

## **EFFECT OF PERMEATION GROUTING USING CEMENT BENTONITE GROUT IN SANDY SOIL**

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### **ABSTRACT**

*Grouting is the process of ground improvement techniques which is used to improvise the foundation where there is loose state of the soil. Grouting can be classified as permeation grouting, compaction grouting or hydraulic fracturing. Permeation grouting is an effective way to send the grout into the ground without disturbing the soil structure. In this investigation, an attempt is made to study the effect of cement with bentonite grout in improving the bearing capacity of the sandy soil. Cement bentonite grout with different ratio of 10:1 ( Water: Cement +Bentonite) , 9:1, 8:1, 7:1, 6:1, 5:1, 4:1 are injected into the soil. Grouting experiment is performed with perforated PVC pipe in a tank of 20cm x 20cm x 20cm sandy soil. To study the improvement in the strength property of the grouted soil the plate load test is performed with 5cm x 5cm plate on the grouted sand after 3 days curing and 7 days curing. The experimental results revealed that the increase in cement bentonite content increases load carrying capacity of the sandy soil.*

### **INTRODUCTION**

Grouting is the process of ground improvement attained by injection of a fluid like material that is capable of forming a gel and binding the soil particles. Grouting can be permeation grouting, compaction grouting or hydraulic fracturing. Permeation grouting involves the free flow of grout into the soil voids with minimal effect. Grout materials may be solution grouts or suspension grouts. Permeation grouting technique is generally used to reduce ground permeability and control ground water flow, but it can also be used to strengthen and stiffen the ground (CIRIA, 2000).

Dr. Abdel- Monem Moussa et al.,(2007) has made a conclusion in their journal that as the “compressive strength of the grout decrease the bentonite content and the water content in the slurry is increases.” In their study explains the observing nature of the bentonite is more when compare with the other admixtures which is added in the slurry.

N.G. Terezopoulos et al., (1987) concluded that multipack techniques of tunnel grouting can be adopted to control ground water in flow problems of tunnel in water bearing and weak ground”. A.Bezuijen et al., (2007) concluded that reduced injection pressure will lead to a reduced cake thickness because both bleeding and leak-off will be reduced. It also explains about the grout travelling which make the bentonite as a free flowing nature that leads to the thickening the grout so that it increases its strength.

Suat Akbulut et al. (2002) concluded that the soil particle size and the cement maximum particle size have important effects on the successful grouting”. Purbi Sen et al. (2011) concluded that, it is desirable to use a mixture of lime and cement or pretreatment of soil with lime before use of cement or use of lime only if possible. Costas.A.Anagnostopoulos, (2005) has concluded that the combination of such material with cement in grouting purpose with respect to water cement ratio contributes significantly to the improvement of grouted soil.

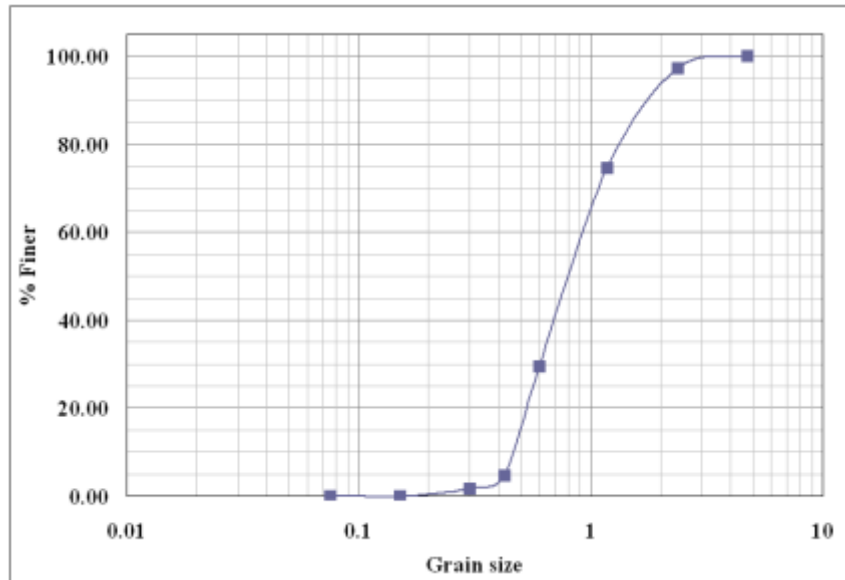


Fig. 1 Grain size distribution curve of the sand

**MATERIALS**

Table 1 Properties of the sand

Specific Gravity	Coarse Sand, %	Medium Sand, %	Fine Sand, %	D <sub>60</sub> , mm	D <sub>30</sub> , mm	D <sub>10</sub> , mm	C <sub>c</sub>	C <sub>u</sub>	e <sub>max</sub>	e <sub>min</sub>	Classification
2.6	25	70	5	0.9	0.6	0.47	0.85	1.91	0.71	0.48	SP

Locally available river sand is utilized for this study and the properties of the sand are given in table 1. The grain size distribution curves of these fractions are shown in fig.1. The cement used for the study is 43 grades Portland Puzzolona Cement, the properties of which are given in table 2.

Table 2 Properties of the cement

Grade	Specific Gravity	Fineness, %	Consistency, %	Initial Setting Time, min
PPC	3.15	95	35	30

After attaining the entire preliminary test in the bentonite their properties is given in table 3 which is used for this study

Table 3 Properties of bentonite

Liquid limit (%)	Plastic limit (%)	Shrinkage limit (%)	F.S.I	Specific gravity
270	75	1.24	320	2.68

## METHODOLOGY

For preparing permeation grouted samples, a tank of size 20cm x 20cm x 20cm is fabricated with poly-carbide sheet. The sand to be grouted is filled in the tank at the loosest unit weight of  $17.7 \text{ kN/m}^3$ , corresponding to initial void ratio ( $e_{\text{max}}$ ) of 0.71. Fig. 2 shows the tank and pipe setup for grouting process. Four PVC Pipes of 20 mm diameter are used for the grouting, with perforations in surface of the pipe with 3mm diameter which are 36 in number for each pipe. The bottom of the PVC pipe is plugged so as to disperse the grout circumferentially and make the grouting more effective.



Fig. 2 Tank set up after the grout

The grout which is prepared at water: cement bentonite ratio of 10:1, and agitated well to get uniform grout solution is poured into the four PVC pipes uniformly. In order to reduce the chances of segregation of the grout, the grout is agitated and then poured. The procedure is repeated for water: cement ratios of 9:1, 8:1, 7:1, 6:1, 5:1 and 4:1. The Viscosity of the cement grout is determined with Marsh funnel viscosity test (ASTM D6910-04).

The grouted sample was kept under moist condition for a curing period of 3 days and 7 days. The notation followed for the mix proportion is given in table 3.

Table 4 Mixing proportions of Grout and their notations

Notation	Water	Cement	Bentonite
<b>GB1</b>	10	1	10%
<b>GB2</b>	9	1	10%
<b>GB3</b>	8	1	10%
<b>GB4</b>	7	1	10%
<b>GB5</b>	6	1	10%
<b>GB6</b>	5	1	10%
<b>GB7</b>	4	1	10%

## **EXPERIMENTAL SET UP**

The grouted sand which is cured for 3 days is placed in the Triaxial loading frame to perform the plate load test. The plate is of 5cm x 5cm and 4mm thick. Fig 4 shows the experimental setup of performing the plate load test. Data logger is used to monitor the load from the load cell and displacement from the LVDT. Care is taken to load the grouted sand specimen centrally.



Fig.3 Experimental Setup

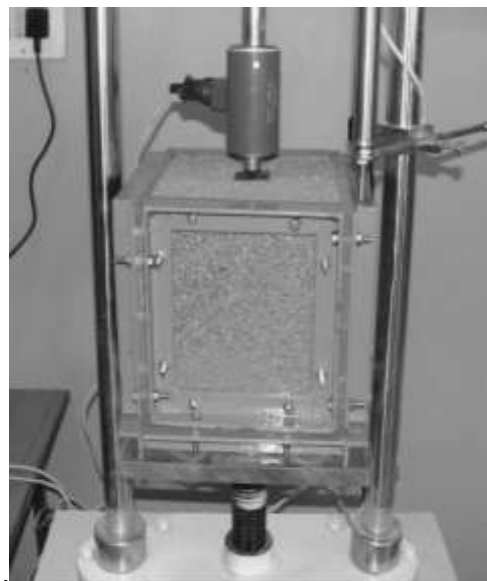


Fig.4 Plate Load test

## RESULTS AND DISCUSSIONS

### Effect of density on

To determine the increase in the strength of the grouted sand, the plate load test is conducted in the same tank with sand loosely filled without grouting. Fig 5 shows the load settlement curve for the sand without grouting, the ultimate load being 0.09 kN. Then sand bed prepared at a unit weight of  $13.1 \text{ kN/m}^3$  (in the loosest state) is grouted with the help PVC pipes and is cured for a period 3 days and 7 days. The efficiency of grouting mainly depends upon the penetration of cement grout through the pores of sand. Therefore the plate load test determination is very much necessary to assess the increase in strength of the grouted soil mass.

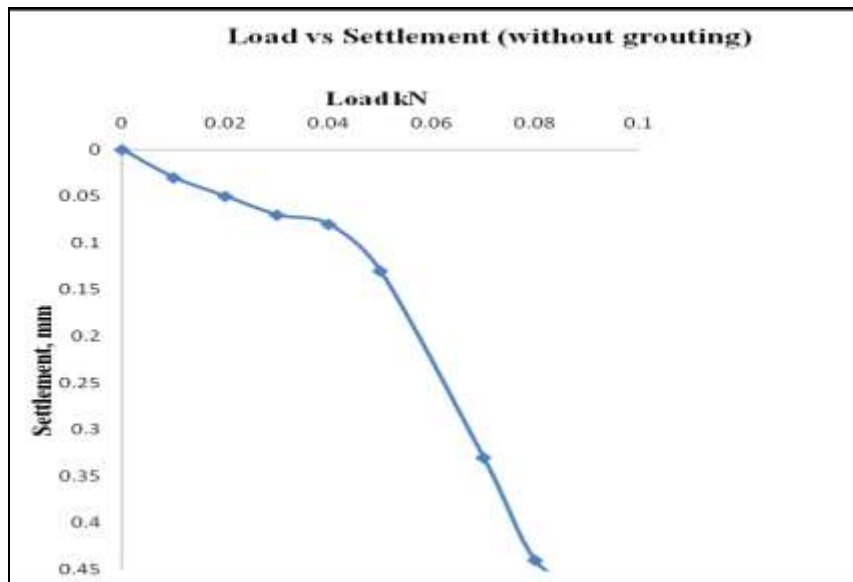


Fig.5 Load Settlement curve for the loose state of soil without grouting

Fig.6 and 7 show the load settlement curve for varying water cement with bentonite solution for the ratios from 10: 1 to 4:1 for 3 days curing of permeation grouted sand in the loose state. From the graph it can be seen that as the grout ratio decreases the ultimate load increases by 5 to 18 times more than the sand without grouting for 3 days curing. In case of 7 days curing the increase in ultimate load is 15 to 30 times more than the sand without grouting.

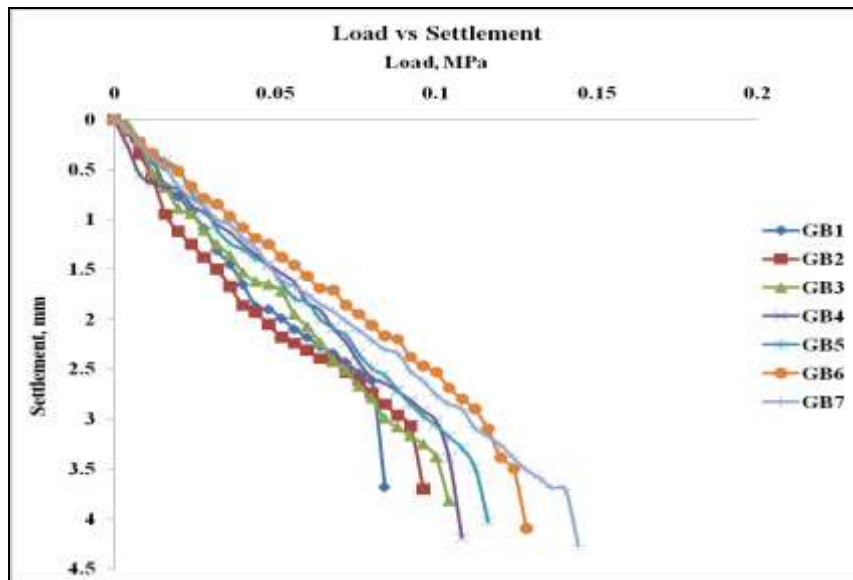


Fig. 6 Load Settlement curve – Loose State; 3 days Curing

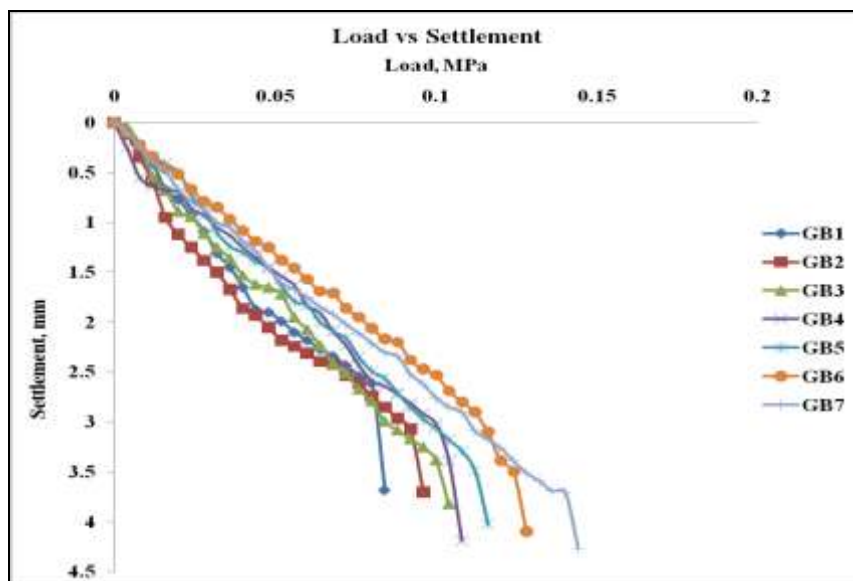


Fig. 7 Load Settlement curve – Loose State; 7 days Curing

Fig.8 and 9 show the load settlement curve for varying water cement ratios from 10: 1 to 4:1 for 3 days curing of permeation grouted sand in the medium dense state. From the graph it can be seen that as the grout ratio decreases the ultimate load increases by 11 to 20 times more than the sand without grouting for 3 days curing. In case of 7 days curing the increase in ultimate load is 18 to 50 times more than the sand without grouting.

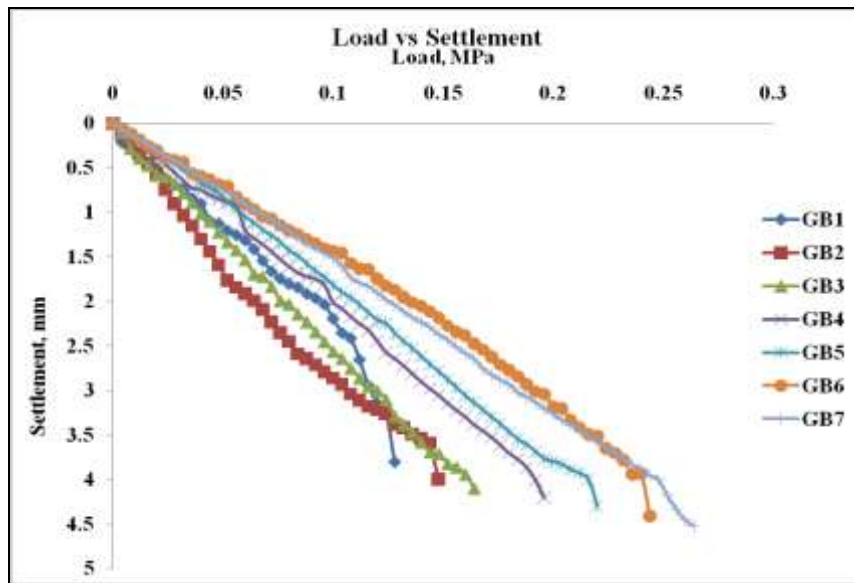


Fig. 8 Load Settlement curve – Medium dense State; 3 days Curing

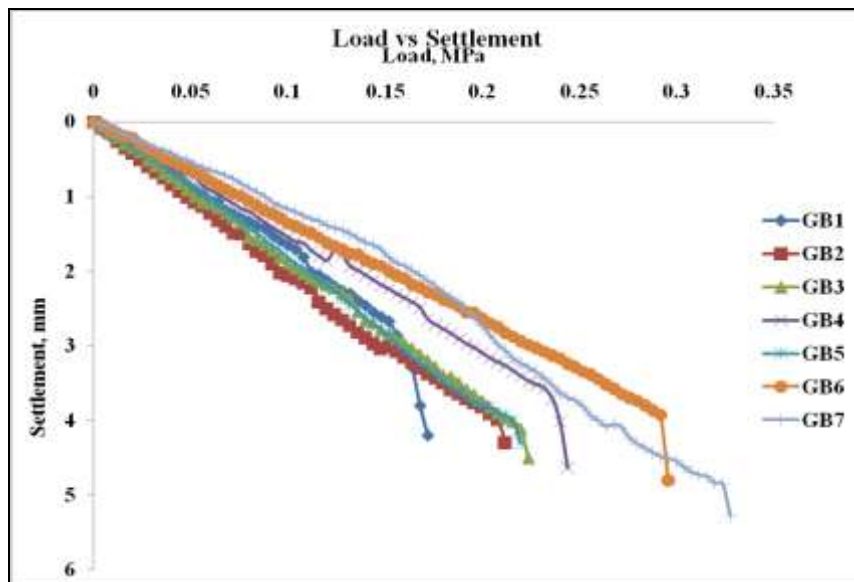


Fig. 9 Load Settlement curve – Medium dense State; 7 days Curing

The ultimate load determined from the load settlement curve for various grout ratios with different curing period of 3 days and 7 days is tabulated in table 5 for the grouting in loose state.

Table 5 Test Results of Cement Grout in Loose state

Grout ratio	Marsh Funnel Viscosity	Ultimate Load test (kN)	
		3 day curing	7 day curing
10:1	29.10	0.53	1.5
9:1	29.31	0.70	1.56
8:1	29.63	1.06	1.87
7:1	30.07	1.53	2.05
6:1	30.53	1.78	2.34
5:1	31.01	1.90	2.57
4:1	32.31	2.40	3.40

Table 6 show the ultimate load determined from the load settlement curve for various grout ratios with different curing period of 3 days and 7 days for the grouting in medium dense state.

Table 6 Test Results of Cement Grout in medium dense state

Grout ratio	Marsh Funnel Viscosity	Ultimate Load test (kN)	
		3 day curing	7 day curing
10:1	29.10	1.00	1.55
9:1	29.31	1.22	1.63
8:1	29.63	1.37	1.75
7:1	30.07	1.59	2.22
6:1	30.53	1.9	2.47
5:1	31.01	2.02	2.65
4:1	32.31	2.27	3.62

From the values of table 5 and 6 a plot is made between void ratio and ultimate load. Fig. 10 shows that as the void ratio increases the ultimate load decreases.



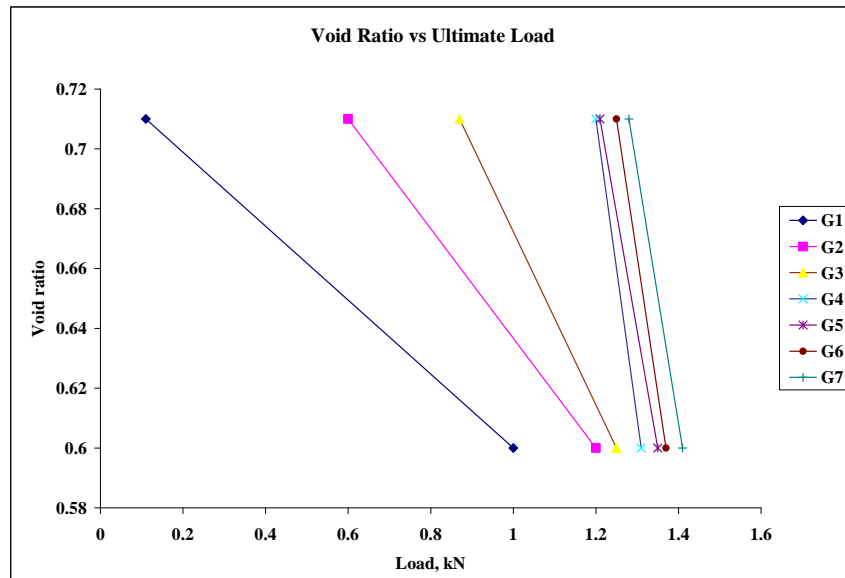


Fig. 10 Relationship between void ratio and ultimate load - 3 days curing

From the values of table 5 and 6 a plot is made between funnel viscosity and ultimate load.

Fig. 11 shows that as the funnel viscosity increases the ultimate load increases.

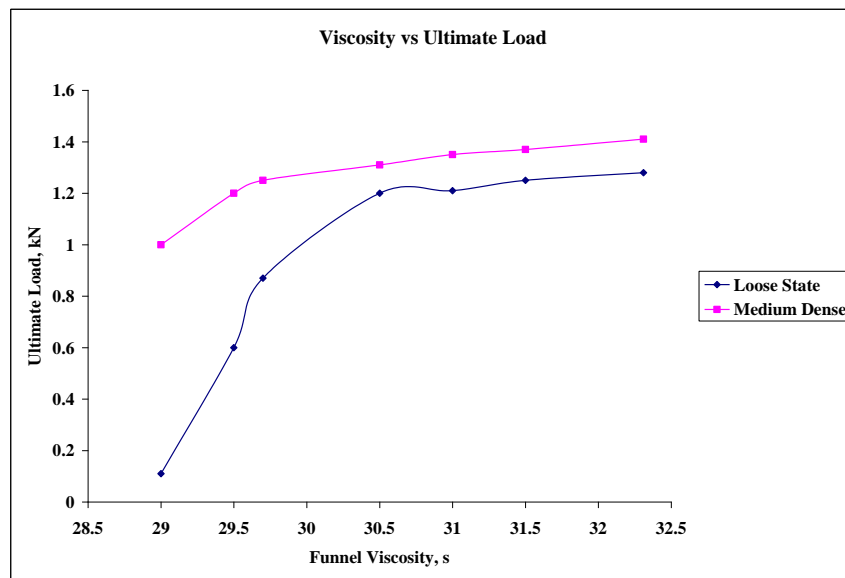


Fig. 11 Relationship between Funnel viscosity and ultimate load - 3 days curing

## CONCLUSIONS

The efficiency of grouting mainly depends upon the penetration of cement grout through the pores of sand. The following conclusions are drawn from the plate load tests. It can be seen that as the grout ratio decreases the ultimate load increases by 5 to 18 times for 3 days curing and 15 to 30 times for 7 days curing in case of loose state of soil (void ratio – 0.6). Whereas in the case of medium dense state ( void ratio – 0.55) it can be seen that as the grout ratio decreases the ultimate load increases by 11 to 20 times for 3 days curing and 18 to 50 times

for 7 days curing. Also it can be concluded that as the void ratio and grout ratio decrease the ultimate load increases. Moreover the funnel viscosity of the grout solution shows that increase in the viscosity increases the ultimate load.

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