

Comparative Study on Permeation Grouting with Biopolymer and Chebolic Myrobalan Grout in Sandy Soil

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ABSTRACT: One of the effective ways to improve the engineering properties of the sandy soil is Permeation Grouting. In this technique the grout is injected into the ground without disturbing the soil structure. In this investigation an attempt is made to study the comparison of permeation grouting with cement biopolymer grout and cement chebolic myrobalan grout. Bio polymer (Hydroxy Propyl Methyl Cellulose – HPMC) is an eco friendly product, and another eco friendly product which is the aqueous extract of Chebolic Myrobalan, the dried fruits of the Indian tree, Terminalia chebula, is used to prepare the grout solution with cement. The cement biopolymer grout, and cement chebolic myrobalan grout are 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, separately. The grouted samples are subjected to plate load test after 28 days of curing period. The results of this study conclusively proved that the strength of the soil specimens grouted with cement chebolic myrobalan grout is higher than that of cement biopolymer grout which is in turn higher compared to that of the cement grouted specimens. Test results revealed that the decrease in water content in grout increases load carrying capacity of the sandy soil.

KEYWORDS: Soil Improvement, Biopolymer, HPMC, Chebolic Myrobalan, Permeation Grouting, Plate Load Test, Sandy 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) and natural extract from herbs 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 and an aqueous extract of Chebolic Myrobalan, the dried fruits of the Indian tree, Terminalia chebula, are used to prepare the grout

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solution with cement 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.

P. Thirumalini et al 2011 [24] in their study they have concluded that the compressive strength Treating lime mortar with 5% herbal juice provides greater flexural, tensile and compressive strengths. K. Vignesh Bharathy et al.[25] studied the possibilities of using natural materials like “Terminalia chebula” (Kadukkai) as an admixture in lime and cement mortar, and showed that Terminalia chebula is effective in increasing both workability and compressive strength of lime mortar and decreased the porosity by half. Terminalia chebula when added to cement mortar has no effect on workability but increases the compressive strength by 1.48 times of reference mortar.

II. MATERIALS

The materials used in this study are soil and the grout materials are cement, biopolymer and chebolic myrobalan extract.

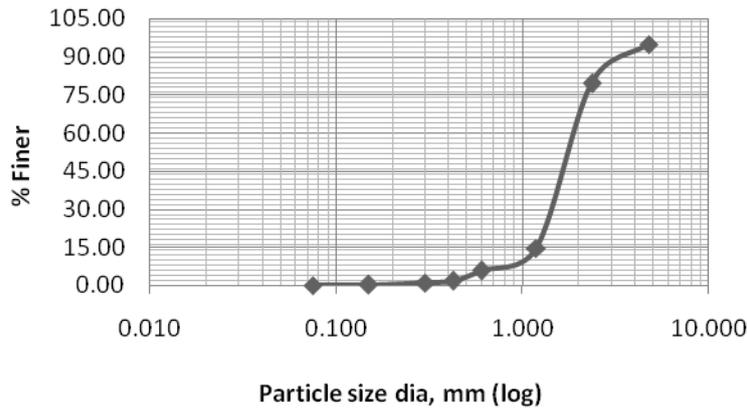


Fig. 1 Grain size distribution of soil

Locally available Palar river sand is utilized for this study and the properties of the sand are given in table 1. 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 (C_c) and Coefficient of uniformity (C_u) are calculated and tabulated in table 1. Also the other properties such as the Specific gravity, maximum and minimum void ratio are also calculated and given in the table 1.

Table 1 Properties of the Sandy soil used in this Study

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

A. Cement and Cement Grout

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 2. Based on the porosity of the soil in the tank the amount of grout solution to be filled is calculated for water cement ratios of 4:1, 6:1, 8:1 and 10:1. This cement grout is used for permeation grouting into the soil specimen and the test results are used for the comparison.

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Table 2 Properties of the Cement used in this Study

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

B. Preparation of Cement Biopolymer Grout

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 biopolymer are tabulated in table 3.

Table 3 Properties of the Bio Polymer (HPMC) used in this Study

Properties	Formula	Density	pH (25° C)	Methoxyl Content (wt %)	Appearance
Values	(C ₆ H ₁₀ O ₅) _n	1.26 – 1.31 g/cm ³	6.08	28.1	White powder

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 x 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 at the rate of 1 % by weight of cement, which is added as dry mix to the cement.

C. Preparation of Cement Chebulic Myrobalan Grout

A lean mix of 60g of Terminalia Chebula with 4000 ml of water is made, by soaking the dried fruits of Chebulic myrobalan in the water for 24 hours. Then the solution is filtered and is mixed with cement in the ratios of 4:1, 6:1, 8:1 and 10:1.

Then the prepared grout is mixed thoroughly and the consistency of grout is maintained throughout. The soil is grouted with three types of grout materials namely cement grout, cement biopolymer grout and cement chebulic myrobalan grout separately in different tanks. Since the testing is done in various specimens, the notations are assigned for the grouts as mentioned in table 4.

Table 4 Notations for Grout solutions

Grout Type	Notation		
	Cement	Cement Biopolymer Grout	Cement Chebulic Myrobalan Grout
4:1 Water cement ratio	C1	CB1	CCM1
6:1 Water cement ratio	C2	CB2	CCM2
8:1 Water cement ratio	C3	CB3	CCM3
10:1 Water cement ratio	C4	CB4	CCM4
UngROUTED Soil	Loose state	Medium dense state	Medium dense state
	G5	G6	G6

The fluidity of grouts is 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. The flow time of the grout reflects the level of viscosity.

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The Marsh values of the cement grout, cement biopolymer grout and cement chebolic myrobalan grout are shown in table 5. It can also be seen from table, the fluidity of grouts decreased with increase in water/solid ratio.

Table 5 Marsh cone viscosity of Cement grout, Cement Biopolymer grout and Cement Chebolic myrobalan grout

Specimen Type	C1	C2	C3	C4	CB1	CB2	CB3	CB4	CCM1	CCM2	CCM3	CCM4
Marsh Value, sec	32.31	30.53	29.63	29.05	30.50	29.19	28.46	28.01	29.46	27.45	26.22	25.06

A graphical representation of comparison between the cement grout, cement biopolymer grout and cement chebolic myrobalan grout with the Marsh value for various ratios from 10:1, 8:1, 6:1 and 4:1 is shown in fig.2. From the graph it can be seen that cement chebolic myrobalan grout is having more fluidity, than the cement biopolymer grout and cement grout.

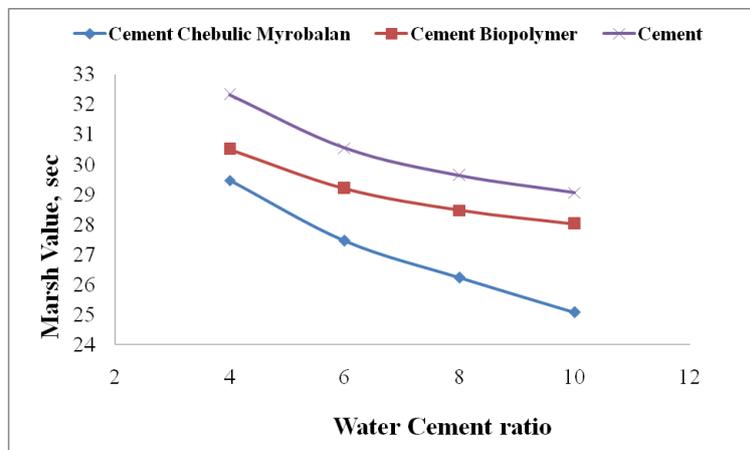


Fig.2 Graphical representation of comparison between the cement grout, cement biopolymer grout and cement chebolic myrobalan grout with the Marsh value for various ratios from 10:1, 8:1, 6:1 and 4:1

II. METHODOLOGY

Permeation grouting of sandy soil is done with cement grout, cement biopolymer grout and cement chebolic myrobalan grout each separately in different containers. The container is an acrylic tank of size 50cm x 50cm x 50cm. 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. 4. Then the soil is filled in the tank without disturbing the four grout pipes. The cement grout 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. The same procedure is followed for the cement biopolymer grout and cement chebolic myrobalan grout, separately in different containers.

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. 5. 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

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the Linear Variable Displacement Transformer (LVDT) which is mounted on the tank. A steel plate (14cm x 14cm) is placed on the top of the soil specimen at the center.

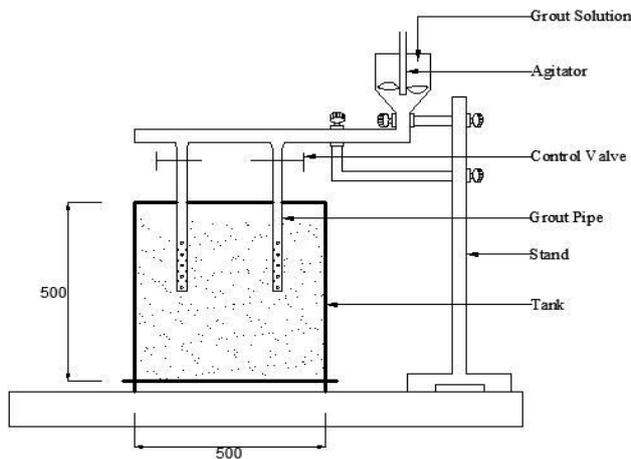


Fig. 3 Schematic representation of grouting

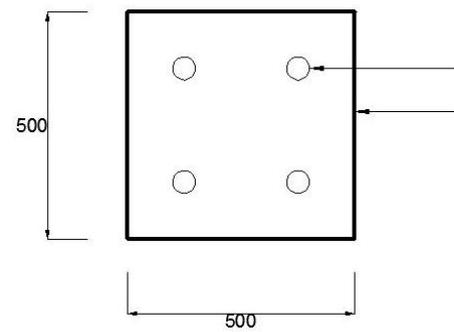


Fig. 4 Plan view of grout pipes

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. 5 Typical 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 28 days, and the values are recorded. From fig.6 it can be seen that the medium dense soil is taking more load when compared to loose state soil.

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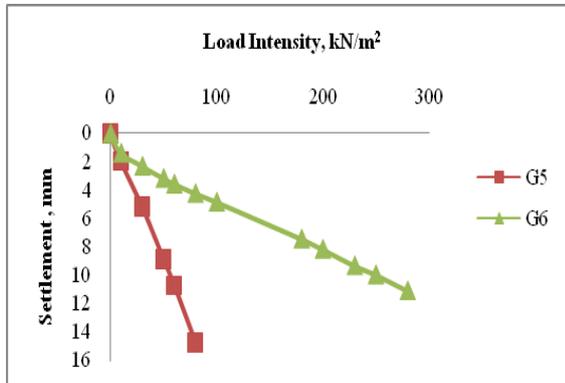


Fig. 6 Plot between load intensity and settlement - ungrouted soil

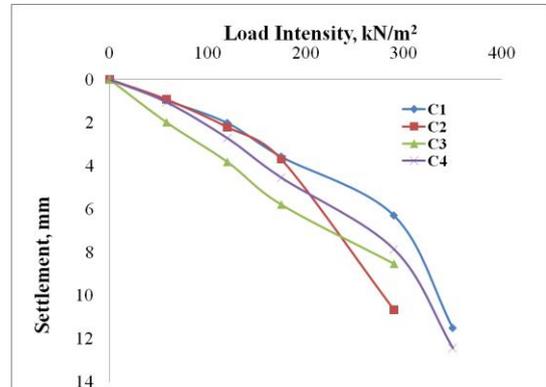


Fig. 7 Relationship between load intensity and settlement behaviour of loose state of soil grouted with cement grout solution after a curing period of 28 days

Fig.7 shows the plot between the load intensity and settlement for the soil specimens grouted with cement grout C1, C2, C3 and C4 respectively, for a curing period of 28 days in the loose state. From the graph it can be observed that C1 is having an increase of 88% in the load intensity for an allowable settlement of 5mm, when compared with C4. It is obvious that as the cement content increases the load carrying capacity also increases.

Similarly, the plate load test results of cement biopolymer grouted specimens namely CB1, CB2, CB3 and CB4 and cement chebulic myrobalan grouted specimens namely CCM1, CCM2, CCM3 and CCM4 are observed and recorded after a curing period of 28 days in the loose state. A comparison is made between the load settlement behaviour of the above said soil specimens in form of graphical representation as shown in fig. 8. From the fig. 8 it can be observed that the cement chebulic myrobalan grout is taking more load when compared to cement biopolymer grout. The increase in the load intensity is in the order of 3 to 8 times when compared for an allowable settlement of 5mm.

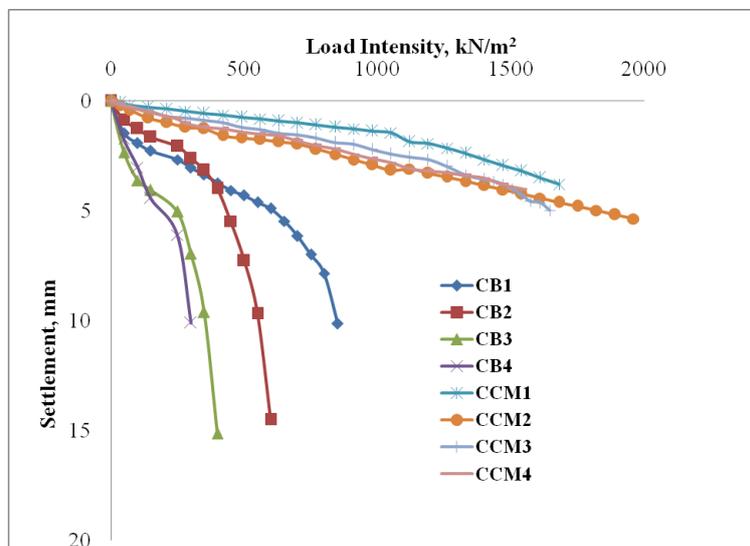


Fig. 8 Relationship between load intensity and settlement behaviour of loose state of soil grouted with cement biopolymer grout and cement chebulic myrobalan grout solution after a curing period of 28 days

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A plot between the allowable bearing capacity corresponding to 5 mm settlement and specimen type is shown in fig. 9, which clearly shows the effectiveness of cement chebulic myrobalan grout. The increase in the allowable bearing capacity is around 15% when CCM1 is compared with that of CCM4.

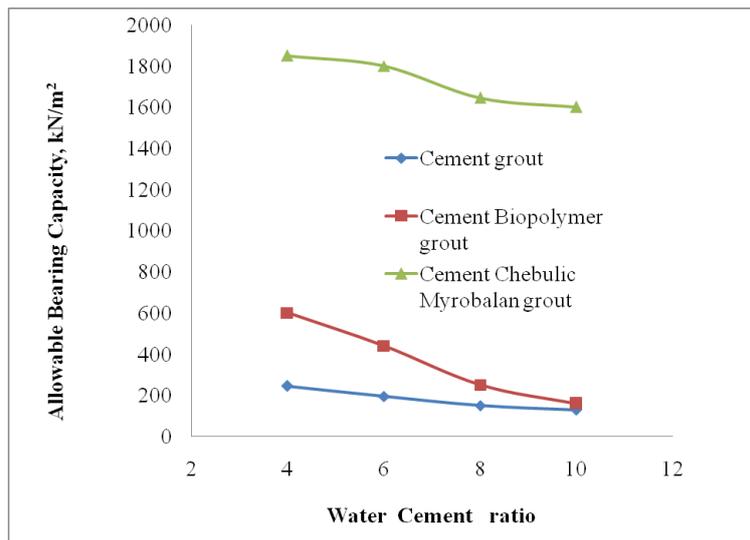


Fig. 9 Relationship between load intensity and settlement behaviour of loose state of soil grouted with cement biopolymer grout and cement chebulic myrobalan grout solution after a curing period of 28 days

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 times increase in the load carrying capacity in case of type CB2 which may be attributed to reduction in water content and the presence of biopolymer. Also the strength of cement chebulic myrobalan grouted specimens when compared with cement biopolymer grout the allowable bearing capacity shows an increase of 3 to 8 times, which may be attributed to the natural binding property chebulic myrobalan solution.

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

Based on the test results it can be concluded that cement chebulic myrobalan grouting is an effective technique to improve the bearing capacity and reducing the settlement of loose sandy soils.

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