grouted and the solid particles in the grout. The depth of permeation of any grout in a soil formation is strongly controlled by the size of the smaller voids in the formation and the larger particles in the grout [5, 6, 7].

By increasing the milling fineness of the cement, reducing or completely eliminating the coarse fraction the penetrability of a cement grout can be improved [8].
For this particular study the bearing capacity of local Ganga sand is tried to improve with cement grout at different water cement ratio (8:1, 7:1, 6:1 and 5:1), which was injected with the help of perforated pipes. To verify the grouted sand strength a lab based small plate load tests were conducted in poly-carbide sheet fabricated tank of 15cm x15cm x 15cm.

2 Material and Model

2.1 Soil and grout material

Locally available Ganga sand (collected from the Ghats of River Ganga, Varanasi) was considered for this experiment. The detailed properties of soil are shown in Table 1. Fig.1 shows the grain size distribution of the experimental soil. The grouting material used was 43 grade Portland Puzzolona cement, the properties are provided in Table.2 below.

Table 1. Properties of Ganga Sand

Properties	Values
Specific Gravity (G)	2.62
Coarse Sand (%)	0.00
Medium Sand (%)	3.02
Fine Sand (%)	95.62
C_u	1.67
C_c	0.89
OMC (%)	19
Angle of internal friction Φ	31
Maximum Dry Density	15.2
Permeability k (cm/sec)	0.001358
Classification	Poorly Graded Fine Sand

Table 2. Properties of Cement Grout

Properties	Values
Grade	PPC
Specific Gravity (G)	3.03
Fineness (%)	90
Consistency (%)	35
Bulk Density (Kg/m^3)	1440
Initial Setting Time (Min)	80

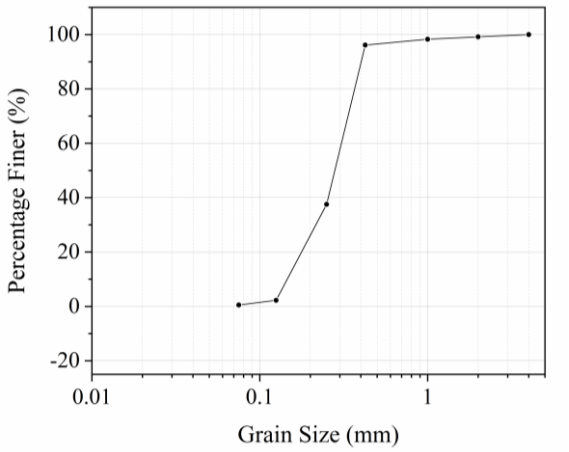

Fig. 1. Grain size distribution curve of the Ganga sand

2.2 Model and experimental setup

For preparing sample a poly-carbide sheet tank of 15cm x15cm x 15cm was prepared (Fig.2 (a)) and Ganga sand was compacted in that tank with a relative density of 70%. The grouting material (cement slurry) was injected in sample with 4 pieces of about 20cm perforated (perforations of 2mm diameter) PVC hose pipe (Fig.2 (b)). The cement solution was prepared with 4 different consistencies (w/c ratio - 8:1, 7:1, 6:1 and 5:1) and left for curing in moist condition for 5 days.

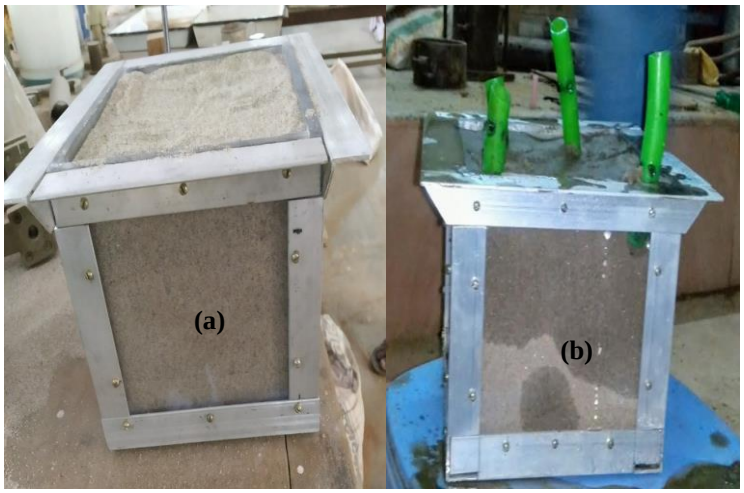

Fig. 2. (a) Poly-carbide sheet tank with grouted sample **(b)** Set up of Tank for grouting with perforated pipes.

The 5 days cured sample was placed on triaxial frame for plate load test. To perform the test a plate of 5 cm x 5 cm and 5 mm thick was connected with proving ring to distribute the load (set up shown in Fig. 3). The plate was set carefully at center of the sample to record load and displacement.

Fig. 3. Plate load test setup

3 Results and Discussion

The plate load tests were performed on grouted samples as well as on sand sample without grouting and load settlement curves were used to compare the increment in the load carrying capacity and strength of the grouted sample. Fig. 4 shows the load settlement curve of the local Ganga sand compacted as relative density of 70% without grouting. The ultimate load capacity of the Ganga sand (without grouting) sample was 0.4032kN, which can be seen in Fig.4.
Fig.5 shows the load settlement curves for the sand grouted with cement at different w/c ratios. The ultimate load carrying capacity for different consistency cement grouts are shown in the Table.3.

Table 3. Ultimate load carrying capacity of cement grouted sand

w/c ratio	8:1	7:1	6:1	5:1
Ultimate load capacity (after 5 day curing)	3.2579	3.4907	3.9512	4.4619

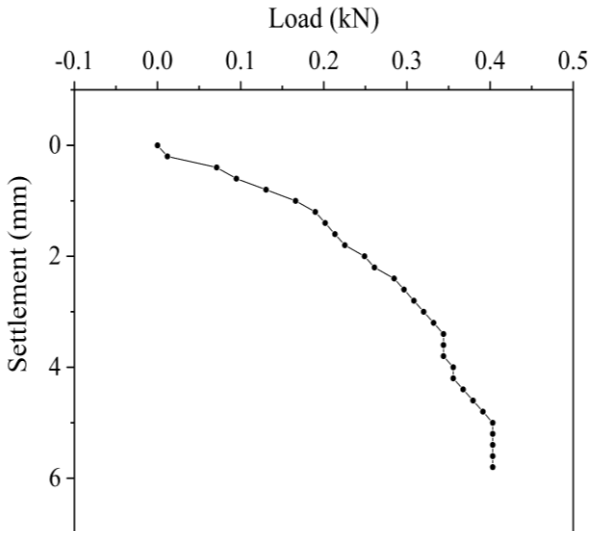

Fig. 4. Load settlement curve for local Ganga sand (without grouting)

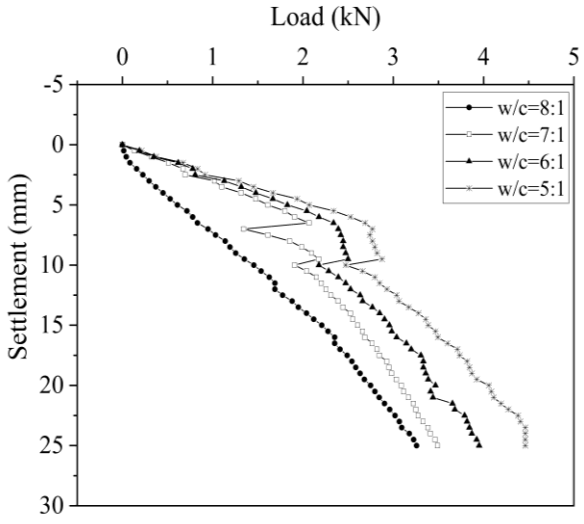

Fig. 5. Load settlement curves for cement grouted Ganga sand

It can be observed from the Table 3 that ultimate load carrying capacity increases as the water content decreases but we have to restrict the consistency below w/c 1:5, due to the problems involved by high viscosity and flowage. In Fig.5, it can be seen that as the consistency increases there is a sharp decrement in load. The layer of cement get harden at one place because of uneven distribution and high viscosity of cement paste and could not penetrate further. When this layer breaks, it causes a sharp sudden

decrement in load which can be observed in the graph presented in Fig.5 as a sharp local failure from 7 to 10 mm with increase in consistency. There is about 8.08 times increment in ultimate load carrying capacity for w/c 1:8 cement grouted sand, 8.65 times improvement for w/c 1:7, 9.79 times for w/c 1:6 and 11.06 times for w/c 1:5 as compared to non-grouted sand.

4 Conclusions

The study is focused on the ultimate load carrying capacity improvement of grouted sand. The grouting efficiency depends on the penetration of the cement grout through the pores of sand. It can be seen that ultimate load carrying capacity increases 8 to 11 times after 5 days of curing as grout ratio decreases. This not only increases the bearing capacity but also reduces the settlement under same load. Improvement in strength parameters with cement grouting were also seen in previous studies [9]. This could be excellent for reducing the permeability and blocking the seepage of water under the structure.

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