Improvement of the Gypseous soil properties by using Copolymer and Styrene-butadiene rubber

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Abstract: Gypseous soils are spread in several regions in the world including Iraq, where it covers more than 28.6% [1] of the surface region of the country. This soil, with high gypsum content causes different problems in construction and strategic projects. As a result of water flow through the soil mass, permeability and chemical arrangement of these soils vary over time due to the solubility and leaching of gypsum. In this study the soil of 36% gypsum content, is taken from one location about 100 km (62 mi) southwest of Baghdad, where the sample is taken from depth (0.5 - 1) m below the natural ground surface and mixed with (3%, 6%, 9%) of Copolymer and Styrene-butadiene Rubber to improve the engineering properties of the gypseous soil including collapsibility, permeability and shear strength. Results of the experimental work show noticeable improvement of collapsibility, permeability, and bearing capacity in soil treated with Copolymer and Styrene-butadiene Rubber compared to untreated soil.

Keywords: Gypseous soil, Polymer materials, collapse potential, permeability.

1. Introduction

Gypsoms soil is considered as one of the most difficult unsaturated soils in the construction of roads and buildings. The presence of the gypsum (Hydrated Calcium Sulphate (CaSO₄·2H₂O)) in the soil affects the mechanical and physical properties and makes the soil more sensitive to the water. When the water reaches this kind of soil from a heavy rainfall a rearrangement and a change in volume (decrease) occurs. This change in volume significantly causes a structural failure since the soil loosens the bond between the particles and becomes weak to withstand and resist the load applied on it depending on the soil nature and geological structure, the primary soil density, soil structure, the imposed stress formal and the amount of wetting [2], [3], [15], [16], and [17]. In civil engineering the soil can be classified as Gypsoms soil depending on the amount of gypsum content in it, regardless of soil color or shape, some researchers indicated that a certain percent of gypsum should exist, such as, 3%, 4%, 6% as a lower limit [4]. These rates of gypsum have high effects on the physical and mechanical characteristics of soil, and this effect occurs unevenly in the soil according to the amount of gypsum. To reduce the damage magnitude caused to the structure, the gypseous soil should be improved by two ways: mechanical and chemical. The mechanical method is a physical process by removing and/or adding another soil and the improvement is achieved by using mechanical and chemical techniques. The chemical method is made by adding a chemical substance that is able to change the properties and get chemical reactions in the soil [5], [6]. It has become necessary to use non-traditional suburbs materials to achieve the economic and environmental considerations such as Polymers and resins, which are characterized by its effectiveness in a short time. Even though, still there is no much information about non-traditional suburbs especially for polymers. However, for
economic reasons the chemical composition of polymer is not disclosed by the companies, which make the researchers look for its result in improvement by rather than on performance mode.

Since polymers and resins are not widely used in past, it has become necessary for many researches to know the methods of implementation and the added amounts and the testing methods. The main purpose of this paper is to study the effect of polymer materials on density, shear strength, permeability and void ratio and to know the perfect amount for using.

2. The Material Used and Experimental Work
2.1 Gypseous Soil
To achieve the purpose of this study, natural gypsum soil of percentage 36% gypsum, is taken from one location about 100 km (62 mi) southwest of Baghdad, where the sample is taken from depth 0.5 - 1 m below the natural ground surface, the unit weight of the soil in the location was 14.5 kN/m³ and the natural water content 5%. The undisturbed soil sample was dried by air, made homogenous and put in plastic bags and transported to Soil Mechanics Laboratory at the Civil Engineering Department, College Of Engineering at AL-Qadisayh University to evaluate the engineering properties of the soil.

2.2 Copolymer
Copolymer is a mix of non-ionic environmentally safe co-polymer product, where it is considered a new material used for treatment where it is diluted with water and added to the soil and are characterized by [7]:
- Do not pollute ground water.
- Safe to plant and animal life in the soil.
- Contains soil moistening agents.
- Good resistance to the Ultraviolet rays.
- Good resistance to erosion.
- Penetrates into the soil or any particulate materials. Table 1 showed the other Technical properties [7]

| Element              | Style                  |
|----------------------|------------------------|
| Color                | white (transparent once dried) |
| Form                 | liquid                 |
| Specific gravity     | 1.03                   |
| Solid content        | 20-22 %                |
| Viscosity            | 300 – 350 mPas         |
| Surface Tension      | 40 mN/m                |
| Freezing point °C    | 0                      |
| Boiling point °C     | 100                    |
| pH                   | 5.5                    |

2.3 Styrene-butadiene Rubber or SBR
Ultrabond SBR is an aqueous distribution of Styrene Butadiene Copolymer, when mixed with cementations these products give a great performance for water resistant properties. SBR is use as an admixture to sand and cement mortars, reduces, cementations’ flooring screeds. It can be used for external and internal in areas of intermittent and continuous water connection [7]. Table (2) shows the other technical properties.
Table 2: The properties of Styrene Butadiene Copolymer

| Property                  | Value          | Standard of the test |
|---------------------------|----------------|----------------------|
| Appearance                | Fluid liquid   |                      |
| Color                     | Milky white change to transparent when dry | |
| Density                   | 1,050 kg/ m³  |                      |
| Solid Content             | 36-38 %        |                      |
| Min. Application temperature | +5 °C       |                      |
| Temperature resistant     | -20 up to +90 °C |                |
| PH                        | 8 to 9         |                      |

3. Physical and engineering tests of gypseous soil

The results of physical and chemical properties tests of gypseous soil are shown in Table (3). The grain size distribution is illustrated in Figure (1) and classified as poor grade sand (SP).

Table 3. The results of physical properties tests of gypseous soil.

| Physical Property           | Value          | Standard of the test |
|-----------------------------|----------------|----------------------|
| Specific gravity, G_s       | 2.54           | B.S1377:1975[8]     |
| D₁₀                         | 0.1            | ASTM 422 [9]        |
| D₃₀                         | 0.19           | ---                  |
| D₆₀                         | 0.3            | ---                  |
| Coefficient of curvature, C_v| 1.203         | ---                  |
| Coefficient of uniformity, C_u| 3             | ---                  |
| Unified Classification system | SP            | ---                  |
| Maximum Dry Unit Weight γ_d(max) (kN/m³) | 16.28  | ASTM, 698 [10]     |
| Natural Water content ωopt (%) | 5             | ASTM, 2216 [11] |
| Permeability( cm/sec)       | 3.7×10⁻³       | ASTM D-2434 [12]   |
| C=1.33                      |                |                      |
| Direct Shear (c (kN/m²) and φₒ ) | φ=30.2o     | ASTM D3080_7 [13]  |
| Single Collapse (%)         | 9.47           | ASTM D5333 [14]     |

![Figure 1. Grain size distribution](image)

3.1 Chemical Tests
A series of chemical tests were carried out on the natural gypseous soil. These tests were conducted in Karbala laboratory and X-ray test in laboratory of the state company of Geological and Mining in Baghdad, and the chemical properties are shown in Table (4) and Table (5),

| Chemical Property              | Value |
|-------------------------------|-------|
| Total (SO₄%)                  | 13.87 |
| Total soluble salts (T.T.S %) | 9.8   |
| Gypsum content (%)            | 36    |
| PH value                      | 8.21  |
| CL (%)                        | 0.00319|
| O.M (%)                       | 0.86  |

| Element | Wt. %   | Wt. % sigma |
|---------|---------|-------------|
| O       | 53.46   | 0.3         |
| Na      | 0.56    | 0.07        |
| Mg      | 1.8     | 0.07        |
| Al      | 3.4     | 0.08        |
| Si      | 20.08   | 0.18        |
| S       | 5.06    | 0.1         |
| K       | 1.64    | 0.07        |
| Ca      | 11.65   | 0.14        |
| Ti      | 0.13    | 0.06        |
| Fe      | 2.23    | 0.12        |

4. Results and Dissection

4.1 compaction test

Table (6) shows the compaction test results for natural soil and soil with added Copolymer, and Styrene-butadiene Rubber, respectively. It is clear from the results that there is no significant change in the maximum dry density. The maximum dry density of gypseous soil with added co-polymer increased to (3.2 and 5.65 %) in (3%) for copolymer, Styrene-butadiene Rubber, respectively and after that began decrease to (1.7, and 7%) in 9%. The optimum water content was increased in the first adding of material then it was decreased in 9% adding.

|                     | Copolymer | Styrene-butadiene Rubber |
|---------------------|-----------|--------------------------|
| Maximum dry unit weight, kN/m³ | 16.28 | 16.77 | 16.56 | 16.5 | 17 | 16.5 | 16.32 |
| Water content (%)    | 11 | 13 | 8 | 8 | 11 | 13 | 8 |

4.2 Permeability test:
The permeability test was performed for gypseous soil and treated gypseous soil with polymer materials with 3%, 6%, and 9% at maximum dry density for natural soil and optimum moisture content for all tests. It was found that the permeability coefficient decreased as polymer material increased. Table (7) shows the results of adding Copolymer and Styrene-butadiene Rubber to the gypseous soil. We can see from the results that the percent of improving to the Copolymer adding is higher than the Styrene-butadiene Rubber to the permeability coefficient.

| % added | 0%   | 3%    | 6%   | 9%   |
|---------|------|-------|------|------|
| Copolymer | 3.7 ×10^{-3} | 1.98×10^{-4} | 2.3×10^{-5} | 5.6×10^{-5} |
| Styrene-butadiene Rubber | 3.7 ×10^{-3} | 5.39×10^{-4} | 5.007×10^{-4} | 1.93×10^{-4} |

4.3 Collapse Test

All the collapse tests were conducted to the same maximum dry density and water content of natural soil with maximum dry density (16.28 kN/m^3) and (11%) optimum water content and to treated soil with different percentage from (Copolymer, Styrene-butadiene Rubber). The results of single collapse tests were shown in table (6) for the gypseous soil and the soil with added Copolymer, and Styrene-butadiene Rubber. it is seen from the results that the collapse potential decreases to (63.35% and 67.79%) in 3% for (Copolymer and Styrene-butadiene Rubber) after that it began to increase to (45.66% and 14.79%) in 9%. The figures (2) and (3) show the results of single collapse test for soil in natural state with soil improved by polymer materials with 3%, 6%, and 9% for Copolymer and Styrene-butadiene Rubber, respectively.

| Percent added | 0% | 3% | 6% | 9% |
|---------------|----|----|----|----|
| Copolymer     | 9.47 | 3.47 | 5.74 | 6.21 |
| Styrene-butadiene Rubber | 9.47 | 3.05 | 3.68 | 4 |

4.4 Direct shear test:

The parameters of direct shear tests were used to determine the bearing capacity of soil as shown in Table (1). It was found that the bearing capacity of soil increased with the increase in Styrene-butadiene Rubber contents to (6%) and then the improving percent decreased, while in Copolymer it has high value in (3%) and after that it decreases to less than the bearing capacity for gypseous soil. Table (9) shows the result of bearing capacity for gypseous soil with added polymer materials.

| Materials                     | 0%    | 3%    | 6%    | 9%   |
|-------------------------------|-------|-------|-------|------|
| Copolymer                     | 315.95 | 442.64 | 294.24 | 201.502 |
| Styrene-butadiene Rubber      | 315.95 | 519.32 | 511.32 | 435.1 |
Figure 2. The results of single collapse test of gypseous soil treated by adding (a) 3%, (b) 6% and (c) 9% Copolymer
Figure 3. The results of single collapse test of gypsous soil treated by adding (a) 3% (b) 6% and (c) 9% Styrene-butadiene Rubber
5. Conclusion:

1- The collapse potential decreases with increase the polymer materials to 3% and after that began to increase. This attributed to a reason that increase in these materials made the partial fewer connected with each other and the cohesion began decrease this made the structure of the mass weak and exhibition to collapse.

2- Decrease in permeability coefficient in 6% for both Copolymer and Styrene-butadiene Rubber because this material made as waterproof and made cover around the soil partials and this cover made a strong bond between these practical lead to decrease in the permeability.

3- Increase in bearing capacity with increase these materials to 6% because at this percentage the polymer has high value in cohesion parameter.

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