"Assessment of Acacia Powder for the Stabilization of Clay Soil"

Saurabh Naresh Dekatey, R VinothKumar

Abstract*: Stabilization of soil improves the engineering properties by altering its behavior. Soil improvement is one of the essential uses of most geotechnical development systems, chemical treatment on soils by changing their peculiarity. In the present study the clay soil is treated with biopolymer namely Acacia Powder. Biopolymers are natural polymers produced by living organisms and are considered environmental friendly and sustainable materials. Biopolymers show superiority over petroleum based polymers in some environmental aspects. At present biopolymers are related mainly to the application of plants or vegetative cover. The major reason to adopt biopolymers is cost effectiveness and availability direct from trees without deforestation. The effectiveness of biopolymer is studied in terms of compaction characteristics, unconfined compressive strength (UCS) and California Bearing Ratio (CBR) value. The biopolymer is added in different proportions of 1%, 1.5%, 2%, 2.5% and 3% respectively for different curing periods and the results showed the improvement in soil behavior for construction purpose. The results showed the increase in strength characteristics of clay soil.

Index Terms: ***Soil Stabilization, Acacia Powder, Biopolymer, Clay soil.***

I. INTRODUCTION

Soil stabilization is a process of altering the behaviour of soil either by physical compaction or by adding chemicals to it. The country like India whose infrastructure is growing rapidly requires more stabilized land. On the other hand around 30% to 40% of India's land is covered with expansive soil. The expansive soil behaves critically when in contact with water i.e. change in volume, this damages the structure. For any land-based structure, the foundation plays a very important and has to be strong to support the entire structure. The easiest way to build a structure on such type of land is to replace the soil, but as per cost effectiveness this method cannot be used. The most common method of stabilizing the soil which is being used is cement and lime stabilization, but these conventional method has a major environmental drawback.[1] The production of cement creates a large amount of carbon footprint and the land which is treated with it cannot be used for any other purpose except construction. In lime stabilization a large amount of lime is needed and the lime ores are limited and that has to be used in proper manner. So in order to prevent conventional stabilization techniques there is necessity to find the environmental friendly material to stabilize the soil which can be used effectively as cement and lime.

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Biopolymers are the substances which can used as substitute for cement and lime for stabilizing soil. These are biodegradable polymers extracted from living organisms like plants, bacteria, algae, etc.[2][3][4] Acacia powder is one of the biopolymers which extracted from the barks or acacia tree by making a small cut on it thus there is no need of cutting whole tree. Thus more production of acacia will lead towards the afforestation. Biopolymers consist of polysaccharides, which are monosaccharide linked at different location which behave as a thickening and binding agent.

II. MATERIALS

A. Clay Soil

The soil sample was procured from Nagpur, Maharashtra. The soil was collected at a depth of 1.5 m from the top layer after removing plant roots and other vegetation matter. The soil was sun dried and pulverized to size passing through 2 mm sieve size. The results of index properties, Atterberg's limits, compaction characteristics and strength characteristics are shown in table 1. As per Indian Standard of Soil classification, the soil is classified as silty clay with the group symbol CH–MH, the compressibility and plasticity of soil is high and degree of expansion is very high. The soil posses low shear strength and is said to be medium stiff, and the soil is said to be poor for pavements. From the results obtained it is observed that the soil in problematic soil and not suitable for construction and need to be stabilized. The results from the various test has been mentioned in table 1.

Table 1. Properties of Untreated Soil.

S.No.	Properties of untreated soil	Results
1	Differential Free Swell	60%
2	Grain Size Analysis	Gravel = 0% Sand = 25.5% % of Combined Silt and Clay = 74.5%
3	Specific Gravity	2.71
4	Liquid Limit	57%
5	Plastic Limit	23%
6	Shrinkage Limit	9%
7	Plasticity Index	34%
8	Consistency Index	0.56
9	Optimum Moisture Content	19.7%
10	Maximum dry density	1.69 g/cc
11	Unconfined compressive strength	62.7 kN/m^2
12	California Bearing ratio	5.7 %

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B. Acacia Powder

Acacia powder, also known as Powder Arabic is extracted from the acacia tree by making a small cut in the bark of the tree. The major components of this powder are polysaccharides and glycoproteins which give its binding properties. It consist of D-galactose, L-arabinose, L-rhamnose, and uronic acid which gives it ionic characteristics[5]. This powder is a blend of polysaccharides and glycoproteins gives it the properties of a paste and fastener. It is a and variable blend of arabinogalactan oligosaccharides, polysaccharides, and glycoproteins. Polysaccharides are polymeric starch particles made out of long chains of monosaccharide units bound together by glycosidic linkages, and on hydrolysis give the constituent monosaccharides or oligosaccharides. They go in structure from straight to exceedingly fanned. Polysaccharides are regularly very heterogeneous, containing slight changes of the rehashing unit. The XRD Analysis of acacia powder is shown in fig. 1.

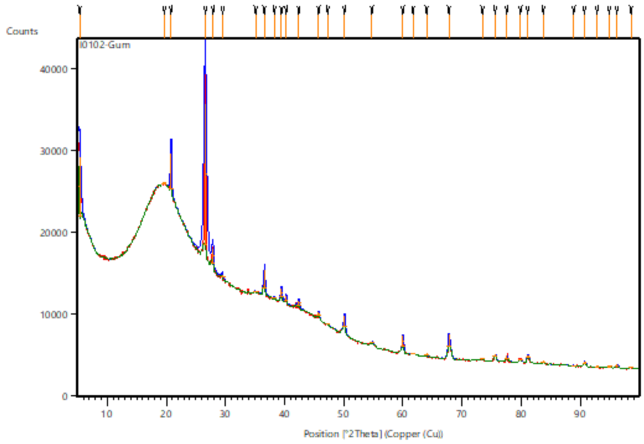

Fig. 1. XRD analysis of Acacia powder.

III. SAMPLE PREPARATION AND TEST PROCEDURE

The soil was sun dried and then pulverized, passing through 2 mm sieve. The acacia powder was added to soil in the proportion of 1%, 1.5%, 2%, 2.5% and 3%. The soil was mixed by dry process.

Standard Proctor compaction test was performed as per IS: 2720 (Part VII) 1980. The test was essential to determine the maximum dry density and corresponding optimum moisture content for clay soil for both untreated and treated soil with acacia powder at different concentrations.

A series of Unconfined Compressive Strength tests were performed according to IS: 2720 (PART X) 1991. To prepare homogenous specimen the soil stabilizing agent was mixed with soil in dry condition ant defined proportions addition of water at optimum moisture content and maximum dry density obtained from standard proctor test. Both treated and untreated soil samples were prepared of 76 mm X 38 mm cylindrical shape. The untreated soil samples were tested on the same day of their casting while the treated soil samples were tested on their prescribed curing days.

A series of California Bearing Ratio tests was performed before and after the soil was treated with acacia powder. To prepare homogenous specimen the soil stabilizing agent was mixed with soil in dry condition ant defined proportions addition of water at optimum moisture content obtained from standard proctor test. The tests were performed according to IS: 2720 (PART XVI) 1987. The untreated soil sample was tested on the same day of their casting while the treated soil samples were tested on their prescribed curing days.

IV. RESULTS

A. Compaction characteristics

The Standard Proctor compaction test were performed on the untreated as well as soil treated with biopolymer at different proportions of 1%, 1.5%, 2%, 2.5% and 3%. The study of compaction characteristics is essential as it affects the mechanical properties such as shear strength, bearing capacity and settlement. As per the results obtained it is observed that there is slight increase in maximum dry density of soil with the increase in proportion of acacia powder. The maximum dry density of soil has increased from 1.69 g/cc to 1.737 g/cc and optimum moisture content has increased from 19.7% to 22.8% with the inclusion of 3% of acacia powder to soil. The variation in optimum moisture content and maximum dry density is shown in fig. 2

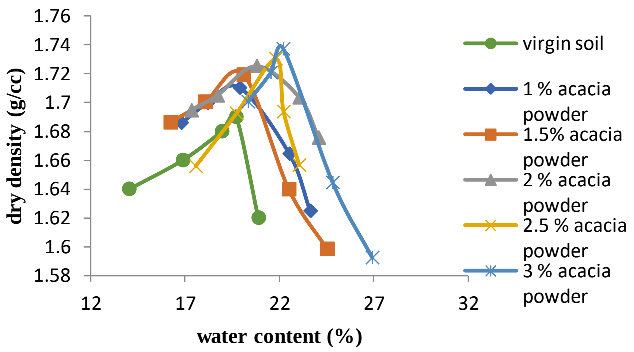

Fig. 2. Compaction curves for the treated soil.

B. Unconfined Compressive Strength

The strength behavior of the soil has been drastically changed after treating the soil with acacia powder. The acacia powder is added in different proportions of 1%, 1.5%, 2%, 2.5% and 3%. The strength characteristics have been observed without curing and curing the sample with each defined proportions for 3 days, 7 days, and 14 days. As per the results obtained it is observed that the unconfined compressive strength of soil has increased from 62.7 kN/m^2 to 203.3 kN/m^2 with inclusion of 3% acacia powder for 14 days curing period. The fig.3 implies that the most optimum gain in strength of soil is achieved at inclusion of 2.5% of acacia powder to the soil. It implies that the strength gain is directly proportional to the increase in proportion of acacia powder and curing periods.

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Table 2. Unconfined compressive strength for treated soil samples.

Soil + % of admixture	Unconfined compressive strength (kN/m^2)			
	Without curing	Curing Periods		
		3 days	7 days	14 days
Untreated soil	62.7			
Soil + 1% Acacia powder	68.67	85.35	138.63	141.73
Soil + 1.5% Acacia powder	74.6	92.48	153.38	158.27
Soil + 2% Acacia powder	84.63	101.77	174.04	176.53
Soil + 2.5% Acacia powder	93.36	116.72	195.44	196.22
Soil + 3% Acacia powder	100.9	148.02	202.49	203.03

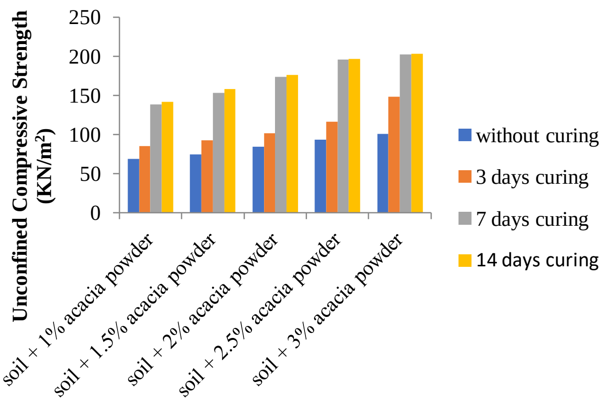

Fig. 3. Unconfined compressive strength for treated soil samples.

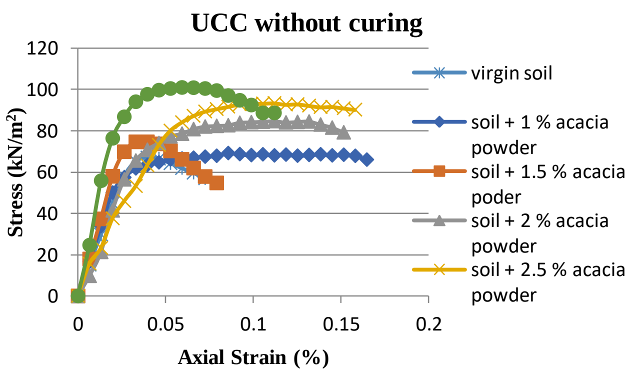

Fig. 4(a)

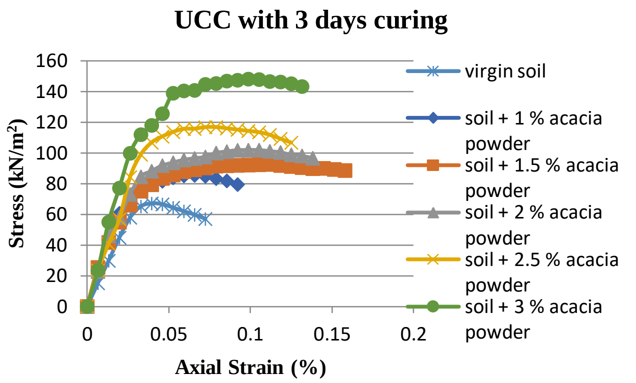

Fig 4(b)

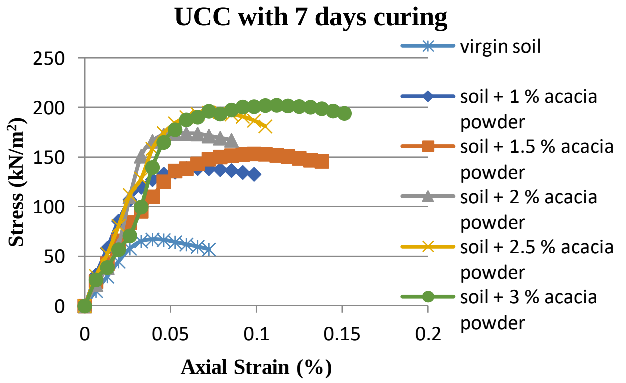

Fig 4 (c)

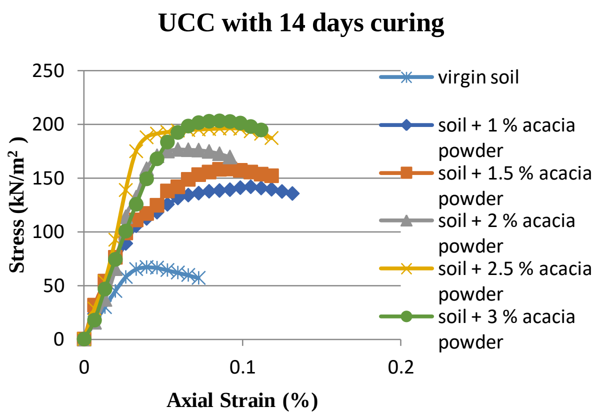

Fig 4(d)

Fig. 4(a)(b)(c)(d) Stress Strain curves for treated soil samples

C. California Bearing Ratio

California bearing ratio is one the major parameter to evaluate the strength of soil. Improvement in CBR value tends to stabilize the bearing capacity of the soil. The penetration in this test indicates the strength of the soil for subgrade. As per the results obtained is it observed that the CBR value of soil is increased from 5.7 to 9.5 after addition of 3% acacia powder for 14 days curing period. As per the fig.4 it is observed that at 2.5% acacia powder tends to most optimum gain in strength in soil.

It is observed that the addition of acacia powder is directly proportional to the gain in strength of soil. Fig 5 shows the following curve with the increase in strength of soil treated with acacia powder.

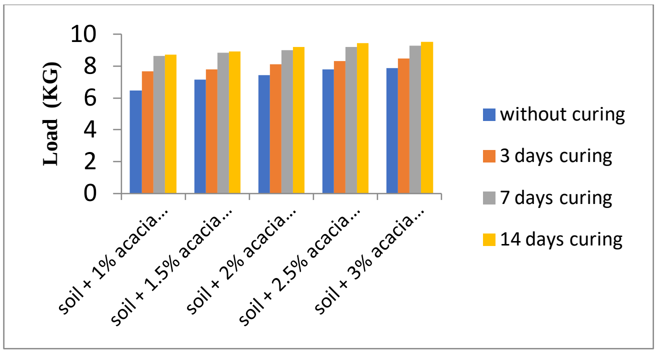

Fig. 5. California Bearing Ratio for Treated Soil

Table 3. California Bearing Ratio for Treated Soil

Soil + % of admixture	CBR Value (%)			
	Without curing	Curing Periods		
		3 days	7 days	14 days
Untreated soil	5.7			
Soil + 1% Acacia powder	6.47	7.66	8.63	8.707
Soil + 1.5% Acacia powder	7.14	7.81	8.85	8.93
Soil + 2% Acacia powder	7.44	8.11	9.00	9.22
Soil + 2.5% Acacia powder	7.81	8.33	9.22	9.45
Soil + 3% Acacia powder	7.88	8.48	9.3	9.52

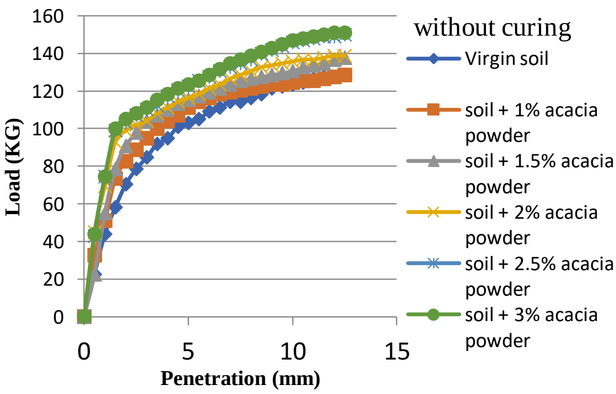

Fig. 6a

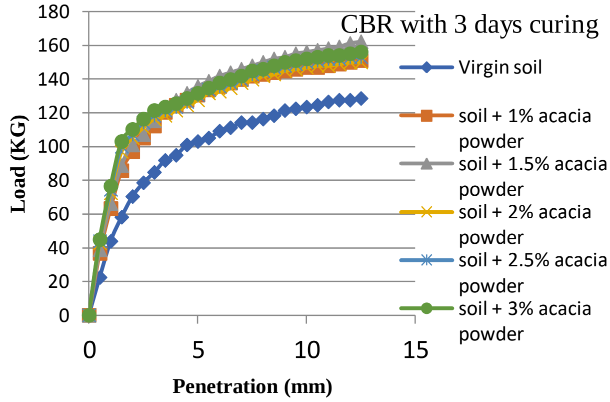

Fig. 6 (b)

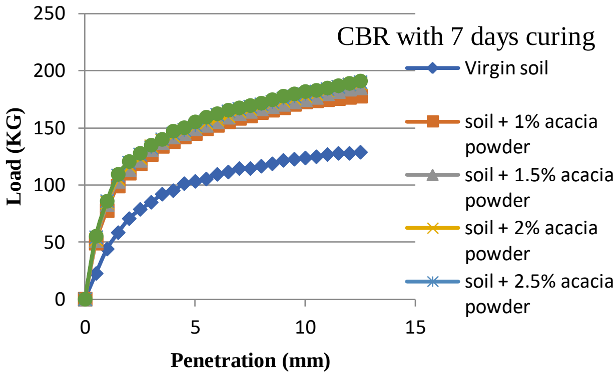

Fig. 6 (c)

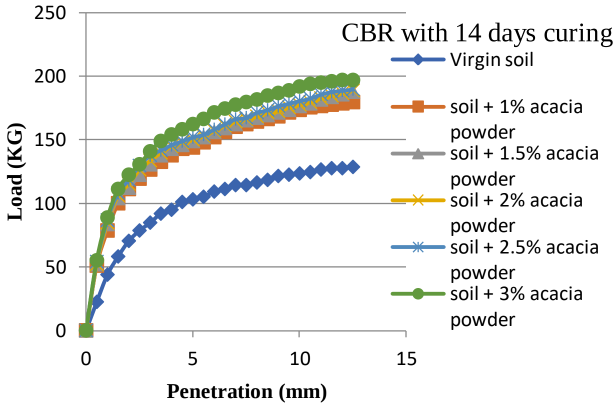

Fig. 6 (d)

Fig. 6(a)(b)(c)(d) Load Penetration Curve for treated soil samples

D. FE SEM ANALYSIS

The micro structural changes have been observed using FESEM analysis at 3% acacia powder mixed with soil. The SEM analysis shows the cementatious product forming after reacting with soil particles for 14 days. Fig 7 and fig 8 indicates the microstructure of untreated and treated soil. From fig 8 it is observed that the viscoelastic substance have been transformed into solid like structure and indicates that acacia powder acted as a binder for soil particles.

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The micrograph of the treated soil indicate that direct interaction between soil and acacia powder is due to the hydrogen bonding or electrostatic bonding due to the presence of hydroxyl group in acacia powder (polysachharides). This factor is believed to be responsible for the increment in strength and stiffness of soil stabilized with acacia powder.

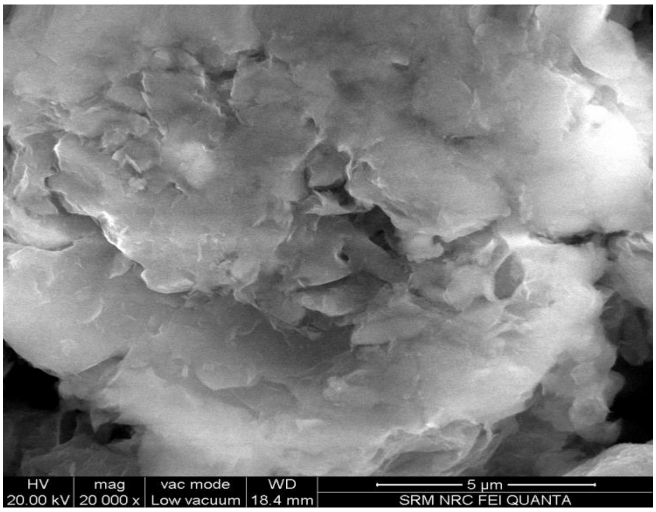

Fig. 7 SEM analysis of untreated soil

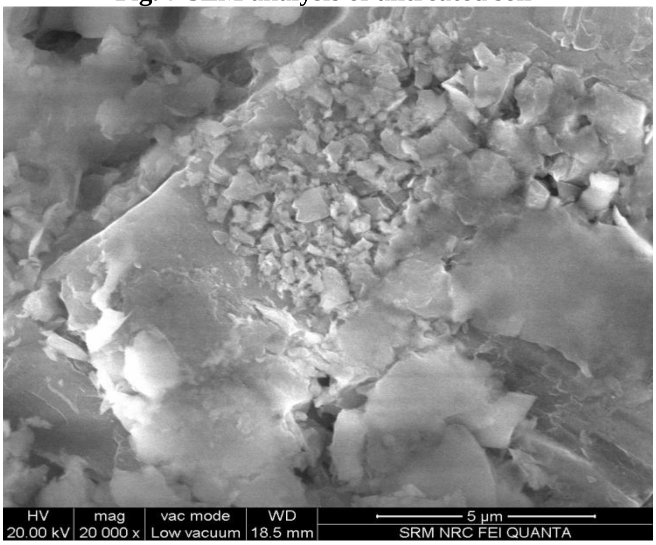

Fig. 8 SEM analysis of soil treated with 3% acacia powder

V. CONCLUSION

Inclusion of Acacia powder as a biopolymer has resulted in increasing the strength of soil effectively without causing harm to environment and the soil. The improvement in unconfined compressive strength and California bearing ratio value of the soil treated with acacia powder is found to be directly proportional to the content of acacia powder with the curing time. The results indicate that the inclusion of 2.5% of acacia powder shown the most optimum strengthening and stabilizing proportion. Also the FESEM report shows the formation of new cementatious product and thus indicates that the acacia powder acted as a thickening agent for the soil. Overall it can be concluded that acacia powder can be used as a environment friendly stabilizing agaent for the clay soil.

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