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Improvement of Coarse Grained Soil by Permeation Grouting Using Cement Based HPMC Grout

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Abstract- **Permeation grouting is an effective way to improve the engineering properties of coarse grained soil by injecting the grout into the ground without disturbing the soil structure. In this investigation, an attempt is made to study the effect of cement biopolymer (Hydroxy Propyl Methyl Cellulose-HPMC) grout, an eco-friendly product in the coarse grained soil using permeation grouting. The cement biopolymer grout is injected into the soil specimen by changing water cement ratio ranging from 4:1, 6:1, 8:1, and 10:1 in an acrylic tank of size 50cm x 50cm x 50cm. The grouted samples are subjected to plate load test after 7 days of curing period. The results of this study conclusively proved that the strength of the soil specimens grouted with cement biopolymer is higher compared to that of the cement grout specimens and also revealed that the decrease in water content in grout increases load carrying capacity of the sandy soil.**

Keywords **– Soil Improvement, Biopolymer, HPMC, Permeation Grouting, Plate Load Test, Coarse Grained Soil**

I. INTRODUCTION

The term Ground improvement and ground modification refers to any procedure undertaken to increase the shear strength, decrease the permeability and compressibility or otherwise render the physical properties of soil more suitable for projected engineering use. The constructional activities in the coastal belt of our country often demand deep foundations because of the poor engineering properties and the related problems arising from weak soil at shallow depths [1]. The soil profile in coastal area often consists of very loose sandy soils extending to a depth of 3 to 4 m from the ground level underlain by clayey soils of medium stiffness. The structures built on such soils may suffer from excessive settlements and would lead to punching shear failure. Grouting is the suitable technique in improving the weak soil.

Grouting technique finds applications in case of seepage control in rock and soil under dams, advancing tunnels, cut off walls etc (Nonveiller, 1989 [10]). The main purpose of grouting is to fill the voids of the formation material by replacing the existing fluids with the grout and thereby improving the engineering properties of the medium, especially reducing the permeability.

Over the past years, many types of chemicals have been used for geotechnical applications. But generally, chemical grouts are toxic and hazardous in nature. This necessitates the need to do research in finding alternate ecofriendly materials for ground improvement. It seems that many natural polymers (Biopolymers) can be used as substitute for conventional components of grouting materials. Hence in this study an attempt is made to use the biopolymer (Hydroxy Propyl Methyl Cellulose-HPMC) as an additive with the cement grout to study the improvement of the soil property. Hamid Reza Khatami et al. [2] have concluded that, biopolymers can effectively improve the strength characteristics of sand without causing environmental toxicity. Laetitia Patural et al. [3] have concluded that, cellulose are thickener, good binder, film former and used as additives to improve the cement based material and also improve the properties of mortar such as water retention, workability, and consistency of material. P. Dayakar et al. [4] have concluded that, permeation grouting is an effective way to send the grout into the ground without disturbing the soil structure. The increase in cement content increases load carrying capacity of the sandy soil.

II. MATERIALS

Materials involved in grouting process are soil and grout materials. In this study, the grout materials are cement and HPMC (cellulose) since it a biopolymer grout.

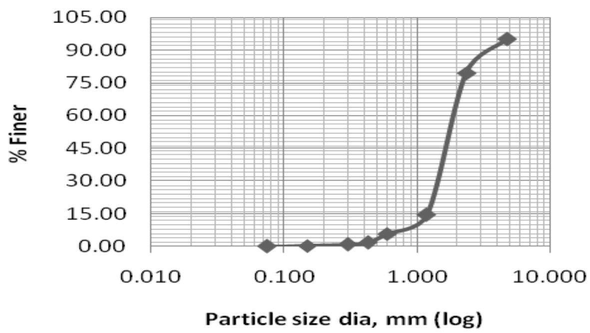

Fig. 1 Grain size distribution of soil

Locally available Palar river sand is utilized for this study and the properties of the sand are given in table I. The grain size distribution curve of the soil used is shown in fig. 1. From the grain size distribution curve [8], the Coefficient of curvature (Cc) and Coefficient of uniformity (C_u) are calculated and tabled in table I. Also the other properties such as the Specific gravity, maximum and minimum void ratio are also calculated as per standards [7] and given in the table.

A. Cement

The cement used for the study is 53 grade Ordinary Portland Cement. The basic properties of the cement used are determined as per Indian Standards and the values are given in table II. HPMC is a naturally found biopolymer produced by living organisms. The biogenic nature of biopolymer is expected to greatly reduce the environmental impact. The properties of the HPMC are tabulated in table III.

TABLE I
PROPERTIES OF SOIL SPECIMEN

Properties	Values
D_{60}, mm	1.9
D_{30}, mm	1.5
D_{10}, mm	1
C_c	1.2
C_u	1.9
Classification	SP
e_{max}	0.67
e_{min}	0.50
Specific Gravity (G)	2.6

TABLE II
PROPERTIES OF CEMENT

Properties	Values
Grade	OPC -53
Specific Gravity	3.15
Fineness, %	93
Consistency, %	35
Initial Setting Time, min	32

TABLE III
PROPERTIES OF HPMC

Properties	Values
Formula	$(C6H10O5)n$
Density	1.26 – 1.31 g/cm^3
pH (25° C)	6.08
Methoxyl Content (wt%)	28.1
Appearance	White powder

B. Preparation of Cement Biopolymer Grout

The porosity (n) is calculated from the void ratio (e_{max}) of the soil specimen which is placed in the Acrylic tank of size 50cm x 50cm 50cm in loose state. Based on porosity the amount of grout solution to be filled is calculated for water cement ratios 4:1, 6:1, 8:1 and 10:1. With this cement grout, biopolymer (HPMC) is used as an additive. HPMC of 1 % by weight of cement is added as dry mix to the cement. Then the prepared grout is mixed thoroughly and the consistency of grout is maintained throughout [6]. The soil is grouted with two types of grout materials namely cement grout and cement biopolymer grout. Since the testing is done in various specimens, the notations are assigned for the grouts as mentioned in table IV.

The fluidity of grouts was characterized with a Marsh funnel viscosity test [9]. The test consists of measuring the flow time of grouts through a cone with an outlet opening of 5 mm.

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TABLE IV
NOTATIONS FOR GROUT SOLUTIONS

Grout Type	Notation	
	Cement	Cement Biopolymer Grout
4:1 Water cement ratio	C1	G1
6:1 Water cement ratio	C2	G2
8:1 Water cement ratio	C3	G3
10:1 Water cement ratio	C4	G4
Ungrouted Soil	Loose state	Medium dense state
	G5	G6

The flow time of the grout reflects the level of viscosity. The Marsh values of the cement grout and cement biopolymer grout are shown in table V. It can also be seen from table, the fluidity of grouts decreased by increase in water/solid ratio.

TABLE V
MARSH CONE VISCOSITY OF CEMENT AND CEMENT BIOPOLYMER GROUT

Specimen Type	Marsh Value, sec
C1	29.50
C2	27.84
C3	26.98
C4	26.81
G1	30.50
G2	29.19
G3	28.46
G4	28.01

III. METHODOLOGY

Permeation grouting of sandy soil with cement biopolymer grout is done in an acrylic tank (50cm x 50cm x 50cm) in room temperature of 28^{o}C. The tank is made completely dry before filling the sand. One-third of the tank is filled with sand. Then the grout pipe is placed in the tank in such a manner to distribute the grout uniformly for the entire tank as shown in fig. 2. Then the soil is filled in the tank without disturbing all the four grout pipes. The mixture of water, cement and biopolymer (HPMC) is poured inside the mixing tank as shown in fig.3.

An agitator is placed inside the funnel for continuous mixing of grout solution. By control valves, grout solution is distributed to all four grout pipes equally. The grout solution will flow through the soil particles by permeation. After filling the grout solution into the sandy soil, the grout pipes are removed from the tank gently without disturbing the sand and replacing the gap of the grout pipes with sand.

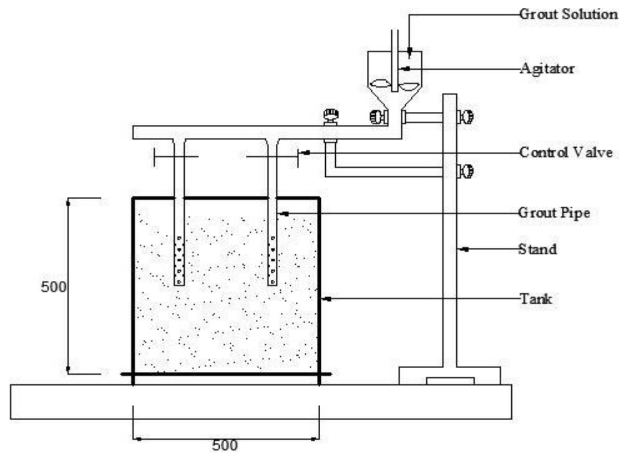

Fig. 2 Schematic representation of grouting

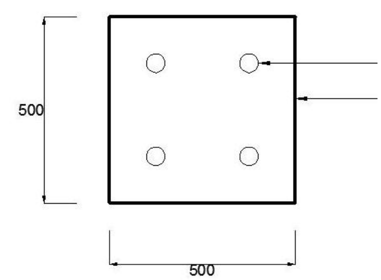

Fig. 3 Plan view of grout pipes

IV. EXPERIMENTAL INVESTIGATIONS

A. Plate Load Test Setup

The test setup consists of a loading frame, base for placing the soil tank and loading jack as shown in fig. 4. The grouted soil in acrylic tank (50cm x 50cm x 50cm) is placed in the loading setup and the axial load is applied to the sample through the center of the plate, via the load cell and the loading frame. The axial displacements are measured by the Linear Variable Displacement Transformer (LVDT) which is mounted on the tank.

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A steel plate (14cm x 14cm) is placed on the top of the soil specimen at the center. A steel spherical ball is placed over the centre of the loading test plate. A load cell is placed over the spherical steel ball, in order to take the readings of the load applied. From this test [6] the load intensity and the corresponding settlement values are recorded using a Data Logger which is connected to a laptop.

Fig. 4Typical Experimental test setup

V. Results And Discussions

Plate load test is done on ungrouted soil in different states such as loose and medium dense state, and the values of Load intensity and settlement are recorded. A plot between load intensity and settlement is shown in fig. 5. Similarly, grouted specimens are subjected to the plate load test after an effective curing period of 7days, and the values are recorded.

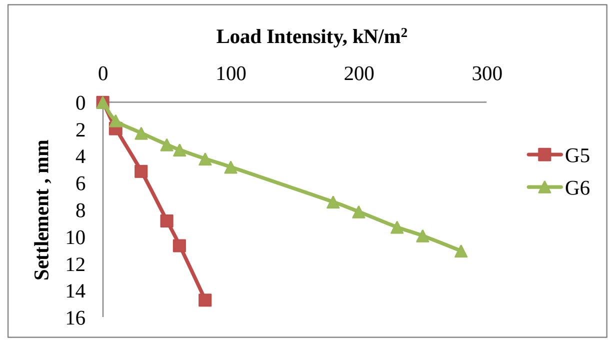

Fig. 5 Plot between load intensity and settlement -ungrouted soil

Fig. 6 shows the plot between the load intensity and settlement for the soil specimens grouted with cement grout C1, C2, C3 and C4 respectively. From the plot, it can be seen that type C1 is more effective than the other types.

Similarly, the plate load test results of cement biopolymer grouted specimens namely G1, G2, G3 and G4 are observed and recorded.

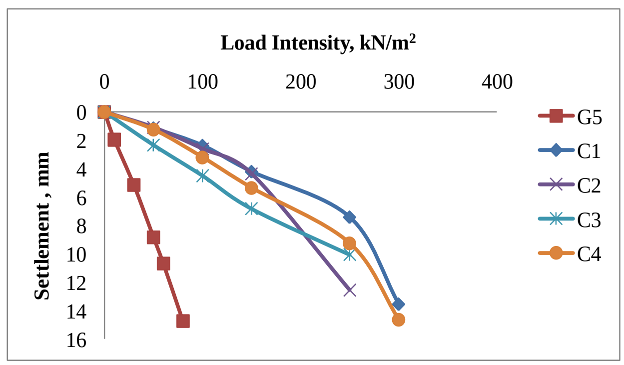

Fig. 6 Plot between load intensity and settlement - grouted soil (Cement grout)

The corresponding load settlement curve is shown in fig. 7. From the plot, it can be observed that the type G2 is more effective than the other types.

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To compare the effectiveness of various grouts namely cement grout and cement biopolymer grout with different water cement ratios, an allowable settlement of 10 mm is considered, and the corresponding load intensities are noted and tabulated in table VI.

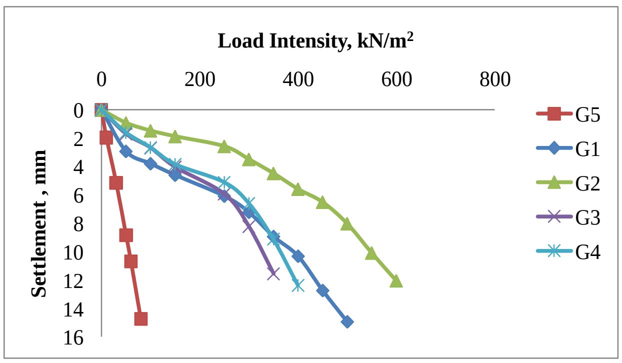

Fig. 7 Plot between load intensity and settlement - grouted soil (Cement Biopolymer grout)

A plot between the allowable bearing capacity corresponding to 10 mm settlement and specimen type is shown in fig. 8, which clearly shows the effectiveness of cement biopolymer grout.

TABLE VI
ALLOWABLE BEARING CAPACITY (10MM SETTLEMENT) OF CEMENT GROUT AND CEMENT BIOPOLYMER GROUT

Specimen type	Allowable Bearing Capacity, kN/m^2
G5	56.46
C1	230.10
C2	232.00
C3	199.49
C4	208.67
G1	390.10
G2	498.62
G3	281.36
G4	315.14

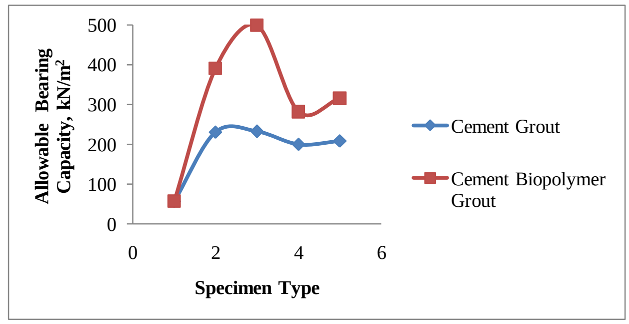

Fig. 8 Plot between Allowable Bearing capacity (10 mm settlement) and Specimen type

VI. CONCLUSION

Strength of cement grouted specimens when compared with the ungrouted specimen gives up to 4 times increase in load carrying capacity in case of type C2, which may be attributed to the reduction of water in the grout. Similarly, the strength of biopolymer grouted specimens when compared with the ungrouted specimens gives up to 8.8 times increase in the load carrying capacity in case of type G2 which may be attributed to reduction in water content and the presence of biopolymer.

The efficiency of grouting mainly depends upon the penetration of cement grout and the cement biopolymer grout through the pores of sand. Thus the present study undoubtedly proves the importance of an admixture like biopolymer in improving the effectiveness of grouting loose sandy beds.

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