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Durability of sandy soil stabilized with guar gum under wet-dry cycles

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Abstract

This study investigates the use of guar gum, a biopolymer, as an environmentally friendly soil stabilizer to improve the durability of sandy soil. Three types of sandy soils (SP, SW, and SP-SM) were treated with different amounts of guar gum (1%, 2%, and 3%) and were tested through several wetting and drying cycles (2, 4, and 5 cycles). Experimental results revealed a significant reduction in the collapse potential (Cp) from 50% to 71% and an increase in the liquid limit. The collapse rate decreased from 45% to 67% after the second and fifth cycles, respectively at the highest addition rate of 3%. The resistance to environmental changes was also improved. These results highlight the potential of guar gum as a sustainable sand stabilization solution for geotechnical practices and this work offers fresh perspectives on the application of guar gum to stabilise sand in situations involving periodic soaking and drying.

1. Introduction

Biological stabilization of soil provides a long-term, effective, and sustainable substitute for traditional treatments. A natural biopolymer, guar gum (GG) is frequently employed as a soil-stabilizing agent due to its superior bonding qualities and ecological footprint [1]. Because the addition of guar gum creates hydrogels that stiffen the soil matrix in addition to clogging the pore spaces, the soil's compressibility is effectively decreased. Because guar gum is prone to deterioration, durability tests are carried out. During the 90-day study period, there was no discernible deterioration of the treated soil samples [2]. Stabilised soils' strength, resilience to erosion, and durability were all markedly improved by a new biopolymer (GG-PAM). With notable gains in unconfined compressive strength and environmental resistance at 1% content, GG-PAM provides a solid basis for road building and maintenance [3]. When mixed with cement, guar gum and chitosan (0.02%) greatly increased the dredging slurry's strength and stability. Curing, immersion, and dry-wet cycles all affected the strength behavior, with hydration products being crucial [4]. It has been shown that guar gum stabilized soil (GGSS) can be used as a landfill liner that is both efficient and environmentally benign, and after 120 days of curing with 2% guar gum, the unconfined compressive strength increased 1.75 times, but the hydraulic conductivity fell 2.72 x 10^5 times, additionally, GGSS demonstrated better resilience to wet-dry cycles and improved the adsorption of heavy metals (Pb, Cu, Cd, and Zn), as a result, GGSS provides an affordable and sustainable substitute for traditional bentonite liners [5].

In geotechnical engineering, biopolymer-based soil treatment (BPST) is studied with a focus on erosion prevention, soil reinforcement, and dust reduction, it examines contemporary biopolymer varieties, site application, soil behavior impacts, and economic viability. The review indicates that biopolymers are a potential, eco-friendly material for ground improvement in geotechnical and building engineering [6]. Research on geopolymers' impact on fiber-reinforced loess durability and water stability in the Loess Plateau shows that unconfined compressive strength decreases exponentially with dry-wet cycles, while the water stability coefficient improves linearly with geopolymer dosage, the ideal dosage is 15% [7]. Another study found that increasing the concentration of xanthan gum in biopolymer-treated Jumunjin sand increased its shear strength from 30 kilopascals to 190 kilopascals. However, the strength of the soil declined by 30% over 10 cycles, but after multiple cycles, it showed strength recovery and resilience, suggesting it could be suitable for construction [8].

Enhanced geotechnical construction features enable the application of biopolymer soil treatment as an eco-friendly method to fortify the ground, mitigate soil erosion, and safeguard sloped surfaces [9, 10]. A study explores a novel biopolymeric building material, thermo-gelation biopolymers like gellan gum and guar gum, for soil treatment and enhancement. These eco-friendly materials, which dissolve in warm water and solidify at reduced temperatures, have potential for enhanced soil strength and durability in clayey and sandy soils [11].

This study investigates the durability of sandy soil treated with 1, 2, and 3% biopolymer derived from guar gum under cyclic wetting and drying conditions. It also compares the native and biopolymer-modified materials under collapse tests under soaking and drying conditions.

2. Materials and methods

2.1 *Sandy soil*

Soil Samples were collected from the cities of Samarra and Ramadi at depth one meter from Yarmouk-sammara city, Al-Muthanna-sammara city *N34*^{0}10´*E43*^{0}54´and Ramadi southwest of Al-tharthar lake *N43*^{0}15´ *E32*^{0}33´, which were designated with A, B and C soils, were classified as poorly graded sandy (SP), well-graded sand (SW), and poorly graded sand with silt (SP-SM), respectively in accordance with the standard soil classification system (ASTM D2487-17e1) [12]. The chemical composition of sandy soil was examined, as presented in Table 1. A modified Proctor test was conducted to ascertain the maximum dry density (MDD) and the optimum moisture content (OMC), as presented in Table 1. The Modified Proctor test was selected to provide greater compaction energy and minimize voids in sandy soil. The uniformity and curvature coefficients obtained from the distribution curves are illustrated in Figure 1. The Atterberg Limits for each soil type, as per ASTM D4318 [13], indicate that Liquid Limit (L.L) values were achieved; however, no Plastic Limit (P.L) values were obtainable due to the sandy nature of the soil. Table 1 presents the parameters of the soil utilized in this study.

The collapse test was conducted using the consolidation apparatus (Figure 2). The collapse test is conducted for the collapse potential (Cp) according to the ASTM D5333 [14], 2003 standard to determine the soil's collapse potential. This test is used to classify the risk condition of structure and foundation collapse.

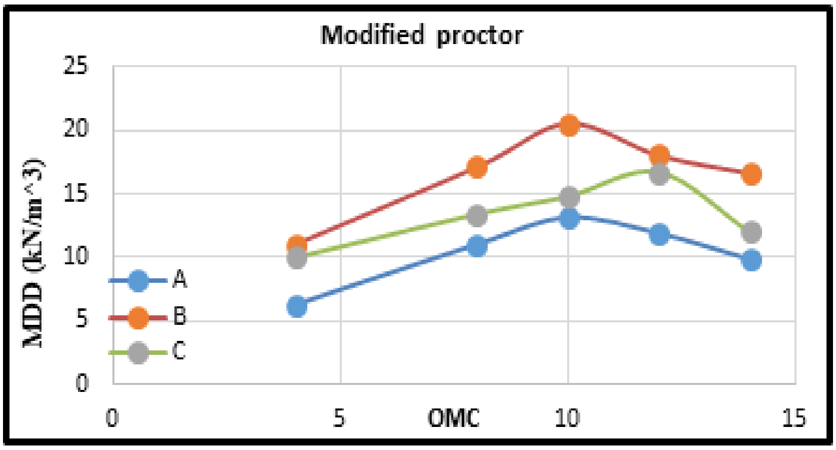

Fig. 1. Proctor results for soil specimens.

Table 1. Properties of soil used in this study.

Properties		Soil A	Soil B	Soil C
Sand content %		**1**	**0.55**	**0.32**
Water content %		**2**	**0.87**	**1.02**
OMC %		**10**	**10**	**12**
γ_d ***Max (kN/m³)***		**13.7**	**20.5**	**16.14**
γ_{field} ***(kN/m³)***		**13.5**	**11.26**	**10.3**
Grain size distribution	***USCS***	**SP**	**SW**	**SP-SM**
	Cu	**4.9**	**6.6**	**3.72**
	Cc	**0.45**	**1.51**	**0.69**
Atterbergs limits	***LL***	**32**	**26**	**22**
	PL	**N.P**	**N.P**	**N.P**

Fig. 2. Consolidation apparatus for collapsible test

2.2. *Preparation of the soil samples*

Guar gum was added at ratios of (1%, 2%, 3%) of the soil mass. These ratios were chosen as a range of ideal additions for biopolymers after reviewing previous research. Guar gum is added as a solution for all three sandy soils. A guar gum solution is prepared (Figure 3a) with the optimum moisture content for each type of soil. Multiple soil samples are prepared and mixed with the soil (Figure 3b) after addition. 6 samples were created for each addition ratio, i.e. 18 samples for each of the three types of soil, for a total of 54 samples .The samples are then wrapped in a plastic insulating cover at room temperature (Figure 3c) and left for 14 days before conducting tests to provide an appropriate curing period and increase the interaction between soil particles and the biopolymer, the curing period of 14 days was chosen based on the recommendations of previous studies that recommended it as the ideal period. After that, they are placed in a collapse apparatus (Figure 4). 5 soaking and drying cycles are adopted; each cycle is 48 hours soaking and 48 hours drying at room temperature.

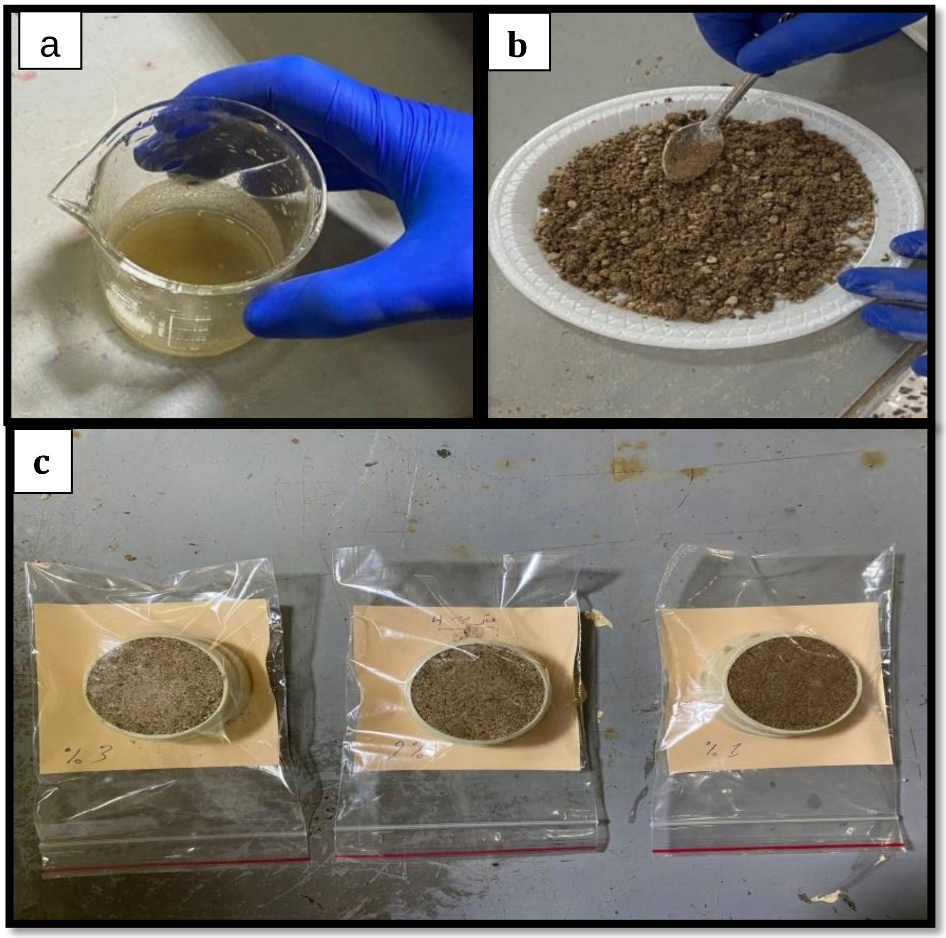

Fig. 3. Stages of adding biopolymer and re-moulding the models(a) A guar gum solution is prepared, (b) solution mixed with the soil and (c) The samples are wrapped in a plastic insulating cover .

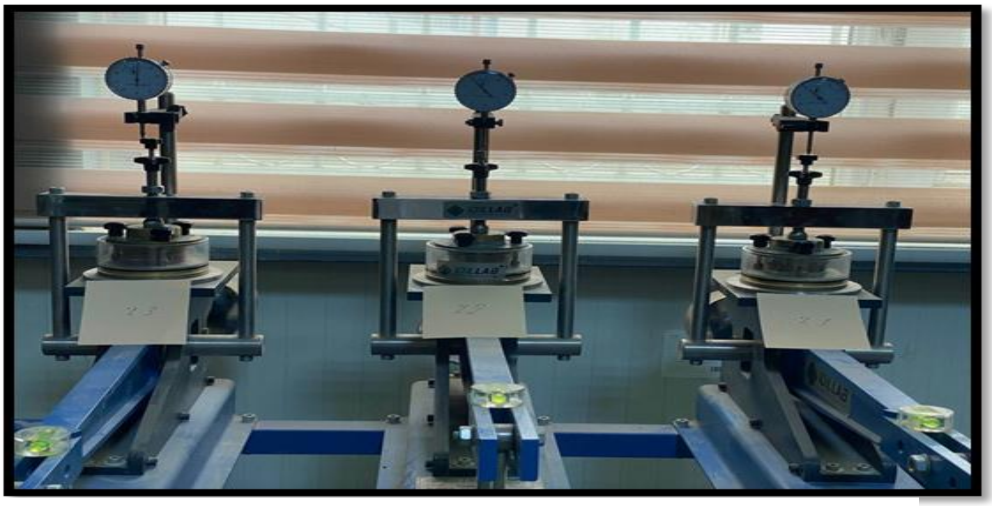

Fig. 4. Placing the samples on the apparatus device after 14 days

3. Results and discussion

3.1. Atterberg limits

The Atterberg limits (liquid limit) values are illustrated in Figure (5). For the soil samples, the liquid limit of the soil in its natural state and with three soils of SP, SW, and SP-SM is shown, where the liquid limit of the soil was low before the addition. It is observed from Figure 5, the liquid limit of the soil treated with guar gum at rates of (1%, 2%, 3%), the addition of guar gum to sandy soil causes an increase in the liquid limit values of the soil. The reason for this is that the soil's ability to absorb water increases due to the addition of guar gum, resulting in higher liquidity.

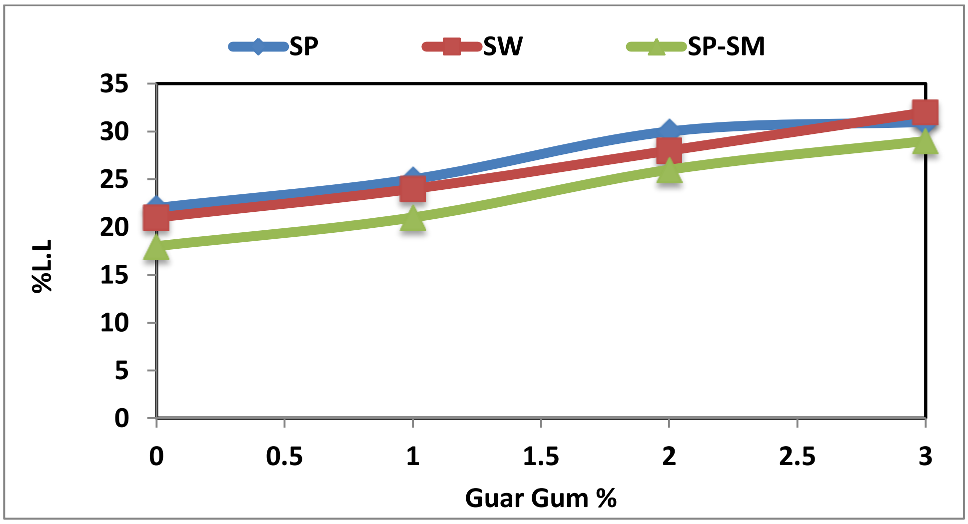

Fig. 5. The relationship between the liquid limit and the percentage of guar gum addition to treated sandy soils.

3.2. *Soil collapse test*

The collapse test conducted on mixture soil aims to examine soil collapse under different conditions. The results obtained from the collapse test of the sandy soil used in this research showed that the soil collapse significantly decreased, where it is observed from the curves shown in Figures 6a-c. The collapsibility decreased with the increase in the added Guar content in the soil, where the percentage decrease in the collapse ranged from 50% to 71%. This decrease may be due to the biopolymer of guar gum, which filled the gaps, coated the soil grain, and significantly reduced the water flow through soil structural, thereby lowering the collapse values, that corresponds with Ahmed's findings [9,10]. This is what the results indicated in the Figure 7.

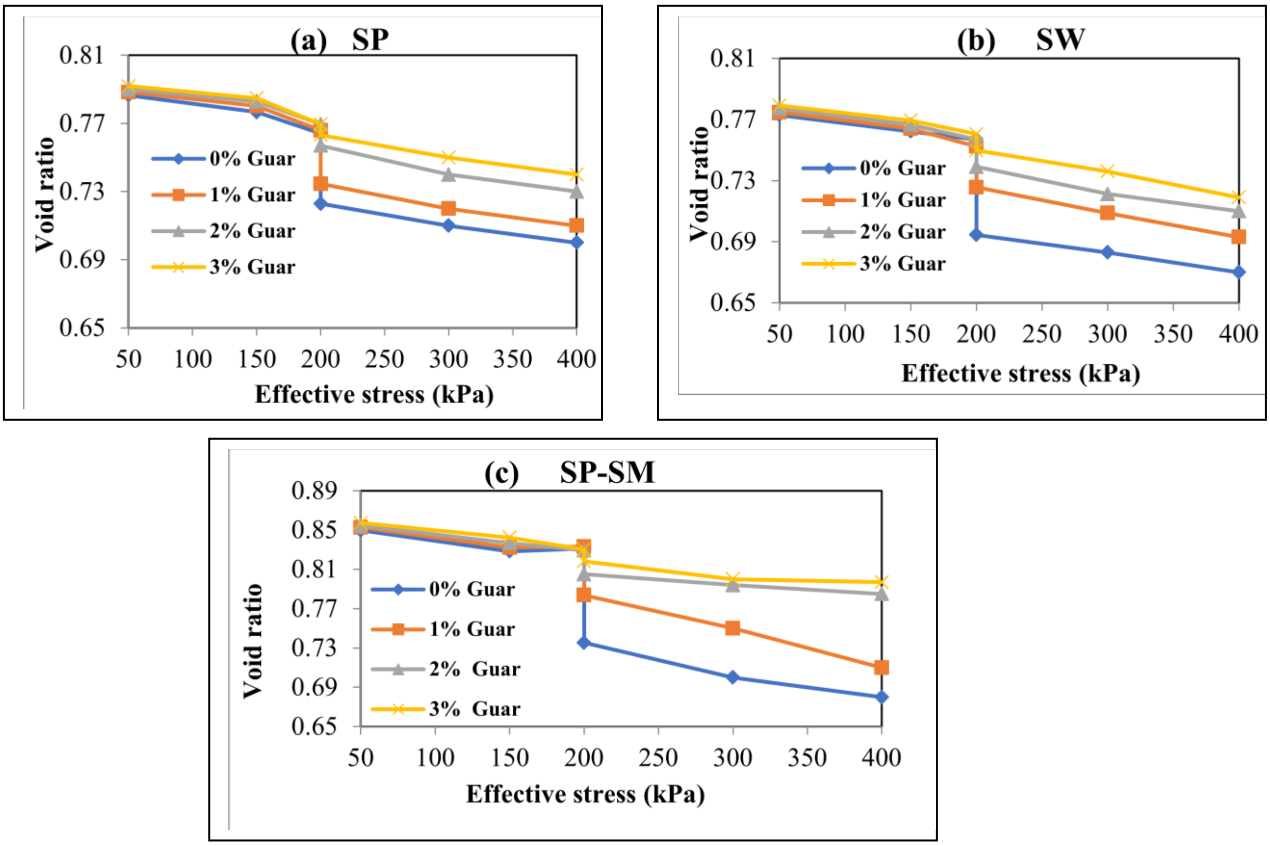

Fig. 6. Development of voids with vertical stress for untreated and treated with guar at different rates.

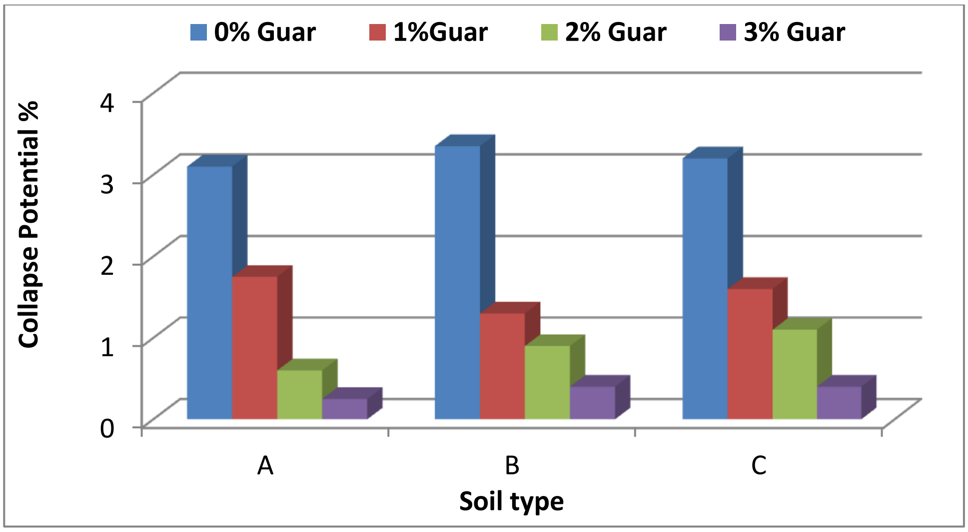

Fig. 7. The relationship between soil type and the collapse potential of soil treated.

3.3. *Durability*

Figure 8 shows the correlation between the collapse potential (Cp) and the progression of the soaking and drying cycles. The graphs indicate that the collapse potential diminished following the second cycle and persisted in its drop until the fifth cycle, at which point a negligible increase was noted. The collapse potential diminished by 67% following the second cycle, but the reduction was 45% after the fifth cycle. This decrease can be linked to the absorption of water and the formation of hydrogel, which leads to better hydration of the hydrogel, thickening of the guar gum biofilm after being soaked and dried, and filling of pores, helping the treated soil particles fit together better and create a strong sand-guar gum mixture. This process envelops the soil particles and fills the interstitial spaces, thereby shielding them from soaking in water. The slight increase in collapse potential after the fifth cycle may be due to the outer parts of the biopolymer absorbing and losing water molecules because of more soaking cycles, which pulls them away from the center of the gel, while the inner parts mostly keep their shape and strength. The repeated soaking and drying make the monomers pull away more from the gel's main structure, creating gaps that make it more brittle.

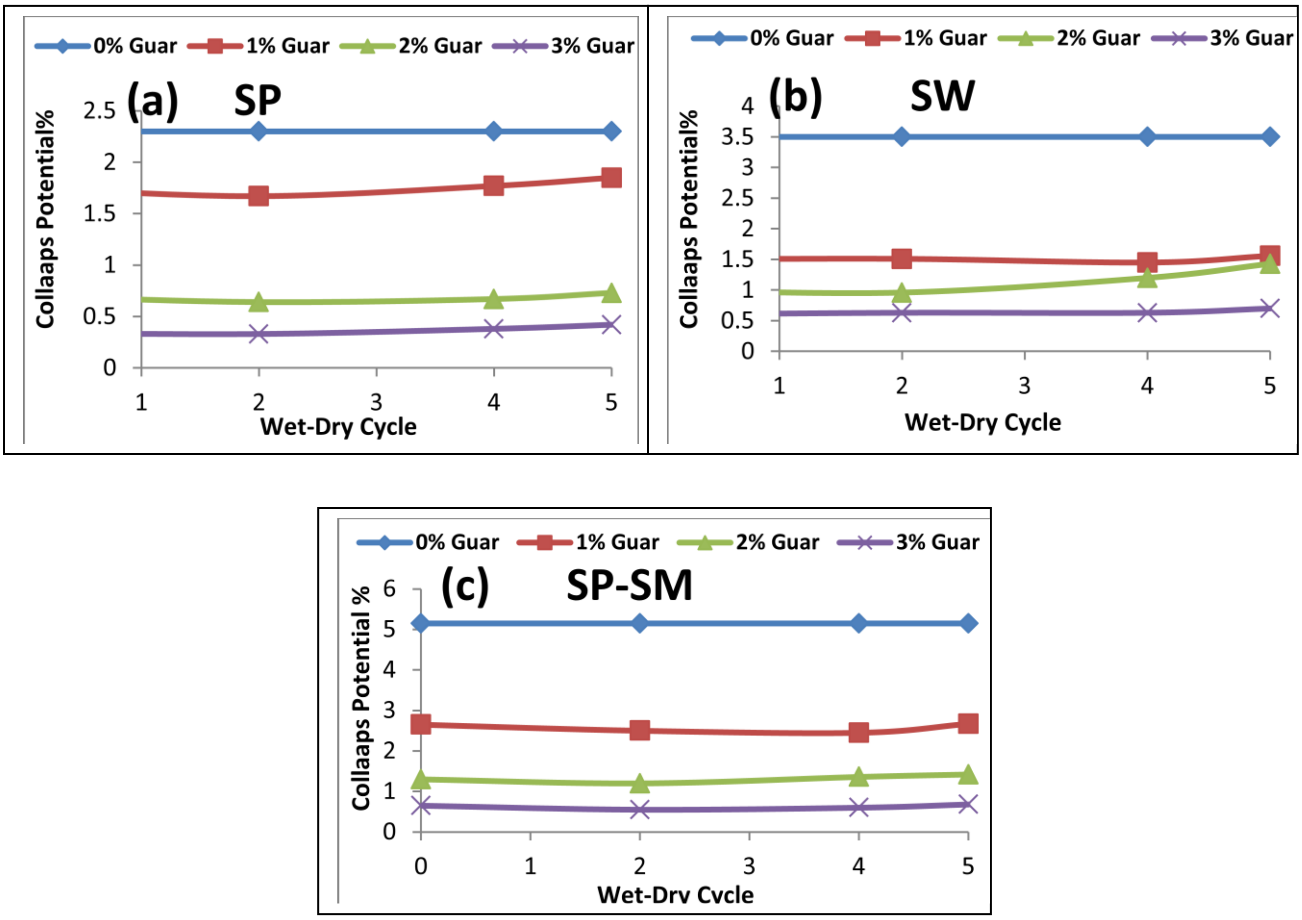

Fig. 8. The relationship between the collapse and the wet-dry cycles for soil treated.

4. *Conclusions*

This study confirms the effectiveness of guar gum in stabilizing sandy soil and highlights its potential as a sustainable alternative to conventional stabilizers in geotechnical engineering. The main findings are:

1. The liquid limit (LL) increased consistently with higher guar gum content.
2. Collapse potential decreased markedly with guar gum addition, showing reductions between 50% and 71%.
3. Under wetting–drying cycles, guar gum-treated samples maintained stability with no significant variation in collapsibility.
4. Guar gum improved soil water resistance, demonstrating suitability for construction in arid regions.

References

[1] N. Thombare, U. Jh, S. Mishra, and M. Z. Siddiqui, "Guar gum as a promising starting material for diverse applications: A review," International Journal of Biological Macromolecules, vol. 88, pp. 361–372, Jul. 2016.

[2] E. R. Sujatha and S. Saisree, "Geotechnical behaviour of guar gum-treated soil," Soils and Foundations, vol. 59, no. 6, pp. 2155–2166, Dec. 2019.

[3] Y. Liu, C. Du, F. Yi, J. Li, and M. Li, "Enhancement on durability of cohesive soil by solidifying with modified guar gum," International Journal of Biological Macromolecules, vol. 309, no. 4, 143003, May 2025.

[4] X. Li, J. He, F. Min, and J. Ji, "Durability and microstructure of guar gum/chitosan-cement modified slurry for flowable fill," Marine Georesources & Geotechnology, published online Jun. 23, 2025.

[5] S. A. Kumar, E. R. Sujatha, A. Pugazhendi, and M. T. Jamal, "Guar gum-stabilized soil: a clean, sustainable and economic alternative liner material for landfills," Clean Technologies and Environmental Policy, vol. 25, pp. 323–341, 2023.

[6] S. Azam, S. N. Abduljauwad, N. Al-Shayea, and O. S. B. Al-Amoudi, "Expansive characteristics of gypsiferous/anhydritic soil formations," Engineering Geology, vol. 51, no. 2, pp. 89–100, 1998.

[7] I. Chang, M. Lee, A. T. P. Tran, S. Lee, Y.-M. Kwon, J. Im, and G.-C. Cho, "Review on biopolymer-based soil treatment (BPST) technology in geotechnical engineering practices," Geomechanics for Energy and the Environment, vol. 24, 100385, 2020.

[8] Z. Wu, J. Xu, H. Fan, L. Li, Y. Ji, and S. Wang, "Experimental study on dry-wet durability and water stability properties of fiber-reinforced and geopolymer-stabilized loess," Construction and Building Materials, vol. 418, 135379, Mar. 2024.

[9] F. M. Muhauwiss, A. H. Hussein, and M. A. Hussein, "Shear strength durability investigation for gypseous soil enhanced by pectin biopolymer," Tikrit Journal of Engineering Sciences, vol. 31, no. 2, 2024.

[10] A. H. Hussein, F. M. Muhauwiss, N. Abed, and A. F. Theyab, "Evaluating the shear strength of guar gum-treated gypseous soil," in Smart Geotechnics for Smart Societies, Aug. 2023, doi: 10.1201/9781003299127-60.

[11] I. Chang, J. Im, and G.-C. Cho, "Introduction of microbial biopolymers in soil treatment for future environmentally-friendly and sustainable geotechnical engineering," Geomechanics for Energy and the Environment, vol. 8, no. 3, pp. 251–264, 2016.

[12] ASTM International, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM D2487-17e1, West Conshohocken, PA, USA, 2017. doi: 10.1520/D2487-17E01.
[13] ASTM International, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, ASTM D4318-17e1, West Conshohocken, PA, USA, 2017. doi: 10.1520/D4318-17E01.
[14] ASTM International, Standard Test Method for Measurement of Collapse Potential of Soils, ASTM D5333-03, West Conshohocken, PA, USA, 2003. doi: 10.1520/D5333-03.