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Use of Biopolymers as Soil Stabilizers: A Review

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Abstract: Soil enhancement methods offer engineers solutions for addressing stability issues encountered during project execution. Rather than employing traditional soil treatment techniques, soil stabilization focuses on enhancing the inherent characteristics of the soil. Currently, polysaccharide biopolymers like xanthan gum, guar gum, welan gum, beta glucan, and chitosan are utilized in soil behavior enhancement to mitigate environmental concerns. Biopolymers show promise in improving soil shear strength and reducing subsidence potential at varying water contents. The effectiveness of treatment relies on factors such as soil composition and the specific biopolymer used.
Keywords: stability, xanthan gum, guar gum, welan gum, beta glucan, chitosan, gellan gum

I. INTRODUCTION

Soil stabilization primarily seeks to enhance the inherent qualities of the soil, boosting its density and strength while also influencing its permeability. Additionally, it serves to decrease compressibility, diminish water sensitivity, and adjust the proportion of fine particles, offering cost-effective solutions. Biopolymers are increasingly replacing conventional soil treatment methods to ameliorate problematic soil behaviour and mitigate environmental concerns.

II. LITERATURE REVIEW

Biopolymers are naturally occurring polymers derived from living organisms (such as plants, algae, and animals). Among them, polysaccharides stand out as the most prevalent group. These are lengthy chains composed of simple sugar units, symbolized by hexagons, typically consisting of six carbon atoms with attached oxygen and hydrogen atoms. Examples include cellulose and starch. Additionally, various other sources like xanthan, lignin, guar gum, gellan gum, welan gum, beta glucan, and chitosan contribute to biopolymer production. In studies by Guo (2014), Chang and Cho (2012), Chen et al. (2013), Khatami and O'Kelly (2013), and Chang et al. (2015), these sources have been explored.

Ayeldeen et al. (2016) utilized different biopolymers like xanthan gum, guar gum, modified starches, agar, and glucan, discovering that they can enhance the mechanical properties, particularly the shear strength, of typical soils (including sand, silt, and clay). Ayeldeen et al. (2017) further investigated these biopolymers and confirmed their positive impact on soil behavior.

A. Xanthan Gum

Xanthan gum, an exopolysaccharide obtained from the bacterium Xanthomonas campestris, is produced via fermenting glucose, sucrose, or other carbohydrates. This versatile biopolymer is utilized across multiple industries for thickening, stabilizing, and emulsifying purposes, and it can also act as a gelling agent when combined with other substances. Various studies conducted by Chen et al. (2013), Chang et al. (2015), Swain (2015), and Cabalar et al. (2017) have delved into the intricate effects of reinforcing xanthan gum with other biopolymers. They've determined that these effects hinge on factors such as the type of soil, concentration of xanthan gum, moisture content, and mixing method. Moreover, the presence of xanthan gum influences the rheological properties, bolstering resistance to compression by altering particle interactions. Chang et al. (2015) particularly examined how xanthan gum reinforcement impacts different soil types, including sandy, natural, red, yellow, and clay soils. They varied concentrations of water and xanthan gum and utilized both dry and wet blending techniques, concluding that the efficacy of treatment is reliant on these variables, with xanthan gum exhibiting greater effectiveness in fine soils compared to coarse ones.

B. Guar Gum

Ayeldeen et.al. (2017) examined a naturally collapsible soil sourced from New Borg El Arab City, Egypt, while introducing two distinct biopolymers, xanthan gum and guar gum, at varying concentrations ranging from 0 to 4%. The findings indicated that higher concentrations resulted in elevated water content, increasing from 12.4% to 15.3% for guar gum and from 12.4% to 14.4% for xanthan gum, respectively, when an additional 2% of the biopolymer was incorporated in both instances. This escalation in concentration also led to a decline in density and volumetric weight.

Moreover, the augmentation in biopolymer concentration caused a decrease in the angle of friction and a rise in cohesion, decreasing from 42 kPa to 105 kPa with the addition of 2% xanthan gum and increasing from 51 kPa to 126 kPa for guar gum. The research concluded that guar gum exhibited superior efficacy compared to xanthan gum in these treatment scenarios.

C. β-1,3/1,6-GLUCAN

In a research conducted by Chang and Cho (2012), the effects of β -1.3/1.6-glucan, a type of biopolymer, on Korean residual soil (commonly found in Asian countries) were explored. Their discoveries revealed that:

1) The application of β -1.3/1.6-glucan polymer fortified the residual soil, and
2) This method presented advantages in terms of technology, economics, and the environment compared to traditional cement treatments, acting as an environmentally friendly additive. In a subsequent investigation by the same researchers in 2014, residual soil underwent treatment with β -1,3/1,6-glucan. Their findings indicated that this treatment modified the mechanical characteristics of the soil structure, hinting at its potential as a beneficial strategy for improving soil compaction performance.

D. Chitin And Chitosan

Chitin and chitosan, extensively utilized polysaccharides, are commonly used. Chitosan, derived from chitin, shares chemical similarities with cellulose, comprising bonded N-acetylglucosamine units. It originates from partially deacetylated chitin, mainly obtained from crustacean shells. Prior to use, these shells undergo deproteinization and demineralization processes (Delphine and Philippe 2004). Hataf et.al. (2018) conducted research in Shiraz, Iran, where low plasticity clays underwent treatment with a biopolymer similar to chitosan, extracted from powdered shrimp shells, and subsequently blended with clay soil. The results of their investigation revealed that the inclusion of this chitosan-like substance bolstered the interactions between soil particles, thus ameliorating mechanical characteristics. Additionally, they noted that chitosan played a role in enhancing the immediate stability of soil under wet conditions, while not impacting its mechanical attributes during dry conditions.

E. Agar

Agar, a polysaccharide sourced from red seaweed, has been employed in Japan for more than three hundred years in various fields including food, construction, and industry. In construction, it functions as a pore-forming agent, as highlighted by Niaounakis (2015). Studies conducted by researchers such as Khatami and O'Kelly (2013), Chang and Cho (2014), and Hataf et al. (2018) have revealed its notable efficacy in bolstering the strength of sandy soil, thus addressing environmental issues.

F. Welan Gum

Welan gum is an exopolysaccharide utilized for modification in diverse industrial fields such as cement manufacturing. It is produced through the fermentation of sugars by Alcaligenes bacteria. As outlined by Niaounakis (2015) and Sonebi (2006), welan gum serves as a viscosity adjuster, improving pseudoplastic properties and enabling thinning under shear force.

G. Gellan Gum

Gellan gum, a microbial polysaccharide, is frequently utilized as a gelling agent in food processing because of its hydrogel characteristics. In research conducted by Chang et al. (2016), they examined its efficacy in soil stabilization. Sandy soil underwent treatment with different concentrations of gellan gum (ranging from 0.5% to 5.0% relative to soil mass). Findings suggested that even at lower concentrations, gellan gum improved the strength, cohesion, and friction angle of the sandy soil.

III. CONCLUSION

Current research is investigating the application of biopolymers such as xanthan gum, guar gum, gellan gum, beta glucan, and chitosan to improve soil conditions. The combined conclusions drawn from prior studies on soil enhancement using biopolymers indicate several noteworthy aspects:

1) Xanthan gum demonstrates superior effectiveness on fine soils when compared to soils with coarser grains.
2) Agar gum demonstrates remarkable effectiveness in strengthening sandy soil.
3) Guar gum outperforms xanthan gum in effectiveness for these treatment applications.
4) Welan gum acts as an agent for modifying viscosity.
5) Chitosan shows promise in improving short-term soil stability in humid conditions without affecting mechanical properties in dry conditions.

The efficacy of treatment varies based on the particular biopolymer utilized and the soil type under consideration, resulting in a wide spectrum of outcomes in soil enhancement experiments.

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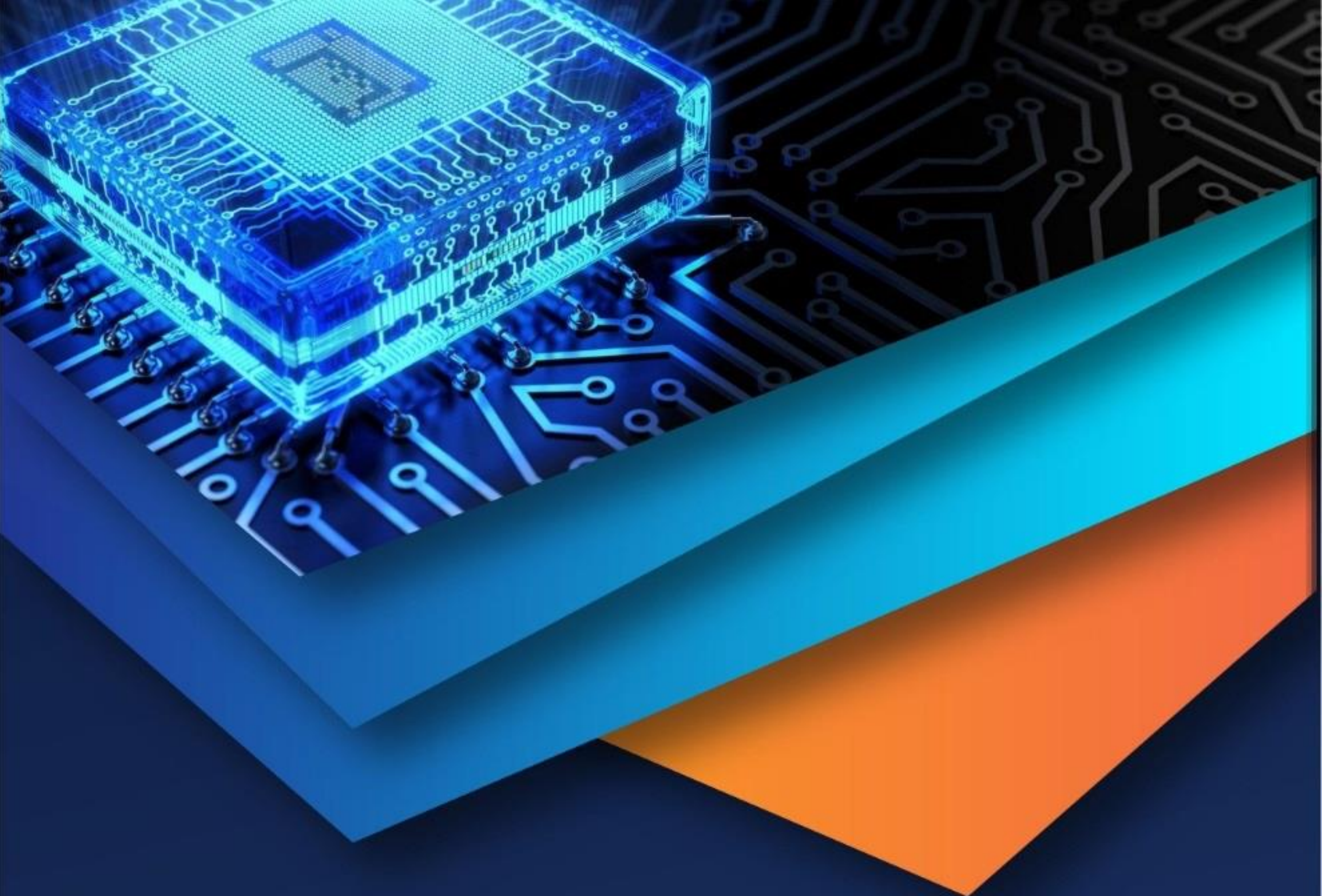

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