Effect of Guar and Xanthan Gum Biopolymer on Soil Strengthening

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Abstract—Natural biopolymers discussed as environmentally friendly and sustainable grouting chemicals. This paper presents guidelines for selecting potentially useful biopolymers for strengthening cohesionless soil. Guar and Xanthan were identified for the study over a range of concentration (0.5%, 1%, 1.5%). Unconfined compressive strength test performed for sand treated with various percentage of biopolymer for various water content and air dried of 3, 7, 28 days. The guar and xanthan create gel matrices and indirectly with the sand particles on surface (e.g. coating), between particle-to-particle contacts (e.g. cementation). Strengthening effect of Guar and xanthan gum was shown to have greatest effect on poorly graded sand with fine particle and with air drying periods.

Key words: Ground improvement; Guar gum; Xanthan gum; unconfined compressive strength; sandy soil

I. INTRODUCTION

Over the last century, ground improvement techniques, which are rising rapidly as worldwide development for the utilization of unstable or soft soils, have been developed and nowadays many of them are widely used in geotechnical engineering projects. Considerable developments have occurred since the twentieth century. Ground improvement techniques continue to make considerable progress, both quantitatively and qualitatively, as a result of not only technology developments but also of an increasing awareness of the environmental and economic advantages of modern soil improvement methods. Various ground improvement techniques can be characterized as the modification of existing soils or earth structures to provide better performance under design and/or operational conditions. It is proper to categorize the wide sort of soil improvement techniques in the following ways: densification, consolidation/dewatering, chemical additives, heating/freezing (Hausmann, 1990; Cabalar et al., 2009). The main goal of most soil treatment methods whose basic principles has been not changed since the past of mankind (Van Impe, 1989, Terashi and Juran, 2000) is to improve the soil characteristics. The ground improvement techniques utilize either mechanical energy or man-made materials.Guar gum is formed from cymposis tetragonoloba and Xanthan gum is formed by xanthomonus campestris during the process of fermentation. The objective of this research is to evaluate the strength behavior of soil with natural biopolymers, and to determine the effect of the biopolymer stabilizers on engineering properties of cohesionless soils. Unconfined compressive strength of biopolymer- sand specimens are measured. All specimens were prepared at moisture contents of optimum, 5% dry of optimum and 5% wet of optimum. The biopolymers used are Guar and Xanthan Gum with concentration of 0.5%, 1%, 1.5% by weight of dry soil.

II. MATERIAL AND METHODS

A. Fine Sand:

The materials used in the tests described in this paper were fine sand, Guar and Xanthan gum. The commercially available sand was obtained from chandisar river, Dholka, Gujrat. The sand has a specific gravity of 2.66, maximum dry density of 16.48 kN/m³. A gradation of the sand falling between 0.6 to 0.075 mm was artificially selected. The grain size distribution curve of fine sand taken for the investigations is presented in Figure 1 while properties of this soil in Table 1.

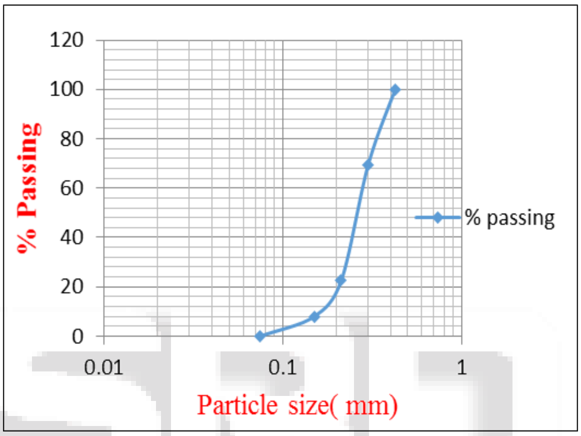

Fig. 1: Particle Size Distribution

Parameter	Value
D_{60}	0.27mm
D_{30}	0.20mm
D_{10}	0.159mm
Cu	1.69
Cc	0.93
Soil Type	Poorly Graded Fine Sand

Table 1: Properties of Sand

The Guar gum was purchased from Hindustan Gum And Chemical LTD. Viramgam, Gujrat while the xanthan gum was purchased from Rasayan trading , Navrangpura ,Ahmadabad, Gujrat.

B. Guar Gum:

This neutrally charged polysaccharide comes from Cyamopsis tetragonoloba seeds. Guar gum can from hydrogen bonds through its many hydroxyl (-OH) groups. The neutral charge of guar gum is due to its lack of ionisable carboxylic acid (-COOH) groups. Although guar gum is not microbial produced, it can produce viscous, pseudo plastic aqueous solutions like a neutrally charged microbial EPS. Guar gum's availability, inexpensiveness, and ability to increase aqueous systems' viscosity give it commercial significance.

C. Xanthan Gum:

This anionic polysaccharide is produced by the bacteria Xanthomonas campestris. Xanthan gum's negative charge comes from its carboxylic acid (-COOH) groups, since hydrogen atoms easily dissociate from these carboxylic acid groups to form carboxylate (-COO−) anions. Xanthan gum can also form hydrogen bonds with its numerous hydroxyl (-OH) groups. Small amounts of xanthan gum significantly increase an aqueous system's viscosity, which makes it a commonly used commercial substance. However, since the xanthan gum solution is pseudoplastic, its viscosity decreases with an increased shear rate. Xanthan gum also forms a viscous hydrocolloid when mixed with water, so it can also be considered dissolved in water.

III. Sample Preparation

For the sample preparation, two different mixing methods can be adopted: dry mixing in which the biopolymer was directly mixed with the soil before adding water and wet mixing in which biopolymer was mixed with water to form hydro-solution before mixing in the soil. Dry mixing method was used. Soil sample mixed with various percentage of biopolymer (0.5%, 1%, 1.5%).

IV. Experimental Work

The sand sample mixed with guar or xanthan gum biopolymer concentration of 0.5%, 1%, 1.5%. For the standard proctor test, specimens were prepared by compacting poorly graded fine sand with guar or xanthan gum in wet state and distributing three equal layer by 25 blows per layer and optimum moisture content obtained. 5 % variation was taken from OMC for dry and wet side water content. The optimum moisture content was obtained 20%, 25%, 20% for 0.5%, 1%, 1.5% of guar gum concentration. The optimum moisture content was obtained 15%, 20%, 25% for 0.5%, 1%, 1.5% of xanthan gum concentration. The compaction curve is shown in fig. 2 and fig.3. for guar and xanthan gum treated sand. UCS test were carried out for the determination of compressive strength of the sample. A conventional laboratory testing method was used to determine the compressive strength characteristics of the specimens. Experimental work was carried for guar and xanthan gum with variation 0.5%, 1%, 1.5% contents and kept for air dried condition for 3, 7, 28 days. The sample prepared for the variation of biopolymer and water content. The tests were performed as per procedures described in IS code 2720-10. UCS system used during the experimental study shown in Fig. 4. Failure sample shown in fig5.

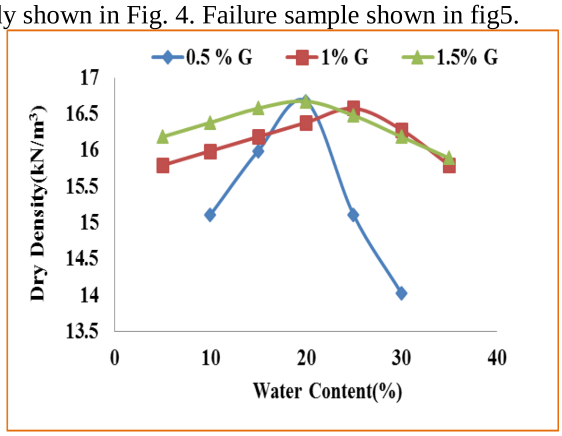

Fig. 2: Compaction Curve for sand mixed with different % of Guar gum

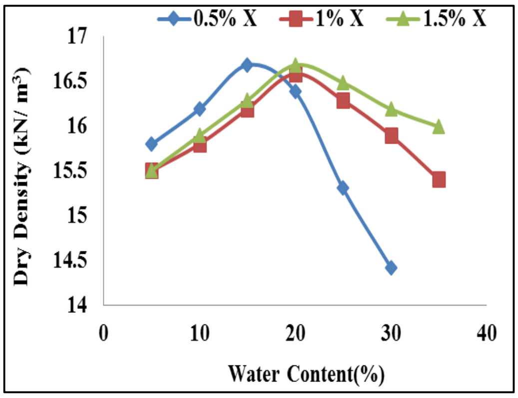

Fig. 3: Compaction Curve For Sand Mixed With Different % Of Guar Gum

Fig. 4: Experimental set up of UCS

Fig. 5: Failure Sample

V. Results and Discussion

The strength behavior of poorly graded fine sand were determined at three different ratio (0.5%, 1%, and 1.5%) of Guar or Xanthan gum and air dried time of 3,7,28 days. Using these test results, compressive strength was determined.

The UCS value first decreasing and then increasing with variation of guar gum content of 0.5%, 1%, 1.5%. The UCS value increases with air dried time 3 to 7 days and 7 to 28 days. The UCS value increases with the decreasing moisture content from optimum moisture content and decreases with the increasing moisture content from optimum moisture content. The UCS value increases for the dry side water content due to continuous Guar gum gel hardening due to the continuous dehydration of residual moisture in Guar gels. The results of unconfined compression test are shown in figure 4, 5, 6 for 3, 7, 28 days of air dried time. The UCS value decreases for the 1% of guar gum content due to the lack bonding between sand- guar gum - water mixture. High Guar gum content should be avoided due to material cost and workability (e.g. high viscosity leading to poor mixing) problems. The most economical and efficient concentration of Guar gum gum for soil treatment thus appears to be approximate 0.5-1.5%.

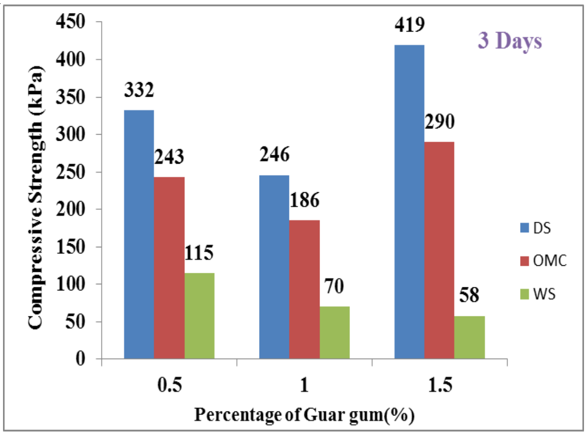

Fig. 4: Effect of guar gum on strength after 3 Days

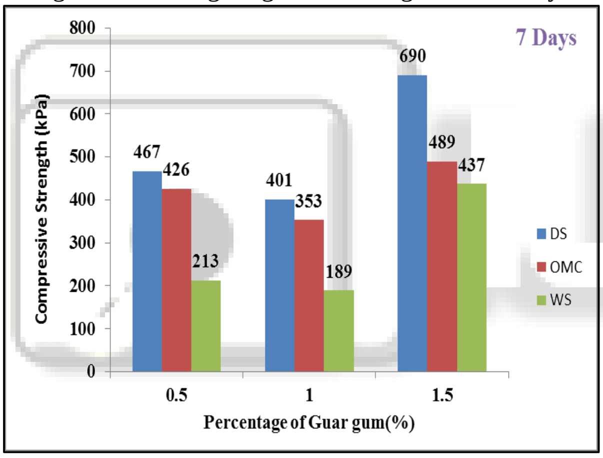

Fig. 5: Effect of guar gum on strength after 7 Days

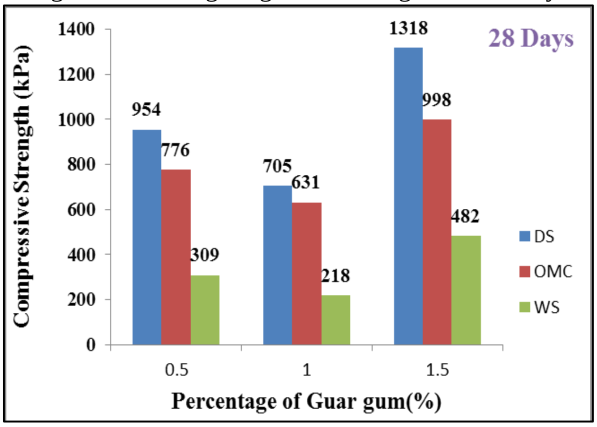

Fig. 6: Effect of Guar Gum On Strength After 28 Days:

The UCS value first increasing and then decreasing with variation of xanthan gum content of 0.5%, 1%, 1.5%. The UCS value increases with air dried time from 3 to 7 days and 7 to 8 days. The UCS value increases with the decreasing moisture content from optimum moisture content and decreases with the increasing moisture content from optimum moisture content. The UCS value increases for the dry side water content due to continuous Xanthan gum gel hardening due to the dehydration of residual moisture in Xanthan gels. The results of unconfined compression test are shown in fig. 7, 8, 9 for air dried of 3, 7, 28days. The UCS value decreases for the 1.5 % of xanthan gum content due to the higher viscosity after 1% of xanthan gum content. High Xanthan gum content should be avoided due to material cost and workability (e.g. high viscosity leading to poor mixing) problems. The most economical and efficient concentration of Xanthan gum gum for soil treatment thus appears to be approximate 0.5-1%.

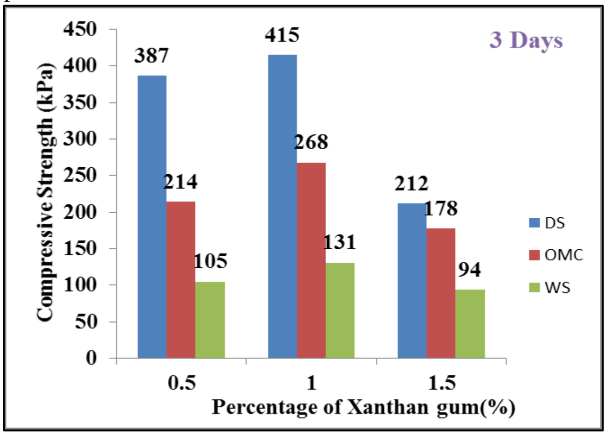

Fig. 7: Effect of xanthan gum on strength after 3 Days

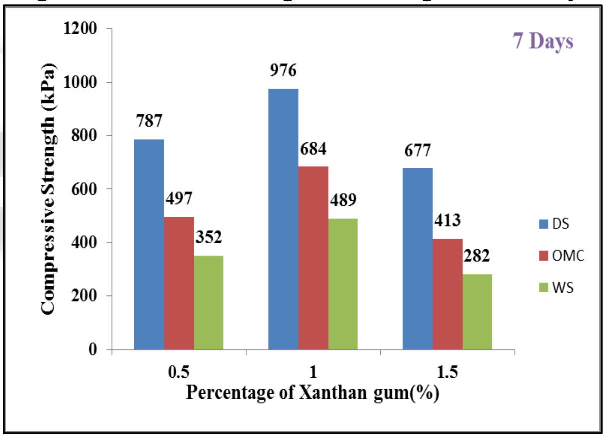

Fig. 8: Effect of xanthan gum on strength after 7 Days

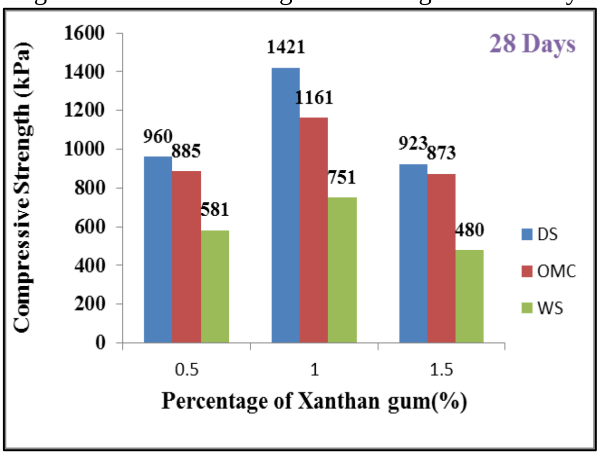

Fig. 9: Effect of xanthan gum on strength after 28 Days

VI. Conclusion

The present study investigate the effect of Guar or Xanthan gum on poorly graded fine sand. It has been shown that biologically induced cementation can significantly improve the compressive strength of poorly graded fine sand. The strength behavior of biologically cemented sand were determined at different percentage (0.5%,1%,1.5%) of Guar or Xanthan gum and air dried time of 3,7,28 days. The tests reported in this study show that the behavior of poorly graded fine sand mixtures with various Guar or Xanthan contents leads to following conclusions:

– Decrement in the compressive strength value is 25.90%, 23.45%, 39.13% for 1% of guar gum compare to value of 0.5% guar gum for DS, OMC, WS side water content and increment in the compressive strength value is 26.20%, 19.34% ,37.39% for 1.5% of guar gum compare to value of 0.5% guar gum for DS,OMC,WS water content for 3 days air dried time.
– Decrement in the compressive strength value is 14.13%, 17.13%, 11.26% for 1% of guar gum compare to value of 0.5% guar gum for DS, OMC, WS side water content and increment in the compressive strength value is 47.75%, 14.78% ,51.25% for 1.5% of guar gum compare to value of 0.5% guar gum for DS,OMC,WS water content for 7 days air dried time.
– Decrement in the compressive strength value is 26.10%, 18.68%, 29.44% for 1% of guar gum compare to value of 0.5% guar gum for DS, OMC, WS side water content and increment in the compressive strength value is 38.15%, 28.60%,35.89% for 1.5% of guar gum compare to value of 0.5% guar gum for DS,OMC,WS water content for 28 days air dried time.
– Increment in the compressive strength value is 7.23%, 25.23%, 24.76% for 1% of xanthan gum compare to value of 0.5% xanthan gum for DS, OMC, WS side water content and decrement in the compressive strength value is 45.21%, 16.82 %, 10.47 % for 1.5% of xanthan gum compare to value of 0.5% xanthan gum for DS, OMC, WS water content for 3 days air dried time.
– Increment in the compressive strength value is 24.01%, 37.62%, 38.92% for 1% of xanthan gum compare to value of 0.5% xanthan gum for DS, OMC, WS side water content and decrement in the compressive strength value is 13.97%, 16.90 %, 19.88 % for 1.5% of xanthan gum compare to value of 0.5% xanthan gum for DS, OMC, WS water content for 7 days air dried time.
– Increment in the compressive strength value is 48.02%, 31.18%, 29.25% for 1% of xanthan gum compare to value of 0.5% xanthan gum for DS, OMC, WS side water content and decrement in the compressive strength value is 3.85%, 1.35 %, 17.38 % for 1.5% of xanthan gum compare to value of 0.5% xanthan gum for DS, OMC, WS water content for 28 days air dried time.
– Optimum guar gum content is 1.5%.
– Optimum xanthan gum content is 1%.

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