Mesopot. J. Mar. Sci., 2018, 33(1): 57 - 64

Improving the sub-base materials at Al-Fao port in Basrah Governorate-South of Iraq by adding some synthetic polymers and cement

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(Received: 11 June 2018 - Accepted: 28 June 2018)

Abstract - The improvement process by adding polymers and cement has been carried out to sub-base material used in the compaction processes, in order to observe their effects on the geotechnical properties of the sub-base such as compaction, unconfined compressive strength, shear strength, California bearing ratio and absorption ratio. It has been observed that there is a significant improvement in the geotechnical properties of the soil as the value of the maximum dry density increased from 2.144 to 2.220 g/cm^3, while the value of the optimum moisture contents decreased from 6.3 to 5.2% with a percentage of 5 % of the first polymer (Polyvinyl Acetate & Polyol). It is also revealed that there is an increase in the value of the unconfined compressive strength after adding 5% of the first polymer and 5% cement to the sub-base sample, and then soaked in water for different periods of time, the result was 11550 kPa with a soaking period of 28 days. Also, the angle of the internal friction values increased in testing the direct shear strength from 35° to 45° by adding 5% of the first polymer, and cohesion occurrence among the particles of the material under the action of the polymer as a adhesive material, the value reached 200 kN/m^2. The California bearing ratio increased from 49% to 64% by adding 5% of the first polymer, while the absorption ratio decreased considerably at the same ratio and material from 9.8% to 4.1%.

Key words: Soil improvement, sub-base material, geotechnical properties, polymers, remolded samples.

Introduction

Soil improvement is changing soil characteristics by increasing its strength and treating the problems in order to obtain the best engineering performance without resorting to change the site or replace the soil.

The idea of improvement appeared in the mid twentieth century, and its applications have become widespread in several countries to reinforce the weak soil, coastal soil, layers of bearing foundations, airport pavements, industrial estates, reservoirs, and dams (Shin *et al.,* 1993).

Soil improvement can be done by various methods among which is by adding materials that work mechanically or chemically to improve some of the geotechnical properties of the soil. On the basis of their interaction with the soil, these additives are classified into mechanical and chemical additives.

Polymers are considered as one kind of chemical additives which have become a common use to improve numerous soil properties such as the increase of maximum drying density, the decrease of ideal humid content, increase of unconfined compressive strength, direct shearing strength and decrease the fast absorption in addition to control the ratios of filtration of sandy soils and protecting its wetness.

Polymers have also proved their appropriateness and effectiveness in engineering projects such as constructions, airports, roads pavements or sidewalks, car parks, paving sides of rivers, and control of erosion processes (Al-Tai, 2005).

Newman and Tingle (2004) showed that adding Polyvinyl Chloride compound and Acrylic polymer to sandy soils and clayey soils led to increase the unconfined compressive strength gradually along with a period of maturity for 28 days. Ahmed *et al.* (2013) pointed out that adding Styrene-Butadiene-Rubber (SBR) materials to the sandy soil caused an increase of shear strength as a result of its behavior as a binding agent which increases the soil cohesion. Ilies *et al.* (2017) mixed polyethylene with the sandy soil, which revealed an increase in the soil cohesion to 53% and increase of internal friction to 63%.

The present study aims at improving the geotechnical properties of the sub-base materials by adding some of the polymeric materials and cement at different ratios to determine which material and ratio achieving the best results.

Materials and Methods

1. Sub-base: it is an aggregate material which is made up of graded grains of gravel and crushed gravel with sand and clay. The properties of these materials are summarized in Table (1). They were obtained from Al-Zubair town quarries, Basrah governorate.
2. The synthetic polymeric materials: Three kinds of polymers were prepared at the Polymer Research Center-University of Basrah which were used as follows:
    - The first polymer (Polyvinyl Acetate & Polyol): A compound made up of mixing 75 g of Polyvinyl Acetate with 25 g of water, then the solution was mixed with Polyo1 at a rate of 1: 3, i.e. 75 g of the solution with 25 g Polyo1 (MW. = 86.09).
    - The second polymer (Acrylic Resin): They are polymeric compounds made up of acrylic acids or mono-polymeric methacrylic (MW. = 119).
    - The third polymer (Polyester Resin & Polyurethane): A compound made up of mixing 50 g of Polyester Resin with 5 mg of Polyol, then Izosianid material was added.
3. Cement (White Portland Cement): Which is made up of pure raw materials free from mineral oxides.

Table 1. Sub-base material properties.

<table>
<tr><th rowspan="2">Grain size analysis (%)</th><th>Gravel</th><th>Sand</th><th>Silt</th><th>Clay</th></tr>
<tr><td>59</td><td>36</td><td>3</td><td>2</td></tr>
<tr><th rowspan="2">Chemical material Ratio (%)</th><th>ORG</th><th>SO_4</th><th>Gypsum</th><th>T.S.S</th></tr>
<tr><td>0.075</td><td>0.898</td><td>1.932</td><td>4.25</td></tr>
<tr><th rowspan="2">Compaction parameters</th><th colspan="2">Maximum dry density (gm/cm^3)</th><th colspan="2">Optimum moisture content (%)</th></tr>
<tr><td colspan="2">2.144</td><td colspan="2">6.3</td></tr>
<tr><th colspan="3">Abrasion ratio (%)</th><td colspan="2">21</td></tr>
<tr><th colspan="3">Moisture content (%)</th><td colspan="2">0.78</td></tr>
</table>

Samples Preparation:

The sub-base materials were prepared from four proportions 1, 3, 5 and 7 % of the three polymer types and the ratio that gave the highest value of dry density from each polymer types (5% was added to the sub-base) was chosen and mixed with four proportions 2, 4, 6 and 8 % of water, in order to determine the optimum moisture contents according to ASTM D-698. The optimum ratio of 5 % added from each polymer types to the sub-base was used to prepare cylindrical samples with dimensions of 7.5 × 15 cm (ASTM D-1883-99). The cylindrical samples were left for 7 days for curing period to undergo the unconfined compression tests (ASTMD-2166). The shear strength test was performed by passing the sample through a seive No. 4 (4.75 mm) in two stages, the first was carried out by the direct method (without curing period), while the second was carried out by leaving the samples for 7 days for curing period. This test was conducted according to ASTM D-3080. The California Bearing Ratio (CBR) test and the Absorption test were conducted according to ASTM D-1883 and BS:1377:1975, respectively.

Results and Discussion

Compaction Test:

The results of the optimum moisture contents (OMC) in the conducted tests after adding the three polymers at ratios of 1, 3, 5 and 7 % to determine the ratio that gives maximum dry density value are presented in Figure (1). The results show that the ratio 5% gives the maximum dry density value for the three polymers which are 2.210, 2.190, 2.200 g/cm3, respectively. The optimum ratio of the three polymers which achieved the highest dry density of 5% with weighing ratio of 2, 4, 6 and 8% of water in the previous experiments is determined, and it was added to a dry sample of sub-base. The values of maximum dry density and optimum moisture contents were determined by drawing a density curve (Figure 1).

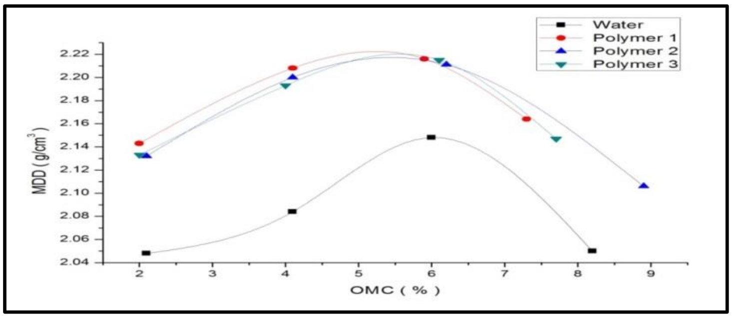

Figure 1. Values of the maximum dry density and the optimum moisture content of the three kinds of polymer.

Unconfined Compressive Strength:

Unconfined compressive strength test was conducted on samples of soil from the sub-base materials by adding the best percentage of polymers (5 %). As known, it is difficult to obtain a cylindrical sample from the non-cohesive soil due to the large size of the grains and the absence of binding materials among the grains, therefore there is no cohesion. However, after mixing the sub-base sample with 5% of the three polymers and left to stand for 7 days for a curing period (Figure 2), the remolded samples was used for unconfined compressive strength test.

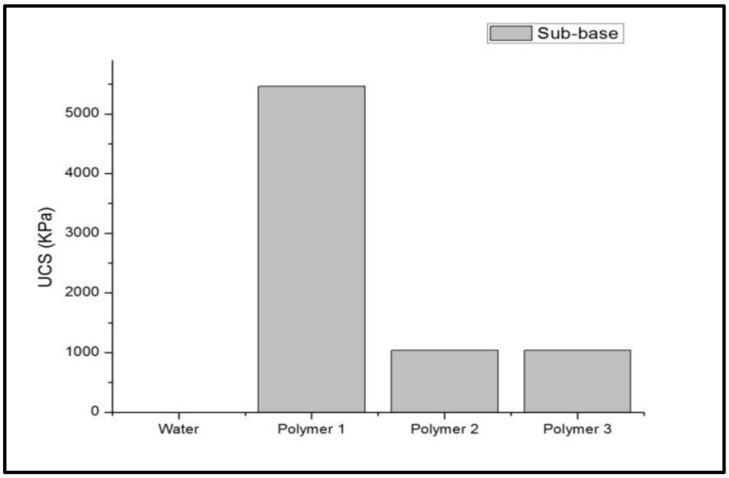

Figure 2. Values of the unconfined compressive strength for the sub-base samples with 5% of polymers.

The results showed that the highest unconfined compressive strength of 5460 kPa was achieved by adding the first polymer, while the second and third ones showed the lowest values (1000 kPa) (Figure 2). This increase is rendered as the sub-base materials are of high infiltration. Therefore, this helps the polymers to penetrate the materials and work as adhesive substance which leads to an increase cohesion and stiffness. Moreover, the high density of the first polymer plays a major role in raising the mixture density.

Other tests on the remolded samples that prepared by mixing sub-base materials, with 5% of the first polymer and 5% of the white Portland cement immersed in water at different period of time (1, 7, 14 and 28 days) were performed. The results showed a significant increase in the unconfined compressive strength values exceeding 11000 kPa for the immersion periods of 14 and 28 days (Figure 3). Immersing the sample in water increases the cement stiffness which leads to an increase in the unconfined compressive strength.

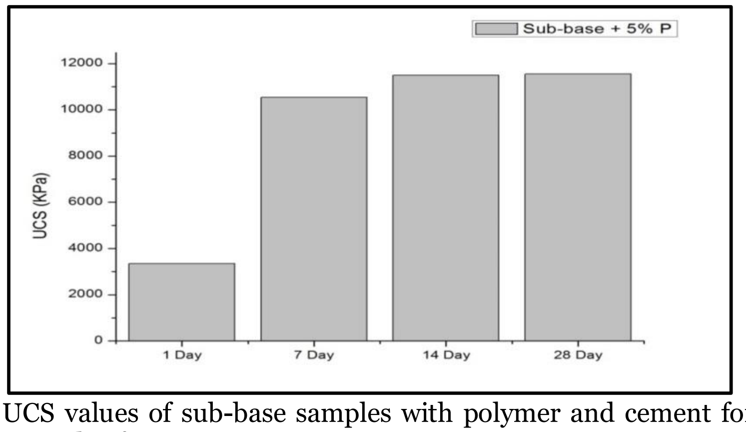

Figure 3. UCS values of sub-base samples with polymer and cement for different periods of immersion in water.

Direct Shear Strength:

The results showed that the value of the internal friction angle of the sample free from additives is 35° while the cohesion value is 0 kN/m² (Figure 4). After adding the three polymers at an optimum percentage of 5% to the sub-base samples, with mixing and then measuring the internal friction angle directly (without curing time), the results showed a clear decrease in the friction angle (**ϕ**) from 33° in case of the first polymer to 30° in the third polymer (Figure 4), as the polymers increase soil moisture and aid to slide the soil grains.

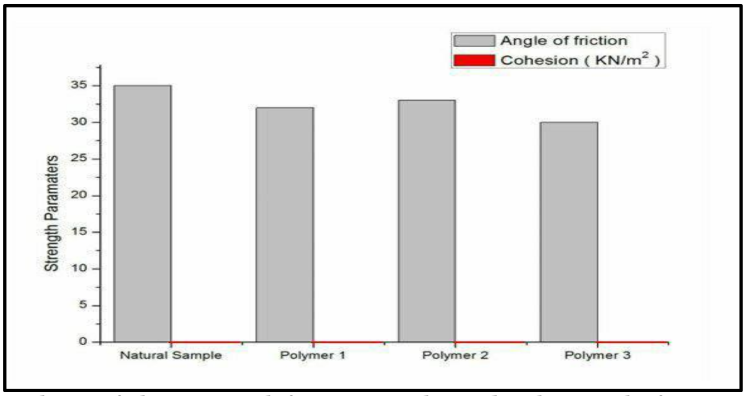

Figure 4. Values of the internal friction angle and cohesion before and after the addition of the polymers.

The previous steps were repeated and the samples were left to dry for 7 days, as a curing period, to achieve adhesion between the polymers and the soil particles. The results indicate that there was an increase in the values of the friction angle with the three polymers. The highest friction angle value of 45° is obtained by using the first polymer, with the resultant of cohesion in the soil which was non-existent in the natural sample for it does not contain connective materials in the natural situation. The highest cohesion value of 200 kN/m² was obtained by using the first polymer (Figure 5).

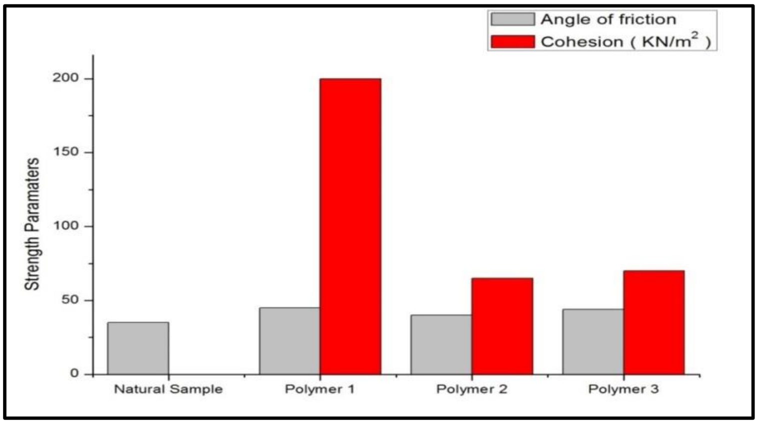

Figure 5. Values of the internal friction angle and the cohesion before and after the addition of the polymers.

California Bearing Ratio (CBR):

California bearing ratio test was performed on the soil sample of the sub-base materials without additives and the results showed that CBR was 49%. This is considered as an acceptable ratio according to the General Iraqi Standard Specifications of Roads and Bridges in 1983 and their modifications in 2003 with a value of 35 % as a minimum permit limit. After adding the three polymers at a percentage of 5 % to the sub-base samples, it was noted that there was an increase in the value of CBR within the three polymers. The highest CBR value of 64 % was obtained with the first polymer (Figure 6). This is due to the reason that the polymers work as adhesive materials which causes an increase in the cohesion and the density of the sample.

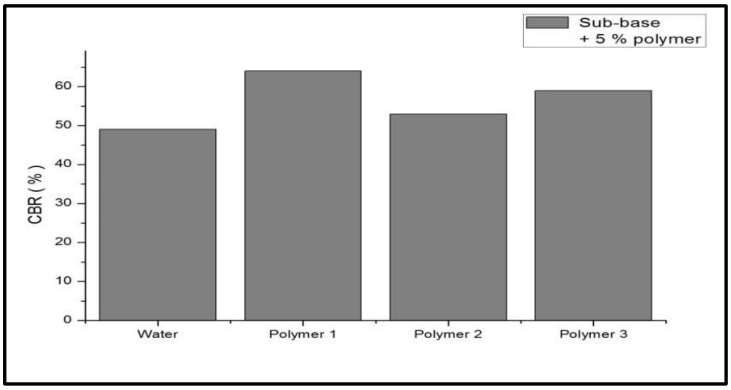

Figure 6. Values of the California bearing ratio before and after the addition of the polymers.

The Absorption Test:

The results showed that the absorption ratio of the sub-base sample free from water was 9.8 %. After adding the polymers of 5% separately, the absorption ratio clearly decreased to 4.1% when the first polymer was used (Figure 7). This is due to the high penetration power of the polymers working as a binding materials and leeding to the formation of a solid adhesive mass and decreasing the absorption ability.

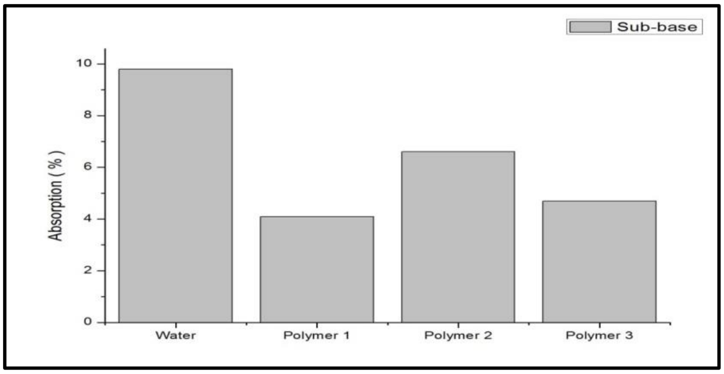

Figure 7. Values of the absorption before and after the addition of the three polymers.

Conclusions

1. The results showed that there was an improvement in the values of the maximum dry density and optimum moisture contents of the three types of polymers by adding 5%, especially in case of the first polymer where the maximum dry density value increased from 2.144 g/cm^3 to 2.220 g/cm^3; and the optimum moisture contents decreased from 6.3% to 5.2%.
2. There were increase in the values of the unconfined compressive strength in the sub-base samples after adding of the three polymers at 5% attaining 5480 kPa when the first polymer was used. A significant increase of 11500 kPa is obtained after adding 5% of the first polymer and cement and immersing the sample for 28 days.
3. An increase of the internal friction angle value after addition of the three polymers at 5% and let the sample standing for 7 days to dry and become stiff. The value was developed with the first polymer from 35° to 45°, and a relatively high cohesion value occurred whereas this property was nonexistent with the natural sub-base samples as the cohesion reached 200 kN/m^2 by adding the first polymer.
4. The value of the California bearing ratio was developed after adding the three polymers at 5% and increased from 49% to 64% by adding the first polymer.
5. The absorption value was improved after adding the three polymers to the sub-base samples, and there was a decrease from 9.8% in the natural sample to 4.1% when the first polymer was added.

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تحسين مادة الحصى الخابط في موقع ميناء الفاو الكبير- محافظة البصرة/جنوبي العراق بإضافة بعض البوليمرات المركبة والأسمنت

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المستخلص - اجريت عملية التحسين على مادة الحصى الخابط المستعملة في أعمال الحدل لملاحظة مدى تأثر الخواص الجيوتكنيكية للمادة كالرص ومقاومة الانضغاط غير المحصور ومقاومة القص ونسبة التحمل الكاليفورني ونسبة الامتصاص بعملية التحسين بالبوليمر والأسمنت. لوحظ تطور كبير في اغلب الخصائص الهندسية, اذ ارتفعت قيمة الكثافة الجافة العظمى من 2.144 غم/سم3 الى 2.220 غم/سم3 بينما أنخفضت قيمة المحتوى الرطوبي الأمثل من 6.3 % الى 5.2 % مع نسبة 5 % من البوليمر الأول. لوحظت زيادة عالية في قيم مقاومة الانضغاط غير المحصور بعد إضافة 5 % من البوليمر الأول و 5 % من الأسمنت الى إنموذج الحصى الخابط وغمره بالمياه لفترات زمنية مختلفة، إذ بلغت 11550 كيلو باسكال مع فترة غمر 28 يوماً. كما ارتفعت قيم زاوية الاحتكاك الداخلي في فحص مقاومة القص المباشر من 35° الى 45° بإضافة 5 % من البوليمر الأول وظهور التماسك بين حبيبات المادة بفعل عمل البوليمر كمادة رابطة وبلغت قيمته 200 كيلو نيوتن/م2. أما قيم نسبة التحمل الكاليفورني فقد أرتفعت من 49 % الى 64 % مع اضافة 5 % من البوليمر الأول, كما أنخفضت نسبة الامتصاص بصورة ملحوظة مع نفس النسبة والمادة من 9.8 % الى 4.1%.