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Bearing capacity and the settlement of foundation on biomodified coastal soil

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Abstract

Construction of the foundation on the marine the soil deposit is susceptible to excessive settlement and the construction of foundation is difficult. Although, the most common practice is to construct the raft foundation in these regions even for the low-rise building, excessive settlement can be observed in several building. So, in the present study, laboratory investigations have been done on the marine soil by modifying it with two different type of biopolymer such as Guar gum and Xanthan gum. The geotechnical properties of the soil modified with 1% and 1.5% biopolymer has been evaluated and the obtained properties has been used for settlement analysis. During the settlement analysis, the foundation soil model has been created as layered soil because the top layer has been replaced by biomodified soil. Several combi-nations have been created by varying the thickness of modified soil layer and the type and percentage of modifying agent. The settlement analysis has been performed in the settle 3D software and the biopolymer modification of soil has been found effective in controlling the foundation settlement.

Keywords: Biopolymer; Guar gum; Xanthan gum; Geotechnical property; Foundation settlement

1. Introduction

Building the foundation of high-rise structure is a difficult task on the marine soil deposit low bearing capacity. Due to the soil condition, commonly raft foundations are used which make the structure uneconomical. Several researchers have studied the bearing capacity of the coastal soil deposits [1, 2] along with the several performed numerical study [3, 4]. Further, several researchers have studied the bearing capacity of the modified ground [5, 6]. The study on the modified coastal soil in Kingdom of Saudi Arabia has also been performed by several researchers [7, 8]. However, although the study on the soil modification using biopolymer is available [9, 10] but it is found that the research on the foundation design over biomodified soil is not available in the best knowledge of the authors. So, due to the low bearing capacity of natural soil deposit, top 3m layer of the soil has been replaced by engineered soil modified using two different types of biopolymers such as Guar gum (GG) and Xanthan gum (XG). For the modification of the soil, 1% and 1.5% Guar gum and Xanthan gum has been mixed with the soil. To study the effect, a case study has been done considering a raft foundation on loose sand with a low soil bearing capacity.

2. Methodology

In this research, the top layer of the natural deposit has been replaced by the biomodified soil. Initially the soil for laboratory investigation has been collected from the depth of 2m. The soil has been modified by two different type of biopolymer such as Guar gum and Xanthan gum in 1.0% and 1.5%. Once the top layer is replaced by biomodified soil, the foundation soil will behave like a layered soil with top and bottom both layer as a sand. The bearing capacity of the layered soil has been calculated by using the bearing capacity equation for layered soil as in Eq (1).

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$$q_u = q_b + \left(1+\frac{B}{L}\right)\times\left(\frac{2c_a'H}{B}\right) + \gamma_1 H^2\left(1+\frac{B}{L}\right)\left(1+\frac{2D_f}{H}\right)\left(\frac{K_s tan\emptyset_1'}{B}\right) - \gamma_1 H \le q_t \quad (1)$$

Further, as the foundation material is sand, so the cohesion will be zero and the Eq (1) will reduce to Eq (2).

$$q_u = q_b + \gamma_1 H^2\left(1+\frac{B}{L}\right)\left(1+\frac{2D_f}{H}\right)\left(\frac{K_s tan\emptyset_1'}{B}\right) - \gamma_1 H \le q_t \quad (2)$$

In the above equation "q_b" is the bearing capacity of the bottom layer and the "q_t" is the bearing capacity of the top layer and the "*Ks*" is the function of angle of internal friction. The bearing capacity of top and bottom layer has been calculated using the Eqs (3) and (4).

$$q_b = \gamma_1(D_f + H)N_{q(2)}F_{qs(2)} + \frac{1}{2}\gamma_2 B N_{\gamma(2)}F_{\gamma s(2)} \quad (3)$$

$$q_t = \gamma_1 D_f N_{q(1)}F_{qs(1)} + \frac{1}{2}\gamma_1 B N_{\gamma(1)}F_{\gamma s(1)} \quad (4)$$

Where; D_f is the depth of foundation, B is the width of foundation, γ is the unit weight of soil. The suffix "1" and "2" shows the property of top and bottom layer respectively.

The properties of modified soil such as angle of internal friction (φ), unit weight (γ) has been evaluated in the laboratory.

3. Result and discussion

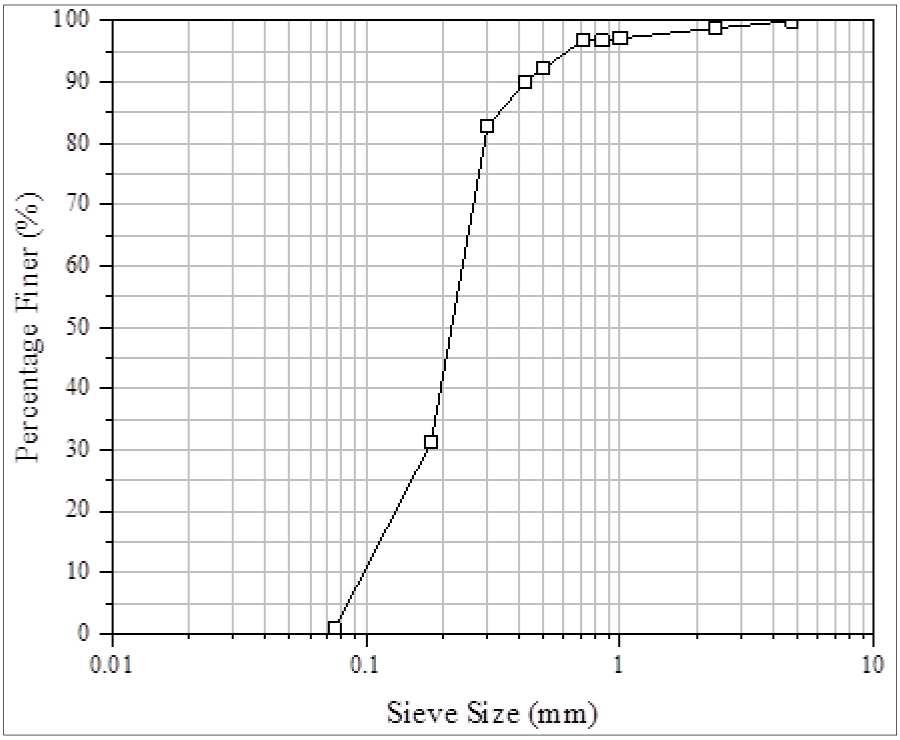

Figure 1 Grain size distribution of Jazan soil

The basic geotechnical property of the soil collected from the depth of 2m has been evaluated in the laboratory. Later the soil has been modified with 1% and 1.5% Guar gum and Xanthan gum. The grain size distribution of the sand has been done as per the ASTM D6913-04 [11], the shear strength parameter has been evaluated as per the ASTM D3080-04 [12], and the unit weight has been evaluated as per the ASTM D698-12 [13]. From the grain size distribution (Fig. 1), it is observed that the soil consists of more than 90% fine sand with coefficient of uniformity and coefficient of curvature as 2.1 and 1.54, respectively, and can be classified as poorly graded sand (SP). The angle of internal friction of sand has been observed as 23^o with maximum the dry unit weight of 13 kN/m^3 (Table 1). However, it is found that the modification of sand increases after modification with biopolymer. The modification of sand using 1% Guar gum and Xanthan gum increases the angle of internal friction upto 37.21° and 39.01°, respectively, whereas the unit weight increases to 15.60 kN/m³ and 16.60 kN/m³, respectively (Table 1). The modification of sand with 1.5% Guar gum and Xanthan gum increases the angle of internal friction upto 40.72° and 47.73°, respectively, whereas the unit weight increases to 15.20 kN/m³ and 15.56 kN/m³, respectively (Table 1).

Table 1 Property of natural soil deposit and engineered soil

Type of Soil	**Frictional angle (φ°)**	**Unit weight (γ) (kN/m³)**
Natural Deposit	23	13.00
Modified with 1% XG	39.01	16.60
Modified with 1.5% XG	40.93	15.56
Modified with 1% GG	37.21	15.60
Modified with 1.5% GG	40.72	15.20

Later, the bearing capacity has been evaluated using the Eq. (2) [14, 15] and the bearing capacity factor N_q and $N\gamma$ has been evaluated using the Eqs (4) and (5) [16].

$$N_q = e^{\pi tan\emptyset}\left(\frac{1 + sin\emptyset}{1 - sin\emptyset}\right) \quad (4)$$

$$N_\gamma = 1.5(N_q - 1)tan\emptyset \quad (5)$$

For the case study done in the present research, a raft foundation with dimension 25.4 m length and 12.4 m width resting at the surface of the soil ($D_f = 0$) has been considered. The thickness of the modified layer (H) in the present study has been considered as 3m. The bearing capacity evaluated by considering the above assumption and with factor of safety of 3 has been presented in the Table 2.

Table 2 Bearing capacity of the modified soil

Soil modified with	**q_b (kN/m²)**	**q_t (kN/m²)**	**q_b/q_t**	**K_s**	**q_u (kN/m²)**	**$q_{u\text{-}safe}$ (kN/m²)**
1% GG	361.89	455.74	0.79	8.00	417.44	139.15
1.5% GG	511.54	817.57	0.62	9.50	600.19	200.06
1% XG	555.19	660.47	0.84	10.5	657.90	219.30
1.5% XG	522.76	868.88	0.60	11.5	643.68	214.56

It is observed from Table 2 that after modification of natural soil by using the biopolymer increases the bearing capacity of the soil. It is found that the modification of to 3 m soil by 1% and 1.5% Guar gum increases the bearing capacity by 269% and 431% respectively. However, modification of top 3 m layer by 1% and 1.5% Xanthan gum increases the bearing capacity by 482.3% and 469.7% respectively. It can also be observed that the Xanthan gum is more effective in improving the bearing capacity. It is worth mentioning that the effectiveness of the biopolymer may decrease due to flow of water in the soil, so in depth study is required in this regard.

Further, as the foundation settlement is a very important parameter in the foundation design, the settlement analysis has been done using a commercially available software Settle 3D. The Fig. 2 shows the soil model with only one layer prepared in Settle 3D. Whereas, the Fig. 3 shows the soil model with two layers prepared in Settle 3D.

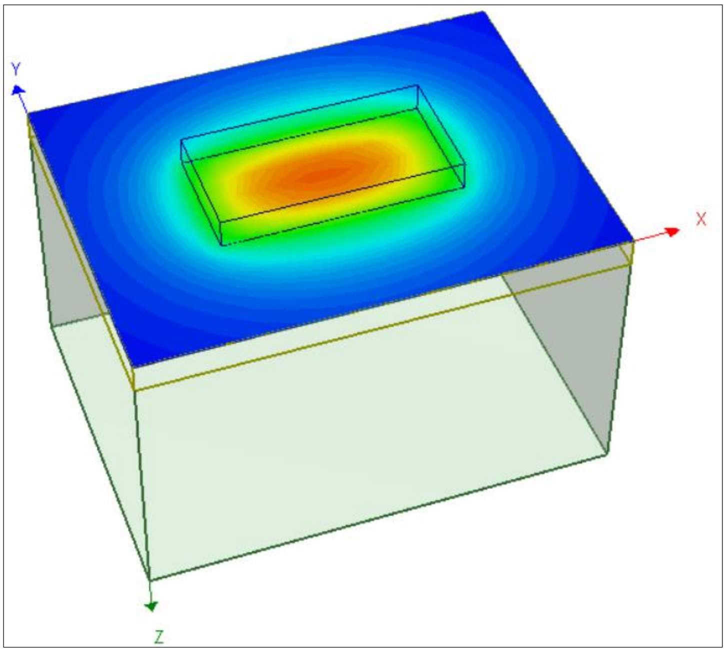

Figure 3 Typical photo shows the layered soil model.

The settlement value of the soil deposit without and with modification has been evaluated by applying the similar load in all the cases. The Fig 4 shows the variation of the settlement of natural deposit as well as modified soil. It is observed that the biopolymer modification effectively lowers down the settlement value of the soil (Fig. 4) along with increasing the bearing capacity (Table 2). A slight increase in the settlement is observed at higher percentage (1.5%) biopolymer, which may be due to the slight decrease in the maximum dry unit weight. The Fig. 5 shows a typical photo of variation of deformation at different location. It can also be observed in the Fig. 5 that the deformation in the soil is maximum at the center of the foundation and decreases with depth and in lateral direction.

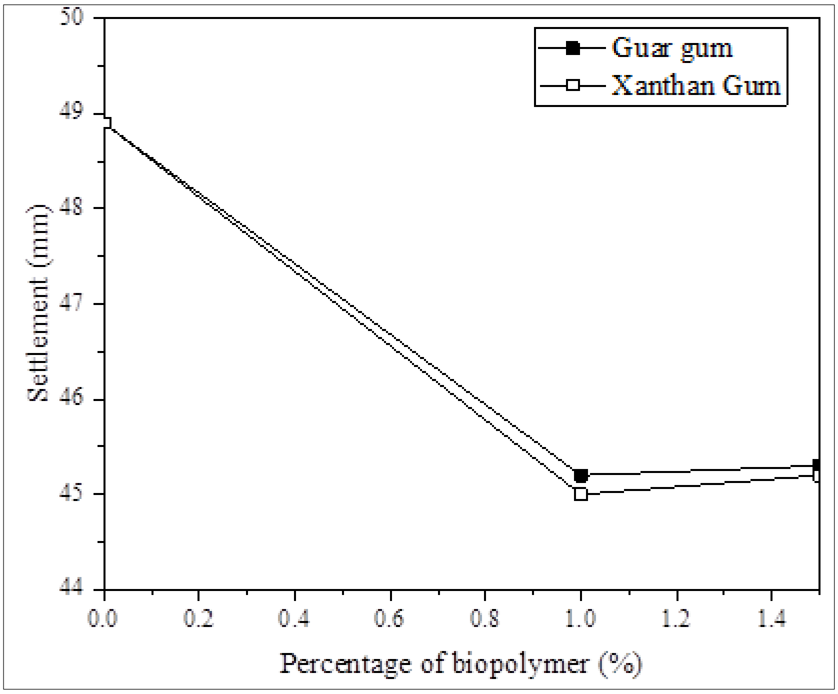

Figure 4 Variation of settlement value

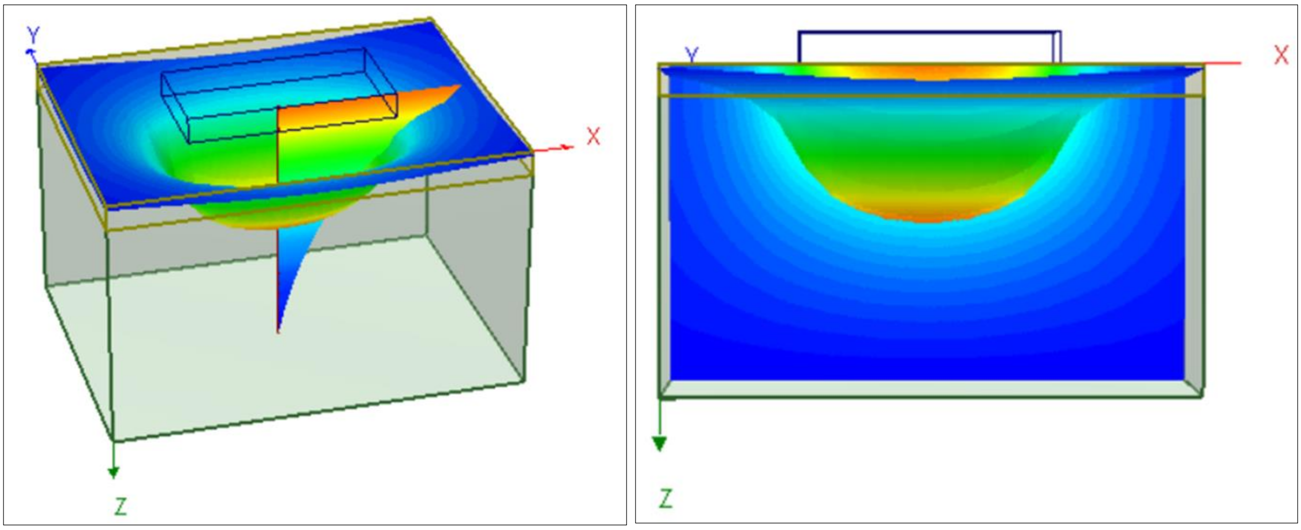

Figure 5 Typical picture showing the variation settlement at different location

4. Conclusion

Based on the numerical calculations and the analysis in the Settle 3D software, following results has been drawn.

The modification of the soil by 1% and 1.5% Guar gum increases the bearing capacity by 269% and 431% respectively, whereas, the modification by Xanthan gum increases the bearing capacity by 482.3% and 469.7% respectively.

The settlement analysis by considering same load intensity for all condition shows that the foundation settlement decreases after biomodification of soil.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Luo Z, Ding X, Ou Q, Fang H (2023) Bearing capacity and deformation behavior of rigid strip footings on coral sand slopes. Ocean Engineering 267:2023.

[2] Yin P, Wang K, Chen L, Zhang Y, Yang K, Wang J (2023) Horizontal Bearing Capacity and Reliability of Piles in Coastal Soft Soil Considering the Time-Varying Characteristics. Journal of Marine Science and Engineering 11(2):247.

[3] Seifi S, Nayer A, Lajevardi S H (2022) Field and numerical studies on bearing capacity of helical screw piles in Caspian Sea coast soil. Innovative Infrastructure Solutions 8(54).

[4] Mase L Z, Saputra J, Edriani A F, Keawsawasvong S, Lai V Q (2022) Finite Element Analysis to Estimate Bearing Capacity of Strip Footing in Coastal Sandy Soils in Bengkulu City, Indonesia. Engineering Journal 26(5):59-75.

[5] Haritha M, Krishnamurthy N R (2022) Case study: Ground Improvement technique with Geosynthetics as reinforcement on soft ground for buildings in coastal Andhra Pradesh. IOP Conference Series: Earth and Environmental Science 1130.

[6] Kuerban F, Li H, Peng Y, Zhou Y, Wang Y (2021) Experimental Study on the Treatment Effect of Vibroflotation Gravel Piles for Saturated Sand Foundations in Coastal Areas. Arabian Journal for Science and Engineering 47:4833-4848.

[7] Alsanabani N, Alnuaim A (2022) Influence of vertical vibration on the bearing capacity of foundation resting on salt-encrusted flat soil improved by cement. Journal of King Saud University - Engineering Sciences. https://doi.org/10.1016/j.jksues.2022.11.003

[8] Alnuaim A M, Alsanabani N M, Alshenawy A O, Al-Amoudi O S B (2022) Vibrating Behavior of Foundations Resting on Salt-Encrusted Flat (Sabkha) Soil Improved Using Cement. Arabian Journal for Science and Engineering 48:5243-5266.

[9] Alam S, Gebremedhin A W, Atomsa H W, Khan A H (2022) A comparative study between strength and durability of bentonite and natural gum stabilised sand. Geomechanics and Geoengineering 17(6):1722-1734.

[10] Swain K, Mahamaya M, Alam S, Das S K (2017) Stabilization of Dispersive Soil Using Biopolymer. Sustainable Civil Infrastructures 132-147.

[11] ASTM D6913-04 (2009) Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis. 10.1520/D6913-04R09E01

[12] ASTM D3080-04 (2012) Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions. 10.1520/D3080-04

[13] ASTM D698-12 (2021) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3)). 10.1520/D0698-12R21

[14] Meyerhof and Hanna (1978) Ultimate Bearing Capacity of Foundations on Layered Soil under Inclined Load. Canadian Geotechnical Journal 15(4):565-672.

[15] Meyerhof G G (1974) Ultimate Bearing Capacity of Footings on Sand Layer Overlying Clay. Canadian Geotechnical Journal 11(2):224-229.

[16] Lundgren H, Mortensen K (1953). Determination by the Theory of Plasticity on the Bearing Capacity of Continuous Footings on Sand. Proceedings, Third International Conference on Soil Mechanics and Foundation Engineering, Zurich, 1:409–412.