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ORIGINAL RESEARCH ARTICLE

Enhancing the engineering properties of gypseous soils by adding the Anthan polymers

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ABSTRACT

Large areas of soil in Iraq are formed up of gypsum soil. As a result, understanding the habits of this soil and its treatment approach is critical, because its current solution is to replace gypsum soil before beginning any building activity. This study used gypsum soil from Tikrit City, which has a gypsum concentration that is around 38%, and the goal of the study is to illustrate the impact of the polymer on the gypsum soil parameters. Simultaneously, researchers are investigating the beneficial effects of polymers on the behavior of gypsum soil. The percentages of the polymer additive (5%, 7.5%, 10%, 12.5%, and 15%) were weight percentages, while the soil tests were chemical, physical, and engineering. When the percentage of additive was increased from 0% to 15%, Soil engineering characteristics enhanced the collapse of the from 5.11 to 1.21, cohesion improved from (28.98 KN/m^2) to (51.16 KN/m^2), and angles of internal friction decreased from 33.190 to 38.850.

Keywords: polymer filling; shear; collapsibility; soil; gypseous soil

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1. Introduction

The most common soluble mineral soil in most area of the world is called the Gypsum soil($CaSO_4.2H_2O$)[1]; in most soils, the gypsum content ranges from <5% to as much as 50%[2,3]. The failure of most engineering structures can be attributed to the gypsum content of the soil on which they are built[4–11]; this is because gypsum soil exhibits good engineering properties only when in dry condition. Gypsum is the material that binds the soil particles. Water dissolves gypsum making it unusable. The gypsum content is small effect the soil characteristics (structure, texture and water retention) when the soil has less than 10% gypsum content[1,12,13].

A number of various approaches for improving the behavior of gypsum soil. One of their strategies was adding other elements to gypsum soil to increase its characteristics[14]. This paper investigated the use of diesel fuel to improve gypsum soil. The study comprised soil improvement tests using gypsum soil (26.55%, 51.6%) to reduce the influence of moisture on this soil using diesel fuel content (0%, 2%, 4%, 6%, 8%). The program evaluated soil permeability, compressibility, and collapse. The results show that the oil additive improved the collapsibility and permeability of the soil sample, which were the main issues; the soil also retained sufficient oil to provide the cohesiveness required to support the load[15].

The improvement of the characteristics of gypsum soil using silicon oil has been reported by Ibrahim and Schanz[16], using 4%–16% of silicon oil. The soil samples were reportedly improved by using 16% silicone oil as the cohesion of soil improved while a decrease in the angle of internal friction was observed comparison with non-treated sample. There was also a clear effect of the employed silicon with high viscosity of the oil led to improve the shear strength of soil, as well as increased the consistency of the soil by binding particles of soil together. Collapse potential of the soil treated with silicone oil was about 4% compared to the untreated soil (at 800 kPa stress level, the collapse potential of the treated soil was 27.4%). The reason for this behaviour could be the water–proofing property of the silicone oil that has coated the soil particles and reduced the solubility of the gypsum in water, thereby reducing the damage to the soil structure and improved resistance to collapse[17].

Al Neami[18] examined the characteristics and behavior of gypsum soil. The gypsum soil had been brought in from Tharthar. The Kaolin was employed as a treatment material, and laboratory tests of mixed and non-blurred trends and the recommended treatment of the Kaolin as a natural addition to treating this soil type were performed. The washing method enhanced soil compressibility, altering the physical properties of gypsum soil. As a result, the shear strength decreased due to this operation. Kaolin should be added to the gypsum soil at four percentages (2%, 4%, 6%, and 8%).

The mechanical characterization of collapsible soil is enhanced using guar gum and xanthan gum. Program for soil augmentation must consider densification, collapsible possibilities, and shear factors. Multiple biopolymer condensations and two treatment phases—after soil-biopolymer mixing and after seven days—make up the exploratory program. Shear characteristics are examined on wet and sun-drenched cured specimens. According to the findings, xanthan and guar gum could enhance collapsible soil. In saturated soil with 2% biopolymer, the collapsible potential decreases from 9% to 1%. In one week, xanthan gum condensation enhanced cohesion stress from 8.5 to 105 kPa, improving soil shear strength from 0.00% to 2%. According to the study, guar gum increases shear strength by 30% while decreasing collapsible potential by 20%[19]. In one area, the properties of gypsum soil that had a 36% gypsum content were investigated. The sample was taken at a depth of 0.5–1 m below the natural surface of the earth and treated with (3%, 6%, and 9%) Copolymer & styrene-butadiene Rubber for enhancing gypsum soil engineering features such as collapsibility, permeability, & shear strength. When compared to untreated soil, soil treated using Copolymer and styrene-butadiene Rubber showed a significant increase in collapsibility, permeability, & bearing capacity[20]. The effect of different amounts of polypropylene fibers in reinforcement soil was studied. The trials were carried out on clay soil with various amounts of polypropylene fibers (0.5 to 1.5%). The liquid and plastic limits, in addition to the unconfined compressive strength, rise whenever polypropylene fibers (0.5%, 1.0%, and 1.5%) are added to the soil. As 1% polypropylene is introduced to the soil, the compression index decreases by 69% and the swelling index decreases by 78%. The specific gravity & max. dry unit weight of polypropylene fiber reduce as the fiber length rises[21]. Nanomaterials, fibers, polymers, waste from industry materials, & biological approaches have all been investigated for treating collapsible soils. The collapse, shear strength characteristics, unconfined compressive strength, permeability, swelling, & durability of treated collapsible soils, in addition to how each ingredient strengthens the soil, have all been examined. Small nanoparticles, fibers, & polymers (less than 4% dry soil mass) enhanced soil metrics. More approximately 30% is preferable for industrial debris such as textile alloy and marble dust[22].

The mechanical characteristics of gypsum soil treated with Xanthan gum polymer (XGP) were examined in this work. The study focused on the magnitude of the beneficial effect of adding XGP to gypsum soil.

2. Materials

2.1. Soil

The gypsum soil in Tikrit was chosen for this study, and a soil sample was taken 4 meters beneath the earth's surface. Soil was used for the physical, chemical, and engineering tests.

2.2. Polymers filling

Xanthan gum ($C_{35}H_{49}O_{29}$) is produced by the bacterium *Xanthomonas campestris* as an anionic extracellular material during the aerobic sugar fermentation. On every two units of the sugar molecule, a linear 1, 4-linked b-D-glucose backbone is substituted by a negatively charged trisaccharide chain (which includes a D-glucuronic acid unit linked between two D-mannose units)[23]. Xanthan gum is an anionic polysaccharide that produces viscous hydrogels by adsorbing water molecules via hydrogen bonding. Because of the significant viscosity rise in a short amount and its low cost, xanthan gum is frequently employed as a fluid thickener in the food sector, as well as an additive for drilling muds for the minerals and petroleum industries[24–26].

In this investigation, xanthan gum from (Shandong Fufeng Fermentation Co., Ltd.) was used. The characteristics of Xanthan gum as described by the manufacturer are shown in **Table 1**.

Table 1. Xanthan gum characteristics (going from Shandong Fufeng Fermentation Co., Ltd).

Biopolymer	Color	Ash content (%)	pH	Viscosity (cps)
Xanthan gum	Cream-white	≤13	6–8	≥1200

3. Sample preparation

The collapsibility test samples were manufactured to be 60 °C × 20 mm (D × H). The samples were collected by hand on disturbed gypsum soil. A sufficient amount of material, somewhat larger than the required test specimen, was sliced away from the outside and dried for 24 hours. For further processing, the samples were placed in plastic bags. XPG was combined with water and homogenized in the dried material, as indicated in **Figure 1**. The sample was placed in molds and stored in plastic bags for 24 hours before testing for collapse potential.

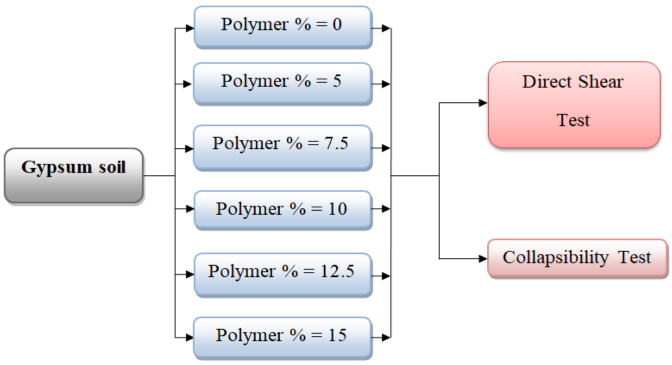

Figure 1. The process flow of the test.

3.1. Physical properties

Standard tests were used to determine the physical characteristics of the soil. The soil water content test followed the ASTM D2216-02 standard, while the liquid and plastic limits tests followed the ASTM D4318-00 standard. The specific gravity of the samples was determined using the ASTM D854 (2010) standard; sieve analysis was performed using the ASTM D422-02 standard procedure; and field density was determined using the ASTM D1556-00 methodology[2,3]. The gypsum content was calculated using the following Equation (1)[27]:

$$x = \frac{W_{45^oc} - W_{45^oc}}{W_{45^oc}} * 4.778 * 100 \tag{1}$$

where:

x = content of the gypsum.

$w_{45\,°C}$ = At 45 °C the sample weight.

$w_{105\,°C}$ = At 105 °C the sample weight.

Tests for pH and total sulfate content were done at the laboratory unit of the Chemical engineering department, Tikrit University. The chemical characteristics of the soil were presented in **Table 2**.

Table 2. Show the properties of untreated soil.

Properties		Value
Moisture content, (ω)%		2.172
Specific gravity, (G_s)		2.60
Atterberg limits	Liquid limit (L.L) %	27
	Plastic limit (P.L) %	N. P
	Plasticity index (P.I) %	-
Minimum dry density, (γ_{min}) kN/m³		11.16
Maximum dry density, (γ_{max}) kN/m³		18.39
Field density, (γ_f) kN/m³		12.78
Relative density, (Dr) %		56.1
Gypsum content %		38
Total sulphate content (SO_3) %		40
pH value		8.0

3.2. Engineering properties

3.2.1. Direct shear test

This test was conducted as described in the ASTM D3080-98 protocol for shear test; **Figure 2** presents the outcome of this test on the samples at field unit weight.

Figure 2. Direct shear box test.

3.2.2. Collapsibility tests

This test was conducted using an oedometer as per the ASTM D5333-03 standard to define the collapse potential (Cp) for the soil (see **Figure 3**).

The test is performed using the Single–Oedometer Collapse Test method: The test consists of placing a disturbed sample of soil in an oedometer and placing weights equal to the soil load pressure in addition to the pressure resulting from buildings erected on the soil, then leaving it for a period of time until equilibrium is reached, then the sample is immersed in water and left until the amount of sample subsidence is reached fixed, then a fusion test is performed on the sample with the maximum weight, and by plotting the ratio of voids (Voids Ratio, e) to the logarithm of pressure (Log p), the collapse potential (CP) is determined. The test was then restarted to max. pressure (800 kPa). The collapse potential (Cp) was calculated from Equation (2):

$$C.p. = \frac{\Delta e}{(1 + e_o)} * 100 \tag{2}$$

where:

Δe = change in void ratio.

e_o = initial void ratio.

Figure 3. Oedometer test.

4. Result and discussion

The use of chemicals to stabilize the soil to prevent gypsum dissolution-induced damage is one approach to improving the engineering features of gypseous soil. When added to gypsum soil, xanthan gum polymer can change its chemical and physical properties. The bacteria Xanthomonas campestris generates large molecular weight polysaccharides with high water retention capacity, which can have a major impact on soil characteristics. When added to gypsum soil, xanthan gum promotes water retention by forming a solid, gel-like structure; its pH is neutral, so adding it to the soil did not appreciably modify the soil pH. Xanthan gum also stimulates the production of stable soil aggregates, which improves soil structure and porosity; it collects soil particles and forms a three-dimensional network inside the soil matrix, resulting in stable soil aggregates that will enhance soil structural stability.

The test set on disturbed treated samples and the outcomes were shown in **Figure 4**; the results are presented in terms of the relationship between daily gauge reading (mm) and the applied load (kPa). The relationships between the XGP content and collapse potential of the gypseous soil is shown in **Figure 5**, where the collapse potential was found to decrease with increases in the XGP content; an increase in the XGP content from 0% to 15% brought about a decline in the collapse potential from 5.08 to 1.16. Observably, the collapse potential of the treated soil decreases with increases in the XPG content, thereby transforming the soil from its troubled state to a moderate condition. This improvement could be attributed to the ionic bonding between the soil particles & the XPG, as attended by the high collection and filling of large voids with the biopolymer gel or air.

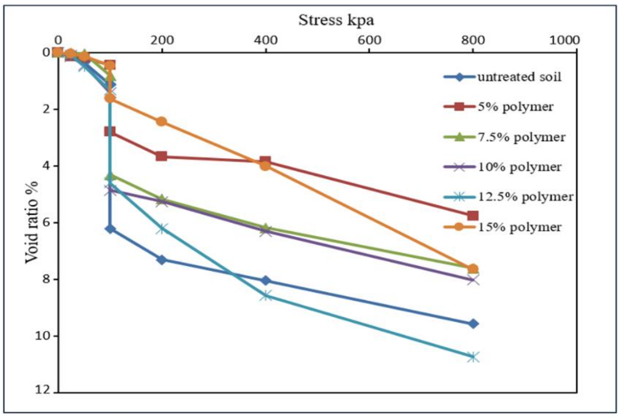

Figure 4. Show the collapsibility test results for soil treated by xanthan gum.

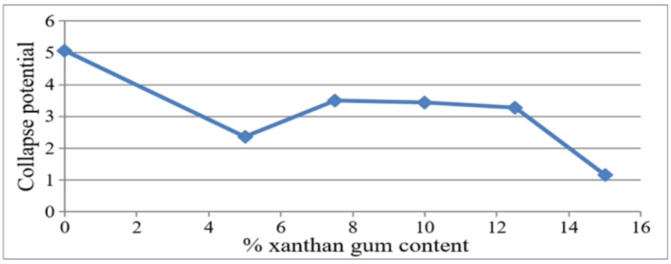

Figure 5. Relationship between the collapse potential and xanthan gum content.

The connection between the XPG content & the cohesion & internal friction of the soil was shown in **Figure 6**; notably, there were declines in the void ratio and collapse potential of the treated soil as the XPG content increased. An increase in the XPG content from 0% to 15% brought about a 2.7-fold increase in the collapse potential of the treated soil, showing that the extent of the collapse of the soil decreases at higher XPG contents, thereby changing the soil phase from its trouble state to a moderate state.

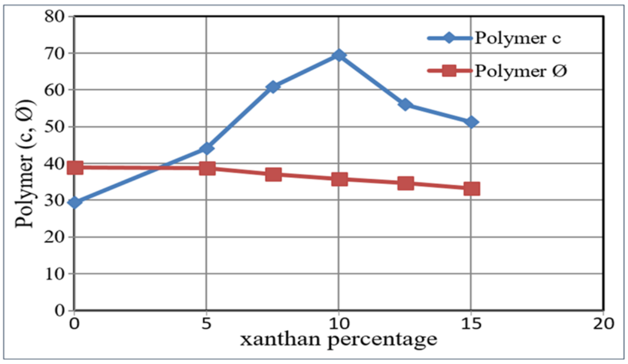

Figure 6. Relationship between the collapse potential and xanthan gum content.

5. Conclusions

From this study we can concluded the following points:

1) Polymers can be considered as an agent for highly gypseous soil.
2) The gypseous soil characteristics was improved by added polymers.
3) Significant reduction in collapsibility for the treated gypseous soil with 7.6% to 12.5% mixed polymers.
4) For the gypseous soil, when added polymer noticed reduced the compressibility characteristics. Also, the maximum cohesion was happened at 10% of polymers ratio.

Author contributions

Conceptualization, NAH and HAA; methodology, NAH; software, NAH; validation, NAH, HAA and

AKM; formal analysis, NAH; investigation, NAH; resources, HAA; data curation, HAA; writing—original draft preparation, AKM; writing—review and editing, HAA; visualization, AKM; supervision, AKM; project administration, HAA; funding acquisition, NAH. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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