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Compressibility Characteristics of Guar Gum Treated Expansive Soil

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Abstract. Traditionally cement and lime are considered as effective stabilizers to improve the geotechnical properties of expansive soils. However, from a sustainable perspective, they discouraged owing to their higher carbon footprint value. To address these negative impacts on the environment, biopolymers are proposed as stabilizers to enhance the geotechnical properties of expansive soil. The present study aims at improving the compressibility characteristics of locally sourced expansive soil using Guar Gum (GG). One-dimensional consolidation tests were performed on GG treated soil at gum dosages at 0.5, 1.0, 1.5, 2.0, and 2.5 % by dry weight of soil mass. The experimental results indicate that the compressibility index of soil with 2.5% GG increased by 1.36 times the compressibility index of untreated soil. This is attributed to the increase in repulsion between negatively charged soil particles and the hydroxyl group (OH^-) of GG at a higher dosage.

Keywords: Consolidation; Compressibility; Guar gum; Hydrogen bond.

1 Introduction

Expansive soil causes a lot of distresses to the structures built over it due to swelling and shrinkage under saturated or partially saturated conditions. Chemical stabilization is often preferred to deal with expansive soils compared to other stabilization methods (Sivapullaiah and Moghal 2011). Cement, lime and fly ash are used as the most common additives to improve the geotechnical properties of expansive soils (Kaniraj and Havanagi 2001; Moghal and Sivapullaiah 2012; Moghal 2017). Recent studies admit that the utilization of these additives contributes to CO_2 gas emission into the environment and can trigger groundwater contamination affecting the growth of vegetation due to alteration of soil pH (Andrew 2019; Soldo et al 2020). To overcome these limitations, the use of bioengineering solutions as an alternate treatment strategy is proposed to improve the geotechnical properties viz., shear strength, permeability, and compressibility (Ayeldeen et al 2016; Latifi et al 2017; Cabalar et al 2018; Moghal et al 2020a,2020b). Nugent et al (2011) carried out one-dimensional consolidation tests on kaolinite treated with guar gum. Results indicated that the compressibility was reduced at lower dosages due to the hydrogen bond between GG and soil. Experimental investigations on silty clay indicated that a reduction of 4% collapse potential was observed with 2% guar gum (Dehghan et al 2018).

Guar gum originates from guar bean, a vegetable plant. It is a water-soluble polysaccharide composed of D-galactose (36.6%) and D-mannose (63.1%) monomer units. India, the largest producer of guar gum accounts for 80% of world production annually. The present study deals with the investigation of compressibility characteristics of the locally available black cotton soil treated with guar gum.

2 Materials

2.1 Soil

The black cotton (BC) soil used in the present study was collected at a depth of 3 feet after removing the top loose soil near National Institute of Technology, Warangal campus. The collected soil was air dried, pulverized and preserved for further experiments. The physical properties were determined in accordance with relevant ASTM standards and are presented in Table 1. According to USCS classification the soil has been classified as lean clay.

Table 1. Physical properties of BC soil

Property	Value	Standard adopted
Specific gravity	2.66	ASTM D854 (ASTM 2014)
Liquid limit (%)	47	ASTM D4318 (ASTM 2017)
Plastic limit (%)	22	ASTM D4318 (ASTM 2017)
OMC (%)	13.47	ASTM D698 (ASTM 2012)
MDD (kN/m^3)	17.95	ASTM D698 (ASTM 2012)
Soil classification (USCS)	CL	ASTM D2487 (ASTM 2017)

Note: OMC - Optimum moisture content; MDD - Maximum dry density; USCS - Unified soil classification system.

2.2 Guar gum

The guar gum used for the study was sourced from SRL Chemicals PVT Ltd, Mumbai, Maharashtra. The gum powder is almost white to pale yellowish in colour (Fig. 1).

3 Methodology

The compressibility characteristics were studied by carrying out a series of one-dimensional consolidation tests on biopolymer treated soil at varying dosages (0.5, 1.0, 1.5, 2.0 and 2.5% by dry weight of soil). The soil was mixed with various dosages of guar gum and compacted at targeted fixed dry density (17.95 kN/m^3) in a consolidation ring of 6 cm diameter and 2 cm height. Samples were allowed to fully saturate at a seating pressure of 6.25 kPa and then loaded under vertical pressures of 12.5, 25, 50, 100, 200, 400 and 800 kPa (maintaining a load increment ratio of unity) and each load was kept for a period of 24 h as per ASTM D4186M-12e1(Moghal et al 2014, 2015). Compression index values were determined from the void ratio and consolidation pressure plots for each load increment.

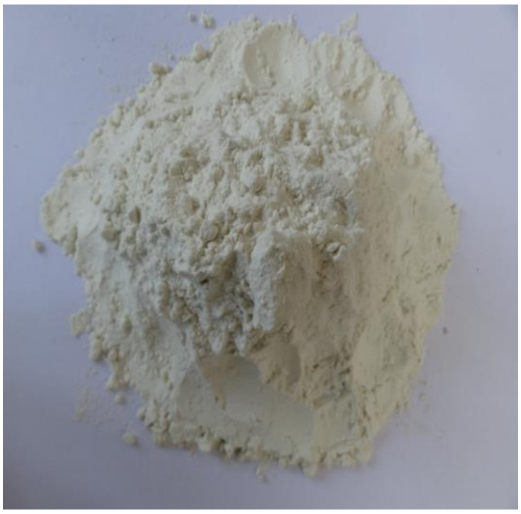

Fig.1. Guar Gum Powder

4 Results and Discussions

4.1 Physical properties

Fig. 2 shows the variation of liquid limit and plasticity index of soil treated with guar gum. It is observed that with the increase in dosage of GG both the liquid limit and plasticity index values increased. The liquid limit of soil increased by 2 manifolds with 2.5% GG compared to untreated soil and it is attributed to the increase in viscosity of solution (Nugent et al 2009).

Fig. 3 shows the variation of maximum dry density (MDD) and corresponding optimum moisture content (OMC) of GG treated soil with varying dosages. From Fig. 3 it is observed that the MDD value reduced by 13.33 % and OMC value increased by 58.6 % with 2.5% GG addition. This is attributed to the replacement of soil grains with guar gum strands leading to a reduction in mass of the treated soil. Further, the presence of higher quantity of GG absorbs more water resulting in the reduction of soil-biopolymer mass. The maximum dry density value of the soil-biopolymer mix depends upon the type of the biopolymer, the viscosity of the solution, gradation of the soil and fines in the soil (Ayeldeen et al 2016).

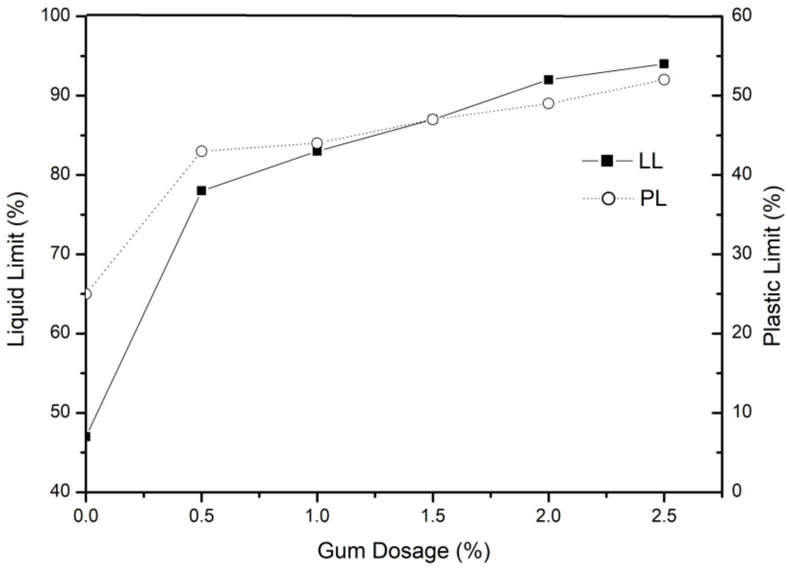

Fig. 2. Variation of liquid limit and plasticity index with guar gum

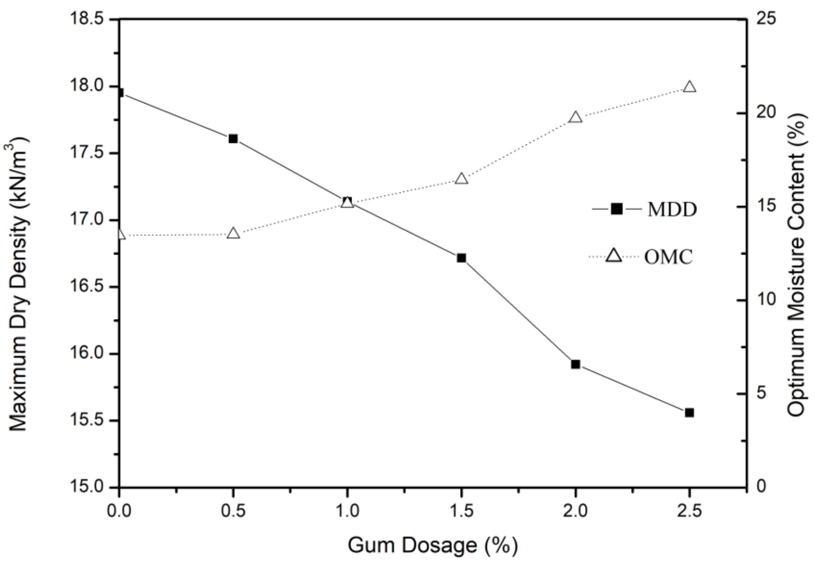

Fig. 3. Variation of MDD and OMC with guar gum

4.2 Compressibility characteristics

The compression curves (e vs. log (p)) of GG treated soil at varying dosages are shown in Fig. 4. The curves follow similar trend irrespective of dosage of gum.

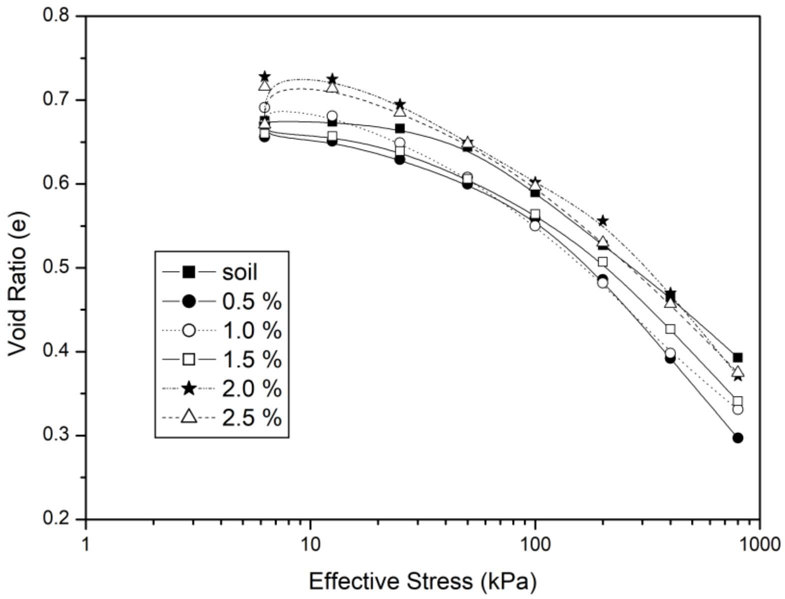

Fig. 4. Void ratio vs. Effective stress (log scale) of guar gum treated soil

The coefficient of compression index (C_c) value of soil at different gum dosages is presented in Fig. 5. With 0.5 % GG, the gum absorbs more water due to its hydrophilic nature, resulting in increased swelling and compression. With 1% dosage, the gum binds the soil particles facilitating crosslinking of the individual soil grains. It is attributed to the development of a hydrogen bond between the soil particles and the hydroxyl group (OH^-) of GG starts at this dosage and hence the compression values are reduced. However, beyond 1 %, any further addition of gum (up to 2.5%) causes an increase in compression due to the development of repulsive forces between negatively charged clay particle and hydroxyl group (OH^-) of guar gum (Nugent et al 2011). Accordingly, the Cc values of biopolymer treated soil (at all selected dosages) are observed to be more than the untreated case. Hence it is corroborated that, the addition of guar gum delays the consolidation process resulting in increased compression values (Cabalar et al 2018).

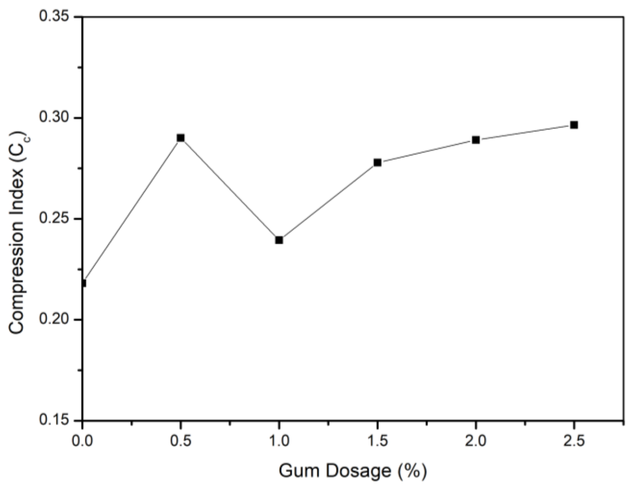

Fig. 5. Variation of compression index of guar gum treated soil

5 Conclusions

In the present study, the effect of guar gum on compressibility characteristics of an expansive soil has been studied. One dimensional consolidation tests were performed at various dosages of guar gum. The conclusions of the present investigation based on experimental results are listed as follows.

- The increase in liquid limit and plasticity index values is attributed to an increase in the solution viscosity especially at higher gum dosages.
- The hydrophilic nature of gum causes absorption of more water, leading to an increase in OMC and a corresponding reduction in the MDD values of the soil-biopolymer mixtures.
- The compressibility values increased at higher gum dosage which is attributed to the increase in repulsion between negatively charged clay particles and the hydroxyl group (OH^-) of guar gum.
- Crosslinking of soil particles and the development of hydrogen bond are the key factors affecting compressibility characteristics of soil-biopolymer mix.

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