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Improving The Geotechnical Properties of Cohesive Soils Using Portland Cement and Some Composite Polymers in A Selected Location in The City of Tanumah / Basrah Governorate – Southern Iraq

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تحسين الخواص الجيوتكنيكية للترب التماسكية باستعمال الأسمنت البورتلاندي وبعض البوليمرات المركبة في مواقع مختارة من مدينة التنومة / محافظة البصرة – جنوب العراق

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ABSTRACT

Background:

The purpose of this research is to ascertain how adding Portland cement and composite polymers, as well as the ideal ratios between them, will affect cohesive soils' geotechnical characteristics.

Materials and Methods:

A composite polymer was created by combining three polymers—isocyanide, unsaturated polyester, polyvinyl acetate, and thinner—as well as a solvent. Portland cement was added to the soil at a rate of 5% of the sample weight. Different percentages of the weight of the cement supplied to the sample—5, 10, 15, 20, and 25%—were utilized as the composite polymer. Several geotechnical tests were carried out, including compaction, unconfined compressive strength, California bearing ratio, absorption, and Atterberg's limits, to ascertain the ideal amount of polymer for the aim of improvement.

Results:

The findings show that adding cement at a rate of 5% by weight of the sample and a polymeric mixture at a rate of 15% by weight of cement can improve the cohesive soil's engineering properties. It was found that the maximum dry density, unconfined compressive strength, and California bearing ratio had increased while the values of the optimal moisture content, absorption rate, liquid limit values, and plasticity index had decreased.

Conclusion:

The composite polymer used in soil improvement not only improves the geotechnical properties and resistance of the soil, but it also efficiently enhances and activates the effectiveness of cement. When 15% of the sample's weight of cement was composed of composite polymers, the soil's engineering attributes increased the most.

Key words: Cohesive soils; Cement; Polymers; Geotechnical properties; Soil improvement.

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INTRODUCTION

Soil improvement means developing the geotechnical properties of weak soils to obtain stable soils with a high bearing capacity and suitable for carrying the engineering structure by increasing the resistance of these soils and addressing the engineering problems they suffer from through mechanical, chemical, and physical methods. Many researchers have studied the possibility of improving engineering properties of weak soils using some additives such as acids, fibers, polymers, etc. [1]. The effect of adding some polymers and Portland cement to cohesive soils showed that there is an improvement in the engineering properties of these soils after the addition [2]. Adding basalt fibers to treated soils with Portland cement, the engineering properties of cohesive soils were greatly enhanced [3]. Using polyurethane to improve the resistance of marine clay, and several tests were conducted, namely examining the moisture content, Atterberg's limits, grain size analysis, density, unconfined compressive strength, organic content, and pH of the samples before and after treatment, it was found that polyurethane is effective in improving soil resistance [4]. Using polyvinyl acetate (PVA) polymer and mixing it with weak clayey soil and observing its effect on these soils and concluding that it is an effective additive to improve these soils [5]. Also using polyvinyl acetate as a chemical stabilizer to improve clayey soil [6]. Many tests were conducted to determine its swelling and shrinkage characteristics, and the results showed that the swelling rate decreases in these soils after treatment.

THE AIM OF THE STUDY

This study aims to determine the effect of adding Portland cement and composite polymers and the best proportions of them on the geotechnical properties and engineering behavior of cohesive soils were chosen from a site in the city of Tanumah. The composite polymers are manufactured for the first time and are environmentally and economically appropriate**.**

LOCATION OF THE STUDY AREA

Cohesive soil samples were taken from the city of Tanumah, Shatt al-Arab District, east of Basrah Governorate in southern Iraq, on the banks of the Shatt al-Arab, near the Iraqi-Iranian border, at the intersection of longitude 47º 52' 3" and latitude 30º 32' 54" as it has been shown in Figure 1.

GEOLOGY AND GEOMORPHOLOGY OF THE STUDY AREA

According to the tectonic division of Ref. [7], the research area is situated inside the alluvial plain in the Mesopotamian region, which is a portion of the unstable shelf range in the Arabian plate. The Mesopotamian region, or what is known as the alluvial plain region, which includes the study area, resulted from continental movements that led to deformations during the Permian and Triassic periods and had a great influence on subsurface structures (folds, faults, and salt structures) [8].

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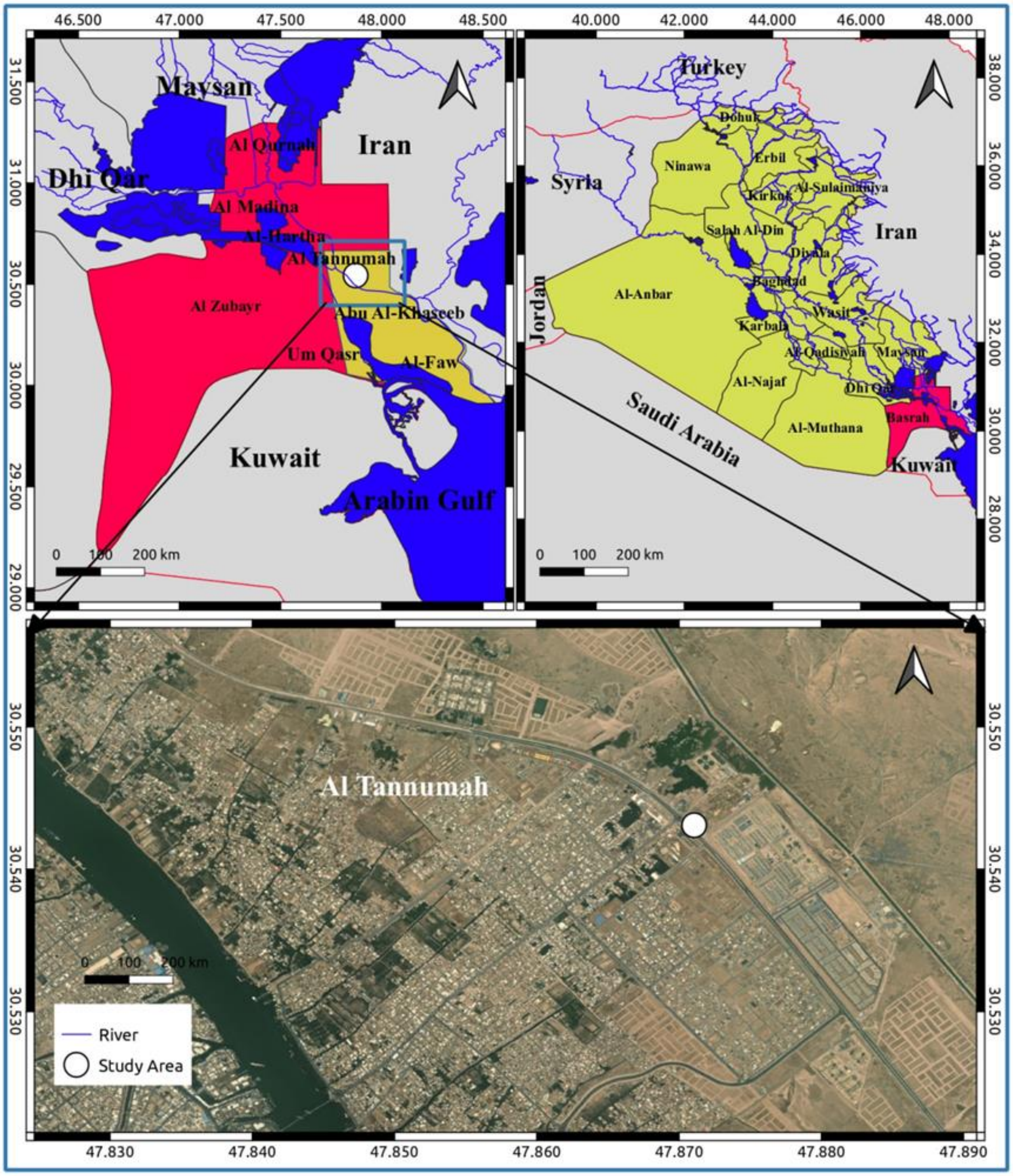

Figure 1: Location of the study area

Basrah Governorate divided into two regions, eastern, called the Alluvial Plain Region and western called the Batin Fan Region [9]. The city of Tanumah is located within the eastern region of Basrah Governorate and in the Delta Plain region, based on the physiographic divisions of Iraq [10]. It is characterized by flatness and does not contain prominent geomorphological features and is covered by floodplains and tidal flats sediments. This area was formed as a result of the accumulation of river and marine sediments and proportions of aerobic sediments [11].

According to Ref. [12], the Quaternary sediments of the region consist of the Dibdibba Formation, followed by the Hammar Formation, and then the modern cohesive deposits, which are modern river deposits formed from the deposits of the Tigris, Euphrates, Shatt al-Arab, and

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Karun rivers, which consist of a mixture of cohesive clay and alluvial sediments, which Its thickness reaches about 7 m [9]. These sediments also contain clastic and chemical sediments such as calcite, gypsum, and halite, which led to an increase in salinity levels in the soil [13].

MATERIALS AND METHODS

MATERIALS:

Portland cement taken from the Basrah Cement Factory was used to mix it with the soil at a rate of 5% of the sample weight because this percentage gave good results from previous research [2].

In this study, a composite polymer was developed that is used for the first time by mixing three polymers, which are isocyanide, unsaturated polyester, polyvinyl acetate, and thinner, as a solvent to manufacture a single material that is soluble in water to facilitate work on the industrial level. The composite polymer was used in different proportions (5, 10, 15, 20, 25%) of the weight of the cement added to the sample to reduce the economic cost.

SAMPLES PREPERATION

Laboratory tests were conducted on three types of samples, as follows:

The first stage: Geotechnical tests were conducted on samples of natural cohesive soil selected from the Tanumah city site, which included modified compaction test, direct shear resistance, absorption, and California Bearing Ratio (CBR).

The second stage: Adding cement at a rate of 5% of the weight of the cohesive soil samples and conducting the same geotechnical tests mentioned above.

The third stage: Adding different percentages of the composite polymer (5, 10, 15, 20, 25%) by weight of the added cement to the cohesive soil samples and re-conducting the tests for modified compaction, direct shear resistance, absorption, and California Bearing Ratio (CBR).

LABORATORY TESTS

Grain size analysis: Using a hydrometer and the two American specifications [14] as a guide, a volumetric analysis of cohesive soils was performed.

Moisture content: A specific weight of soil was dried for 24 hours at a temperature of 105-110°C, and the moisture content was calculated according to the American Standard [15].

Atterberg's limits tests: A sample of the natural cohesive soil passing through a No. 40 sieve free of additives chosen from the Tanumah site was prepared after the sample was dried at a temperature of 105°C for 24 hours. In the same way, a sample of the soil was prepared to which cement was added at a rate of 5%, and five samples of the treated soil with cement at a rate of 5%, the compound polymer was added to it at rates of 5, 10, 15, 20 and 25% of the weight of the cement added to the sample to determine the best mixing ratio. The plastic limit was determined by rolling the sample on a glass plate until it fractured, then repeating the operation three times and taking the average. The liquid limit was determined using a Casa Grande instrument. The test was conducted according to the American Standard [16].

Compaction test: Preparing a sample of natural cohesive soil free of additives, taken from the Tanumah site, and adding five weight percentages of water, namely 2, 4, 6, 8, and 10%. A modified Proctor test was conducted on it to determine the value of the maximum dry density and the optimum moisture content. Then, prepare a sample for the weight percentage of cement, 5%. Then, this percentage of cement was mixed with the composite polymer to prepare five samples for five weight percentages of the composite polymer, which are 5, 10, 15, 20, and 25% of the weight of the cement added to the sample. Testing was conducted on it to determine the maximum dry density and the optimal moisture content. The test was conducted according to the American Standard [17].

The unconfined compressive strength test: Preparing a remolded sample of cohesive soil taken from the Tanumah site without additives and conduct the test on it. Then another sample of the soil was prepared and cement was added to it at a rate of 5% and it was left for 7 days to dry and it was tested. In the same way, five remolded samples of cohesive soil were prepared, to which cement was added at a rate of 5% and a composite polymer in different proportions of 5, 10, 15, 20 and 25 % of the weight of the cement and was left for 7 days to dry, and then they were tested using the same previous steps. This test was conducted according to the American Standard [18].

California Bearing Ratio Test (CBR): The ideal moisture content identified by the modified Proctor test was applied to a sample of naturally cohesive soil that was free of additives. The soil was then tested to find the California bearing ratio. Then, a sample of cohesive soil was prepared and 5% cement was added to it in the same way as the natural sample above. It was left to dry for 7 days and then the test was conducted on it. Then five samples were prepared to which cement was added at a rate of 5% and the composite polymer in different percentages (5, 10, 15, 20 and 25% of the weight of cement, using the same method of preparing the sample mentioned previously. The samples were left for 7 days to dry, and then they were tested to determine the best percentage of additives that achieved the best soil improvement. The test was conducted according to the American Standard [19].

Rapid absorption test: A sample with a specific weight of natural cohesive soil free of additives was prepared and tested, where it was immersed in water for 24 hours, and the wet weight of the sample was taken after immersion to determine the absorption rate. A remolded sample of soil was prepared and 5% cement was added to it. It was left for 7 days to dry and tested. Then five samples of cohesive soil were prepared, to which cement was added at a rate of 5% and a composite polymer in different proportions (5, 10, 15, 20 and 25%) of the cement weighed and left for 7 days to dry, then it was tested using the same previous steps and according to the British Standard [20].

Chemical tests: They were conducted on the cohesive soil taken from the Tanumah site, and included examining the percentage of sulfates (SO_4), chlorides content (Cl), pH, carbonates, and organic content according to the Iraqi specification [21].

RESULTS AND DISCUSSION

The results of geotechnical tests conducted on a cohesive soil sample taken from the Tanumah site showed the following:

Particle size analysis: After washing, 89% of the particles in the Tanumah soil sample passed through sieve No. 200, according to the results of the particle size analysis test. Using a hydrometer, the composition of the material revealed that 49% of the material was silt, 40% was clay, and 9% was sand. As a result, the soil is classified in Table 1 as clayey silt with sand.

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Table 1: The result of the grain size analysis of the Tanumah soil sample

Percentage	Clay%	Silt%	Sand%	Gravel%	Description
Cohesion soil	40	49	9	2	Clayey silt with sand

The moisture content: This test showed that the percentage of moisture content of the natural soil sample free of additives was 27%, which is a high percentage due to the high groundwater level in the study site, which ranges between 0.5-1 meter, as well as the continuous exposure to tidal processes, in addition to the effectiveness of the capillary action in cohesive soils, which allows water to rise between its pores, making it highly moist.

Atterberg's limits: They were determined by testing the natural cohesive soil sample at the Tanumah site, free of additives. The percentages of the liquid limit and plastic limit were 47%, 28%, and 19%, respectively, as indicated in Figure 2 and Table 2, illustrates how the natural soil was categorized as silty soil with low plasticity (ML) using a plasticity diagram.

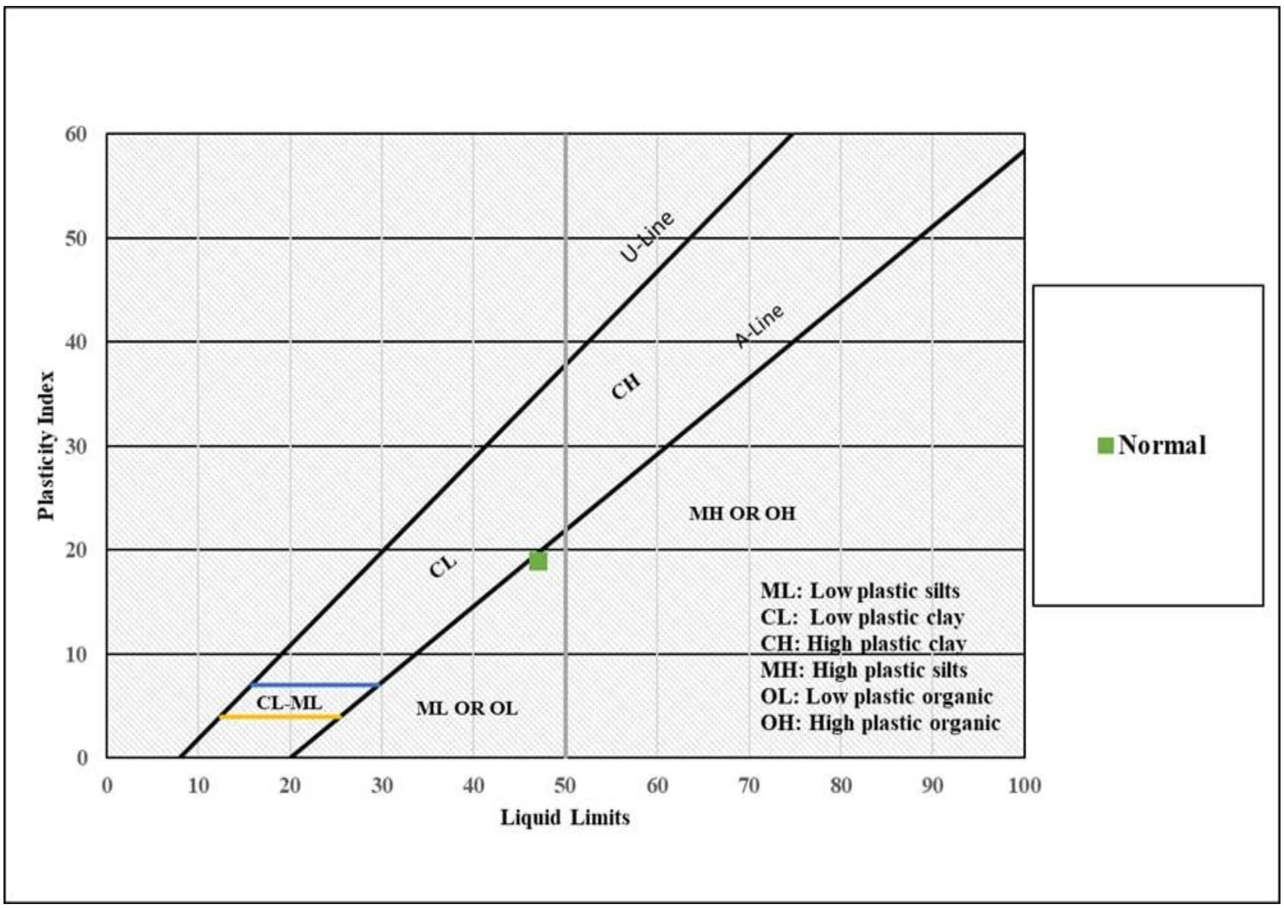

Figure 2: The plasticity diagram displays the liquid limit and plasticity index values for naturally cohesive soil

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Table 2: Values of liquid limit, plastic limit, and plasticity index for naturally cohesive soil

Cohesive soil	L.L	P. L	P. I
N	47	28	19

After that, tests were performed on a cohesive soil sample that had been treated with 5% cement. The findings revealed that the plastic limit had reached 25.2%, the liquid limit ratio had reached 40.4%, and the plasticity index had reached 15.2%. Additionally, five cohesive soil samples were treated with a 5% cement mixture and five various weight percentages of a composite polymer. The results of these tests are displayed in Table 3 and Figures 3 and 4. The change in the values of the liquid and plastic limits depends on the high percentages of soluble salts, calcite and gypsum, as well as the presence of clay minerals and silty soil [22]. Also this explained that the changes in the Atterberg's limits depend on the type of soil and the type of clay minerals they contained [23]. That an increase in the plastic limit values of cohesive soils helps in increasing the cohesion of the soil [24] mentioned in [25].

Table 3: Values of cohesive soils' liquid limit, plastic limit, and plasticity index both before and after the addition of improving materials

P%	L.L	P. L	P. I
N	47	28	19
C5%	40.4	25.2	15.2
C5%+P5%	44.8	36.1	8.7
C5%+ P10%	50.6	42.3	8.3
C5%+P15%	40.7	33.1	7.6
C5%+P20%	32.5	22.6	9.9
C5%+P25%	42.6	30.2	12.4

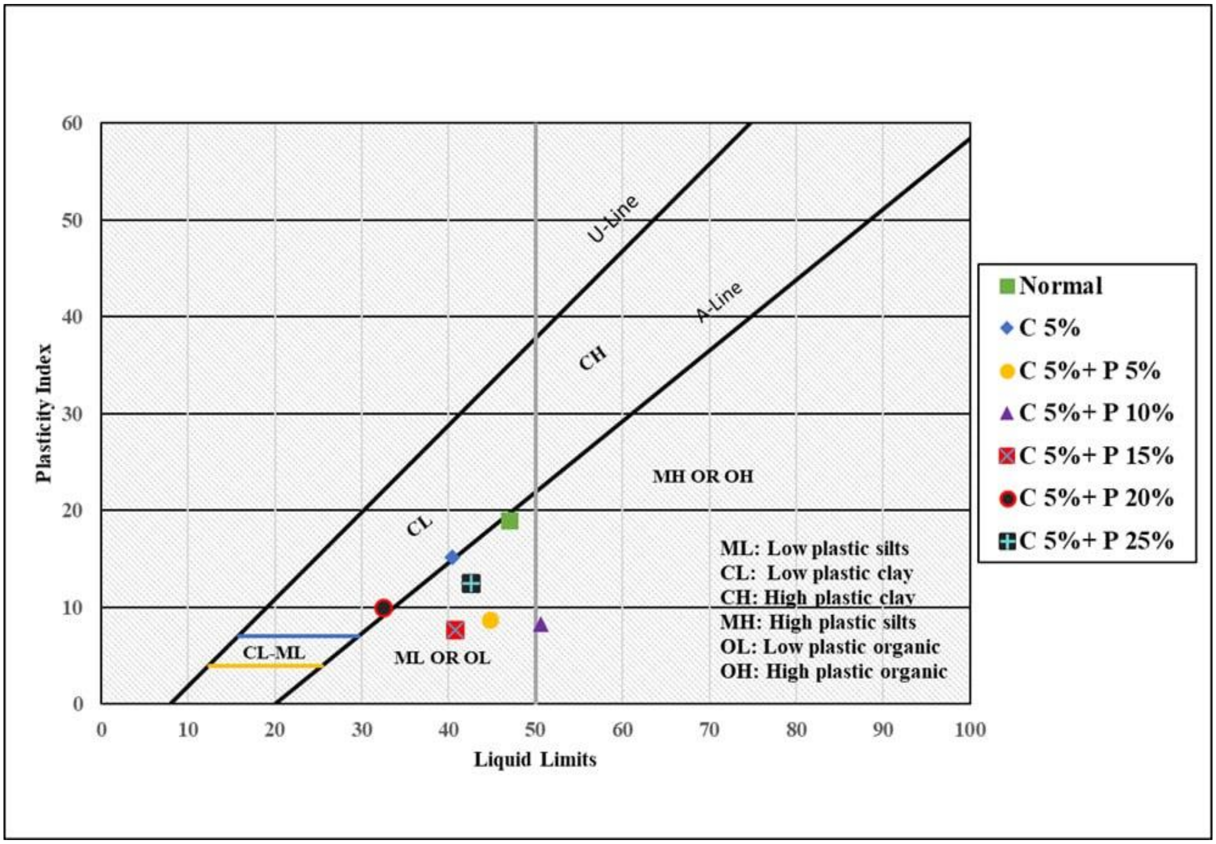

Figure 3: Values for cohesive soils' liquid limit and plasticity index both before and after the addition of improving materials are shown in the plasticity chart

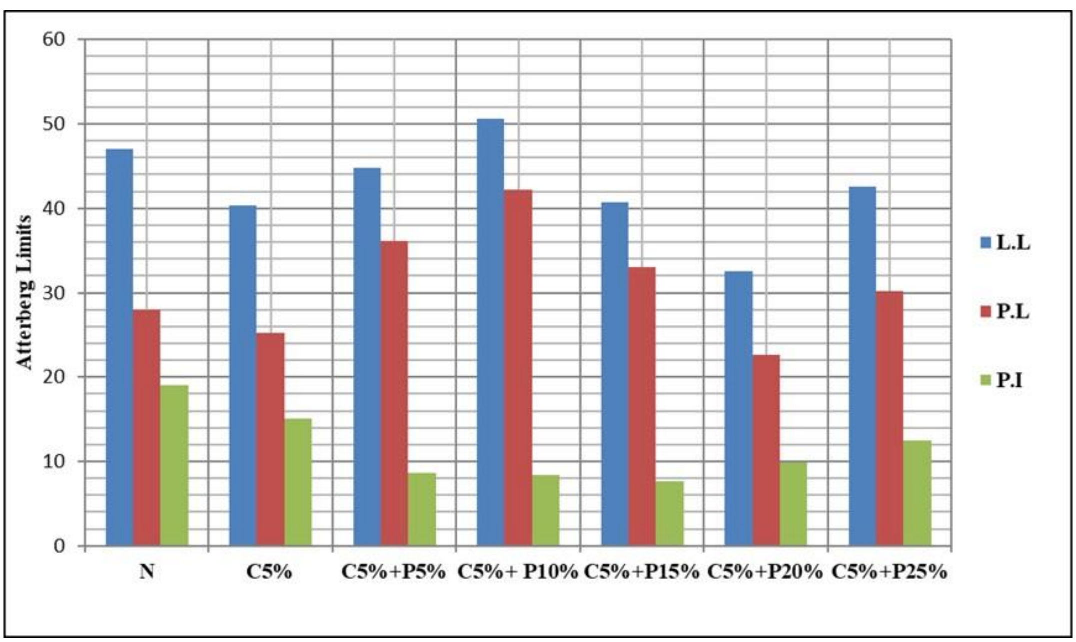

Figure 4: Atterberg's limits values for cohesion soil before and after adding improving materials

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Compaction test: As it has seen in Figure 4, the test was carried out on a sample of naturally cohesive soil for the Tanumah site that was additive-free. The results indicated that the ideal moisture level is 8% and the maximum dry density value is 1.751 g/cm^3. The test then employed a cohesive soil sample that had been treated with cement at a weight of 5%. The ideal moisture content was 14%, and the maximum dry density value was 1.801 g/cm^3. Five samples of cohesive soil treated with a 5% cement mixture and five different weight percentages of a composite polymer 5, 10, 15, 20, and 25% of the weight of cement applied to the sample were likewise subjected to the test. As it has been indicated by Table 4 and Figures 5 and 6, the results demonstrated that combining a 5% cement mixture and a 15% composite polymer produced the highest value of maximum dry density and the lowest optimal moisture content.

Table 4: Maximum cohesive soil dry density values both before and after the addition of improving materials

P%	MDD g/cm^3
N	1.751
C 5%	1.798
C 5%+ P 5%	1.801
C 5%+ P 10%	1.805
C 5%+ P 15%	1.915
C 5%+ P 20%	1.893
C 5%+ P 25%	1.854

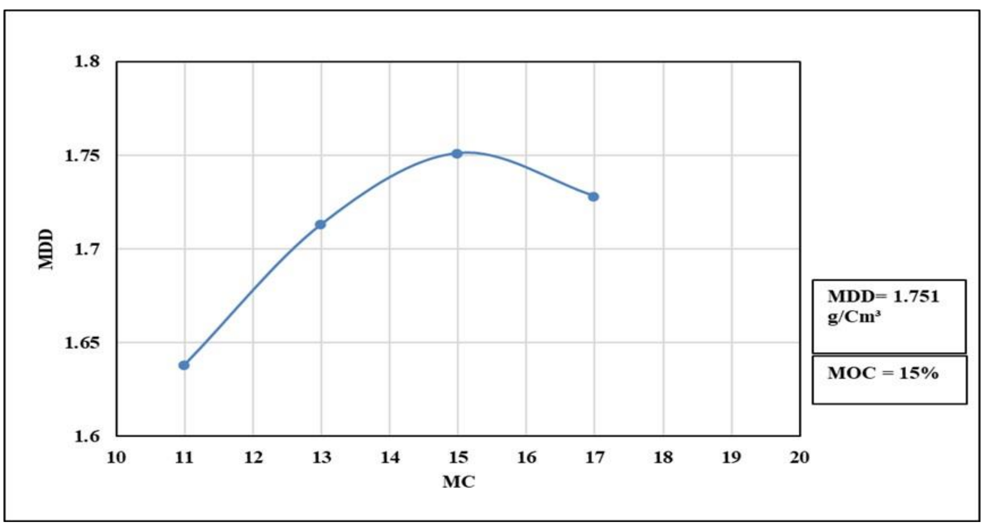

Figure 5: Values of maximum dry density and optimum moisture content for natural cohesive soil

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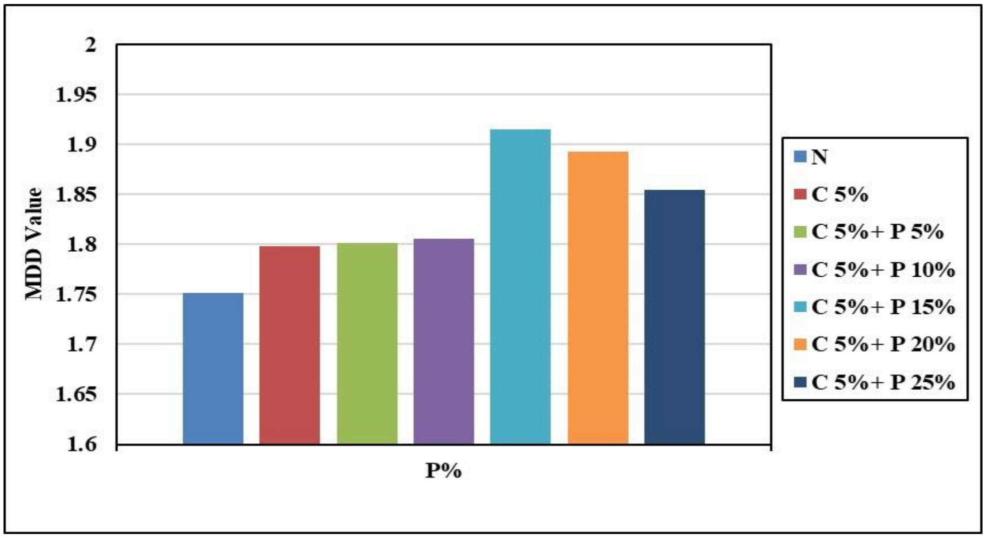

Figure 6: Maximum dry density values for cohesive soil before and after adding improving materials

The unconfined compressive strength: The natural cohesive soil of the Tanumah site was tested using a remolded sample, and the findings indicated that the natural soil's compressive strength is 18 kPa. A duplicate sample was used for the test, treated with 5% cement in the same way as before, and allowed to dry for seven days. The findings indicated that following the addition of cement, the soil resistance was 18.94 kPa. Subsequently, the experiment was carried out on five samples that were treated with 5% cement and composite polymer at five distinct weight percentages: 5, 10, 15, 20, and 25% of the sample's weight in cement. After the samples were allowed to dry for seven days, the outcomes are shown in Table 5.

Table 5: Values of unconfined compressive strength of cohesive soil before and after adding improving materials

P %	UCS kPa
N	1099
C 5%	1266
C 5%+ P 5%	1700
C 5%+ P 10%	1722
C 5%+ P 15%	3008
C 5%+ P 20%	2695
C 5%+ P 25%	1613

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The highest value of resistance was when adding a 5% cement mixture and a 15% composite polymer, as the value of the unconfined compressive strength increased from 18 kPa before the addition to 35.67 kPa after addition, as it has been shown in Figure 7. The reason for the increase in resistance is attributed to the increased cohesion of the soil particles due to the interaction of the cement and the composite polymer, as this mixture led to the binding of the soil particles. It was also noted that the continued increase in the proportions of the composite polymer led to the failure of the soil.

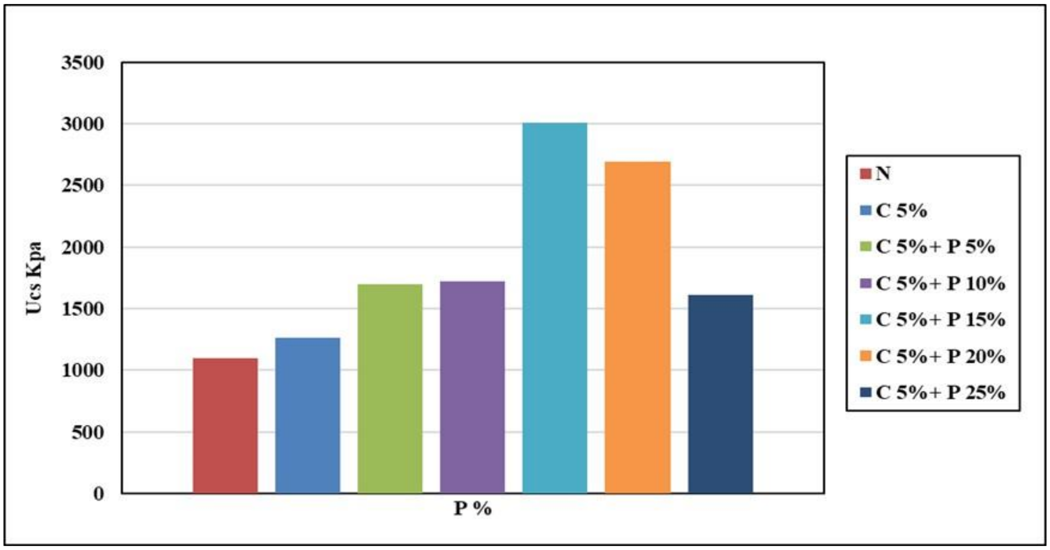

Figure 7: Unconfined cohesive soil compressive strength values both before and after the addition of improving materials

California Bearing Ratio (CBR): The results of this test showed that the natural soil's Californian bearing ratio, when applied to cohesive soil taken from the Tanumah site, is 6.9%. The Californian bearing ratio was 11.9% when cement was added to the cohesive soil at a rate of 5%, according to the test results. When 5% of the cement mixture and 15% of the composite were added by weight of cement, it reached its maximum value of 22%, as it has been shown in Figure 8.

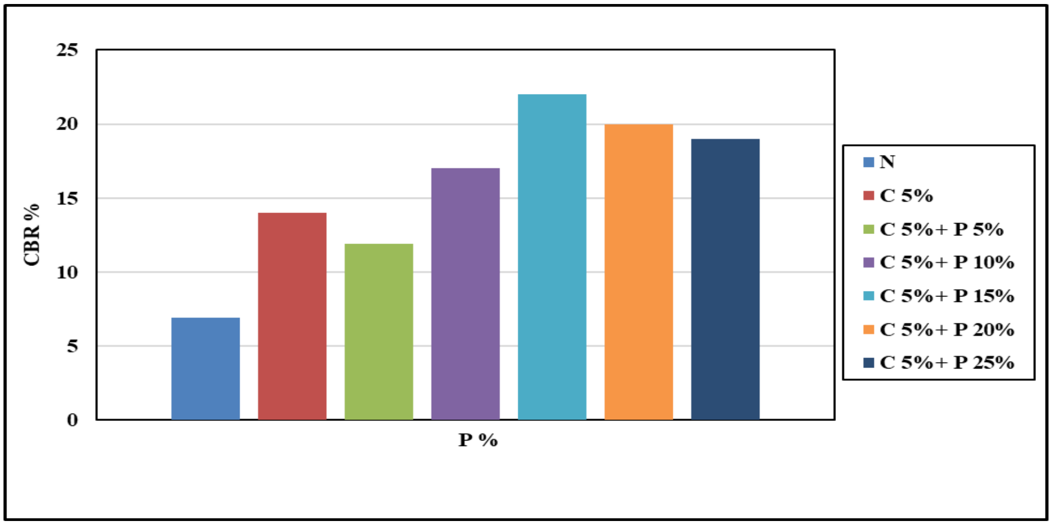

Figure 8: California bearing ratio values before and after adding improvement materials

Rapid absorption test: The cohesive soil of the Tanumah site was used for this test, and it was found that the natural soil's absorption result was 35.6%. It was also noted that the absorption test values decreased when adding 5% cement to the cohesive soil, reaching 31.2%. While it was observed that the absorption values reached the lowest value when adding the 5% cement mixture and the 15% composite polymer, and the value was 5.37%, as in Figure 9.

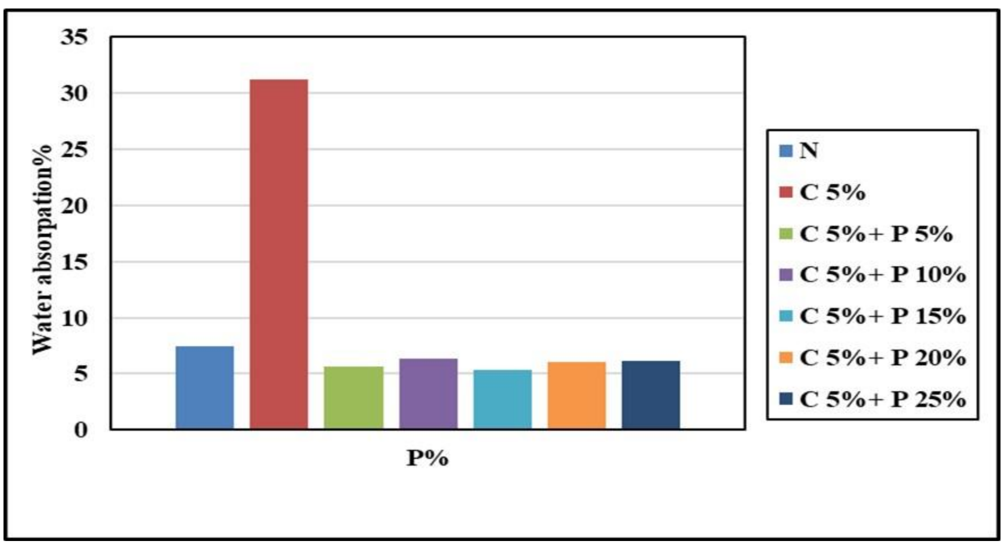

Figure 9: Absorption rate values for cohesive soil before and after adding improving materials

Chemical tests: According to the data, the percentage of sulfates is 2.5, the percentage of chloride is 0.0056, the pH is 7.8, the organic content is 1.20, and the carbonate content is 17.60. The percentages of sulfates, carbonates, and organic content are high, the proportion of chlorides is low, and the acidity value is neutral, as [21].

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The results show that adding cement at a rate of 5% by weight of the sample and a polymeric mixture consisting of (Polyvinyl acetate, unsaturated polyester, isocyanides, and thinner as a solvent) at a rate of 15% by weight of cement leads to improving the engineering properties of the cohesive soil . The maximum dry density, unconfined compressive strength, and California bearing ratio were found to have increased, while the values of the optimum moisture content, absorption rate, liquid limit values, and plasticity index decreased. This is because the mixture functions as a binder that is insoluble in water after solidification , connecting the soil's pores to promote cohesion between particles, minimize voids, and keep water from penetrating within the soil granules. The soil granules are coated by the cement layer and the polymeric mixture, which keep them from absorbing water. In addition, the compaction of the soil led to the expulsion of air, which caused an increase in the density of the soil and gave a higher resistance to withstanding the stress placed on it to increase the strength of the soil and reduce the economic cost.

CONCLUSIONS

The composite polymer used in soil improvement is effective in strengthening and activating the effectiveness of cement and increasing the cohesion between the particles. The use of composite polymer led to increased resistance and improved geotechnical properties of the soil. The results of engineering tests show that the best percentage of composite polymer is 15% of the weight of cement added to the sample, as it gave the best improvement to the engineering properties of the soil.

Conflict of interests.

There is no conflict interest

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مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

الخلاصة

المقدمة:

الغرض من هذا البحث هو التأكد من تأثير إضافة الأسمنت البورتلاندي والبوليمرات المركبة والنسب المثالية بينهما على الخصائص الجيوتقنية للتربة التماسكية.

طرق العمل:

تم استعمال بوليمر مركب من خلال الجمع بين ثلاثة بوليمرات – الأيزو سيانيد، والبوليستر غير المشبع، وأسيتات البولي فينيل، والمخفف – بالإضافة إلى مذيب. تمت إضافة الأسمنت البورتلاندي إلى التربة بمعدل 5% من وزن العينة. تم استخدام نسب مختلفة من البوليمر المركب المضاف للعينة وهي 5، 10، 15، 20، و25٪ – من وزن الاسمنت المضاف للعينة. تم إجراء العديد من الاختبارات الجيوتقنية، بما في ذلك الحدل، ومقاومة الانضغاط غير المحصور، ونسبة تحمل كاليفورنيا، والامتصاص، وحدود أتربيرج، لمعرفة النسبة الافضل للبوليمر بهدف التحسين.

النتائج:

اظهرت النتائج امكانية تحسين الخواص الهندسية للتربة التماسكية بإضافة الأسمنت بمعدل 5% من وزن العينة والخليط البوليمري بمعدل 15% من وزن الأسمنت. لقد وجد أنه على الرغم من انخفاض قيم المحتوى الرطوبي الأمثل، ومعدل الامتصاص، وقيم حد السيولة، ودليل اللدونة، إلا أن الكثافة الجافة القصوى، ومقاومة الانضغاط غير المحصور، ونسبة تحمل كاليفورنيا قد زادت.

الاستنتاجات:

بالإضافة إلى زيادة المقاومة وتحسين الخصائص الجيوتقنية للتربة، فإن البوليمر المركب المستخدم في تحسين التربة يقوي وينشط فعالية الأسمنت بشكل فعال. تم تحقيق أعلى زيادة في الخواص الهندسية للتربة بإضافة البوليمر المركب بنسبة 15% من وزن الأسمنت المضاف للعينة.

الكلمات المفتاحية: التربة التماسكية، الأسمنت، البوليمرات، الخواص الجيوتقنية، تحسين التربة.

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