Stabilization of fertile soils with biopolymers

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***Abstract*- In recent years, the addition of some polymeric materials to the soil for stabilization has received much attention. The addition of some biopolymers, in addition to improving soil properties, can also be considered from two perspectives: the use of compacted soils and the reduction of operating costs. On the other hand, with the increasing population and rapid growth of communities, the need to create various and very special structures to meet the growing needs and create safe and engineered infrastructure is very vital. Due to the inalienable importance of soil under the foundations of buildings and increasing attention to this issue, as well as the unavailability of ideal soil in all places and the inability to change places, due to the lack of ideal soil, methods of Various improvements of this type of soils have been considered. This study aimed to investigate the stabilization of compacted soils with biopolymers. The polymers used in this study included polyvinyl alcohol and polyvinyl acetate for 24 hours at 150 ° C. Experiments included abrasion index, direct shear test, and density. The results showed that polyvinyl alcohol increases the paste index, which decreases with increasing the percentage of additives. Polyvinyl acetate increases the dough index, which increases with increasing the percentage of additives.**

Keywords: **Polymer, Soil Stabilization, Polyvinyl, Polyvinyl Acetate**

1-INTRODUCTION

Fertile soils are among the problematic soils in geotechnical engineering. These soils have a relatively good resistance in their natural state with low humidity, but in case of saturation without any change in the applied load or subjected to vibration force, they settle a lot and in many cases cause cracking or destruction of the foundations. Roads, railway lines, dams, pipelines, and other structures will be available. Fertile soils are scattered in many regions of the world, in Iran these soils are mostly observed in the central and eastern regions. These soils are often composed of young sediments settled in arid and semi-arid areas. These deposits include 1- materials accumulated due to gravity or washing at the foot of the slopes (depositional deposits) 2- accumulation of sediments in rivers or large floods (alluvium) 3- wind deposits caused by They are dust, silt, and fine sand. In recent years, adding some polymeric materials to the soil for stabilization has received much attention. Adding some biopolymers, in addition to improving the soil properties, can be used from two points of view. and the reduction of operational costs should also be investigated. And they are strong; however, with the increase in moisture percentage and the loading of large deformations, rapid settlement and a large decrease in the porosity ratio are observed in them (Braja. M. Das, 2016 and Sohrabi. S., 2017). Large areas of the world - a surface equivalent to 10% of continental masses - are covered by these soils. On the other hand, with the ever-increasing population and the rapid growth of societies, the need to create various and very special structures to meet the growing needs and to create safe and engineered substructures becomes very vital. Considering the importance of the soil under the foundations of buildings and the increasing attention to this matter, as well as the unavailability of ideal soil in all places and the inability to change the location, due to the non-ideal nature of fertile soils, Various methods of improvement of these types of soils have been noticed. With the expansion of the construction industry, many structures and roads are built on fertile soils. If these soils are not improved, the resulting settlement will lead to the imposition of many costs on the project (Majard, 2015). During the improvement process, suitable conditions are created for the implementation of the project on the ground. The result of improvement is the reduction of construction cost and project implementation time. Although the history of land improvement dates back to the Babylonians and ancient Greece, this technology was considered a new technology until 1960 (Mansourikia, 2016).

For construction on fertile soils, the structure must be designed in a resistant way to be stable against large settlements; Otherwise, the soil should be improved in a way to eliminate its sensitivity to moisture (Karbasi Ravari, M., 1380). The necessity of investigating the remainder of soils is due to the relatively wide spread of these soils and the need to design dams, irrigation canals, and other technical buildings in these areas and also due to the development of urbanization and the need to expand some large cities and build residential areas. Water and sewage pipes, etc., are doubly important in these soils. Considering the relatively widespread fertile soils in Iran, and the need for the development of cities and as a result the construction of technical buildings such as dams, irrigation canals, water and sewage pipes, roads and railways, and other technical buildings and also with consideration According to the few pieces of research that have been done in connection with fertile soils in the country, the need to investigate the geotechnical characteristics of fertile soils in Iran becomes more and more apparent. ,

The main goal of soil stabilization is to improve the technical characteristics of the soil. The main characteristics of the soil that are often taken into consideration in stabilization for modification are:

- Resistance - by increasing soil resistance, its stability and bearing capacity increase. ,
- Volumetric stability - to control the swelling or shrinkage of the soil due to changes in its moisture content
- Durability - to increase resistance against erosion, weathering, traffic loads, etc
- Permeability- reducing the amount of permeability and creating a safe path for water to pass

This research aims to stabilize fertile soil by adding polymer materials including two polymers PVA and PVAc to it and after determining the ramification potential according to Table 1, the classification of the fertile indices will be done and the degree of ramification Samples are determined before and after fixation. In other words, by adding different percentages (0.5, 1, 1.5, 2, 3, and 5) of materials, what changes are made in the soil compaction index?

Table 1- Ranking table of Fertile index

The degree of smoothness	index Fertile
non- fertile	0-0/1
Low	0/1-2
medium	2-6
Fairly intense	6-10
intense	> 10

2- RESEARCH METHODS

The main characteristics that cause soils to show collapse characteristics are high layer level (more than 30%), high porosity (more than 40%), low degree of saturation (below 60%), and softening. Fast in the water. ,

General characteristics of Los

The word "Loss" comes from the German word "Loss" which means loose. For most scientific purposes, it is enough to simply define loess as follows: continental debris deposits consisting of silt-sized particles that must have been created by the accumulation of particles transported by the wind.

3- SOIL GRANULATION

The size of the grains that make up the soil varies in a wide range. Depending on the size of the grains, soils are usually called sand, silt, or clay. To describe the soil, different organizations suggest the limits of separating the size of the soil grains. In Table 2, the suggested limits for grain size separators by several different organizations are presented. Currently, the limits proposed by the Unified Soil Classification System are the most common. This system has been accepted by the American Standard Bureau.

Table2- Separating limits of soil grain size

	The size of the seeds (mm)			
Name of the organization	gravel	sand	sediment	clay
United States Department of Agriculture (USDA)	<2	2 - 0/05	0/05 - 0/002	<0/002
United States Department of Transportation (AASHTO)	76/2 - 2	2 - 0/075	0/075 - 0/002	<0/002
Unified Soil Classification System	76/2 - 4/75	4/75 - 0/075	Fine grains (mud). (sediment and sand) 0/075	

4-PERMEABILITY

Soils are generally permeable and water can flow through the interconnected pores between solid grains. Its one-dimensional movement in fully saturated soils follows Darcy's law. ,

1- $q=k.i.A$

In this regard:

q = volume of flowing water per unit of time. ,

k = permeability or permeability coefficient. ,

i = hydraulic gradient or water slope. ,

5- THE DENSITY OF SEEDS

In performing soil mechanics calculations, the density of soil grains is often required. The density of seeds can be accurately determined in the laboratory. The range of grain density is usually between 2.6 and 2.9. The density of pale sand grains, which are mostly made of quartz, is around 2.65 and the density of layered and clayey soils is around 2.6 to 2.9. ,

In loess soils, the range of specific mass values is limited, for example, for Chinese loams, the specific mass ranges from 2.65 to 2.7. ,

6- AROUND ETTERBERG

After registering the works that A. Atterberg and A. Casagrande (1948) did, the Etterberg limit and related indices have become among the most useful properties of soils. Etterberg's limits are based on the fact that fine-grained soil is placed in one of the four states according to its moisture content. When the soil is dry, it is solid soil, as the amount of water increases, it becomes semi-solid, pasty, and liquid. Moisture percentages at the boundary between adjacent states are called shrinkage limit, paste limit, and flow limit.

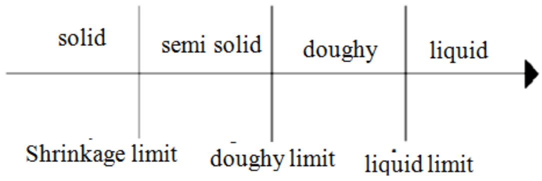


Figure 1: Etterberg boundaries

7- RESEARCH FINDINGS

Investigating the physical and geotechnical characteristics of the soil used The studied soil was collected from the Hamidiyeh region near Kerman City: the results of the tests conducted on the studied soil are as follows:

Fig. 2- Ruminant soil and prototyping template

Table3- specifications obtained for the sandy soil used in the experiments

Amounts	Soil engineering specifications
33	LL%
21	PL%
12	PI%
6.92	W%
21.38	Max $_d\gamma$
Soil type	CL

7-1-Classification of soil

The soil used in the United Classification System (USCS) and anAshtonto (AASHTO) was classified as follows:

7-2- Classification in the unified system:

With the above explanations and considering that about 55% of the soil particles pass through the 20sievesve (more than 50%), it has 14% clay, and its dough an index is 5.82 (less than 50). This soil is placed in the CL-ML category in the unified classification system. ,

7-3- Classification in the Ashto system

Considering that about 55% of the soil particles pass through the 200 sieves (more than 35%), it has a fluidity limit of 24.12 (less than 40) and a paste limit of 5.82 (less than 10), the soil The comment is placed in groups A-4. Also, according to formulas 2-3, the group index for the desired soil is 1. As a result, the classification of soil in the Ashtonsystem is A-4. , Permeability test Using the method explained in parts 4-3-5, the permeability test was performed on the target soil and the permeability of the studied soil was 0.02 cm/hr. ,

7-4-Compression test

Using the method explained in the section4-3-4, the compaction test was performed on the desired soil and the compaction curve obtained for the studied soil is shown in Figure 4.

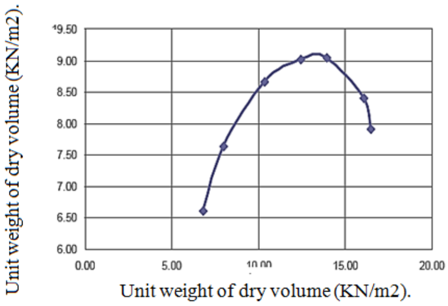


Figure3-Density curve of the studied soil

As can be seen in Figure 4, the soil has a maximum dry volume unit weight of 19.06 kilonewtons per cubic meter and an optimum moisture content of 13.93%. **11-5-Fertile index determination test**
A fertile index determination test was performed according to ASTM D 5333 on the studied soil. According to the obtained results, the Fertile index for the studied soil is 17.5%, which according to Table 2-4 is placed in the category of highly fertile soils. Figure 5-4 shows the Fertile diagram of the studied soil. ,
vertical strain

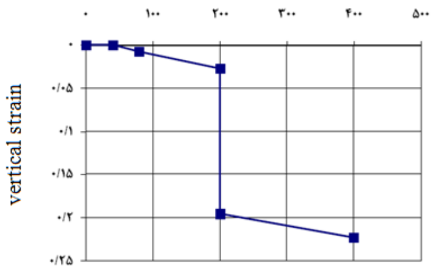


Figure 4- Collapse diagram of the studied soil

7-6-Direct cutting test
The direct shear test wasconducted using the method explained in sections 6-3-4 on the studied soil, and according to Figure 5-5 and the relationship between the the average line of the obtained points, the shear resistance parameters were obtained.

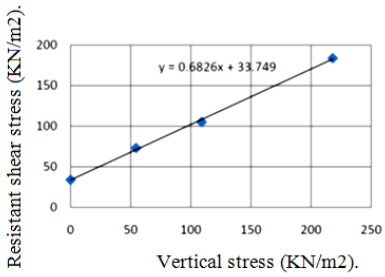


Figure 5- diagram of determination of shear strength parameters for the studied soil

According to Figure 45, the apparent adhesion value is 33.75 kilonewtons/square meter and the value of the internal friction angle is 34.31 degrees.

8- ERODIBILITY TEST
According to the method explained in sections 4-4, the erodibility test was performed on the control soil with 2 different flow rates. Table 4-2 shows the results obtained from the experiment.

Table 4-The results of the erodibility test

Erosion rate	Final weight (kg).	Initial weight (kg).	Wiki(Lit/s)

%26	2149/4	2935/13	1/78
% 44/7	1622/1	2935/13	8/61

8-1- The results of granulation

After the washing test, the soil granulation test was done for the coarse grain part using a sieve granulation method and for the fine grain part using a master sizer. The desired soil granulation curve was determined as follows:

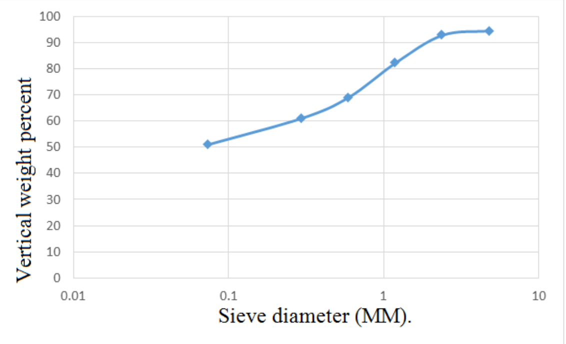


Figure 6- Granulation curve of the used soil

According to the soil gradation curve and using the limits of soil grain size separators in the AASHTO standard (Table 1-3), it can be concluded that the examined soil has 14% clay, 41% silt, and 45% silt. is the percentage of sand. ,

9-RELATIVE DENSITY DETERMINATION TEST

The relative density test was performed according to the MSTM D854 standard for the studied soil and the relative density of the studied soil was 2.73.

9-1- Etterberg limit test

In the early 1900s, Swedish scientist Etterberg developed a method to describe the stiffness of fine-grained soils in terms of moisture content. The amount of moisture (in percent) at the point of transition from solid to semi-solid is called shrinkage limit and at the point of transition from semi-solid to paste, paste limit and from paste to liquid is called liquid limit or flow limit. The mentioned boundaries are known as Etterberg boundaries. The Etterberg limit test according to the ASTM D423 standard should be performed on the soil passed through sieve No. 40 as it was done in this research; be done. The characteristics of Etterberg sandy soil are listed in the table below.

Table 5- Etterberg parameters of the studied soil

Shrinkage limit	Dough index	doughy limit	mental limit
15/2	5/82	18/3	24/12

9-2-Water chemical analysis tests

To carry out the reaction between soil and lime and to carry out hydration, some water is needed. Therefore, it is better to use city water to simulate the samples with the real environment. The effect of water solutes, especially the water hardness parameter, on the compressive strength of the samples and the reaction between soil and lime is very high. As a result, the consumed water was analyzed in the research and the results are presented in Table 4-2.

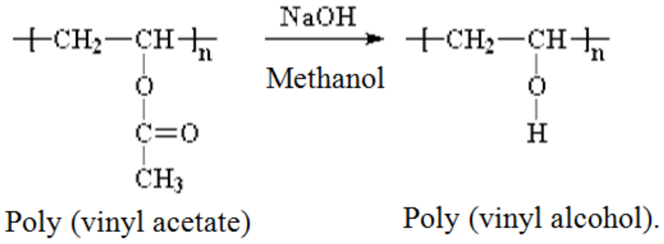
Table 6- Analysis of water used in research

Results	experiments
8.15	Ph
345 mg/lit	Evaporate the residue at 110 degrees
224 mg/lit	Alkalinity versus methyl orange (CaCo2).
296 mg/lit	Total hardness (CaCo2).
89 mg/lit	Sulfates (SO4).
80 mg/lit	Chlorine (CL).
80 mg/lit	Sodium (Na).
1 mg/lit	Potassium (K).
59 mg/lit	Calcium (Ca).
30 mg/lit	Magnesium (Mg).
2 mg/lit	suspended matter
109 mg/lit	total alkalinity (Na2O).

10-PHYSICAL AND CHEMICAL CHARACTERISTICS OF POLYMERS

Polyvinyl alcohol and polyvinyl acetate are adhesive polymeric materials that have been extensively researched to establish soil has been formed. These materials harden by losing moisture and particles It binds the soil together and increases the resistance of the

soil against the forces of erosion and rupture. give These two polymers are widely used in the industry due to their high adhesion and elasticity. In addition to increasing resistance, another use that can be made of these two polymers is sand stabilization. These two polymers can prevent movement due to their stickiness. The quicksands become stormy because in our country and neighboring countries quicksand and the air pollution caused by it are proposed from these two polymers to solve this problem, it can be used. This feature can be used to prevent soil erosion caused by Rainfall was also used.
Polyvinyl acetate is made by mercury in Germany in 1912. The degree of polymerization of polyvinyl Acetate is usually variable between 100 and 5000. Organic salts of polyvinyl acetate groups. In an alkaline environment, they are slowly converted into polyvinyl alcohol and acetic acid. Vinyl acetate is produced from the polymerization of vinyl acetate monomers. Polyvinyl alcohol is produced from the polymerization of vinyl monomers. Alcohol can also be produced.



Polyvinyl acetate solution is considered an adhesive for permeable materials, especially materials such as wood. Paper, fabric, and fine sand for the same reason as a water-soluble adhesive. It has many applications. Therefore, most water-based wood glues are a combination of this polymer. white glue) is made of a special combination of polyvinyl alcohol and polyvinyl acetate.

11- HOW TO MAKE SAMPLES
In this research, about 60 kg of fertile soil was collected from around Hamdiyeh near Kerman, then the polymer materials used in this research were obtained partially and only for tests from companies that sell chemicals (Kimiya Tejarat Razi Company) and It was mixed during the process mentioned in the previous chapter. Due to the necessity of laboratory research to achieve the goals considered in this research, experiments were conducted to determine the characteristics of Fertile soil. To determine the physical and mechanical properties of Fertile soil, Etterberg limit tests were performed, and finally, to obtain the characteristics of the polymer mixture of Fertile soil, Etterberg limit tests, permeability tests, compaction tests, erodibility tests, etc. were performed. All the laboratory tests performed in this research were done in the laboratory of the civil engineering department of Kerman Azad University The results of tests on the additives used.

11-1 -Compaction test
11-1-1-Polyvinyl alcohol
The compaction test was performed on 5% of the mentioned different mixing of polyvinyl alcohol material on the studied soil. The results are shown in Table 7.

Table 7- Compaction test results on mixed soil or polyvinyl alcohol

The amount of polyvinyl alcohol (%).	Maximum dry weight (KN/m3)	Optimum humidity.(%)
0	18/73	13/93
1	18/73	13/09
1/5	18/83	12/5
2	18/93	12
3	19/03	10/9
5	19/42	8/15

By adding this material to the soil, the maximum dry weight has increased with the increase in the percentage of mixing and the optimal moisture level has decreased, and this is due to the replacement of this material instead of water, and as it was observed by placing this material for 24 hours At a temperature of 150 degrees Celsius in the redon oven, this material did not change in volume and no evaporation took place, .
15-1-2-Polyvinyl acetate
The compaction test was performed on the 6% of the mentioned different mixing of polyvinyl acetate material on the studied soil. The results are shown in Table 8,

Table 8- Compaction test results on mixed soil or polyvinyl acetate

The repair rate of the special concrete stump (%).	Maximum dry weight (KN/m3)	Optimum humidity.(%)
0	18/73	13/93
0/5	18/80	13/53
1	18/64	13/47
1/5	18/54	13/2
2	18/5	13
3	18/43	12/89

5	18/53	10/12

By adding this material to the soil, there is no significant change in the maximum dry bulk weight, but the optimal moisture content decreases with the increase in the percentage of mixing. This substance did not change its volume for 24 hours at a temperature of 150 degrees Celsius, and there was no evaporation of it, .

11-2 -Fertile index test

11-2-1 -Polyvinyl alcohol

A fertile index test was done on 5% of the mentioned different mixing of polyvinyl alcohol on the studied soil. The results are shown in Table 9,

Table 9- Fertile test results on soil mixed with polyvinyl alcohol

Fertile index	Mixing Percentage
17/5	0
12/67	1
12/35	1/5
12/66	2
12/9	32
15/14	5

The increase of this substance in the soil has decreased the Fertile index of the soil, but considering that the Fertile index is more than 10 in all mixing percentages, they are all placed in the category of highly fertile soils. And in the mixing ratio of 1.5%, we had the largest decrease in the Fertile index, i.e. 29%.

11-2-2-Polyvinyl acetate

A fertile index test was done on 6% of the mentioned different mixing of polyvinyl acetate material on the studied soil. The results are shown in Table 10

Table 10- Fertile test results on composite soil or polyvinyl acetate

Fertile index	Mixing percentage
17/5	0
9/52	0/5
7/34	1
4/22	1/5
2/52	2
2/37	3
1/30	5

By adding this substance to the soil, the Fertile index decreases. And as the mixing percentage of this material increases, the Fertile index decreases, and for the mixing percentage of 0.5% and 1% of the soil, they are placed in the group of soils with relatively intense Fertile percentage. In the percentage of mixing, 1.5%, 2%, and 3% indicate a medium Fertile index, and 5 indicates a high Fertile index.

12-CHANGES IN SHEAR STRENGTH

12-1- Polyvinyl alcohol

A fertile index test was performed on 5% of the mentioned different mixing of polyvinyl alcohol on the studied soil. The results are shown in Figure 11-4. ,

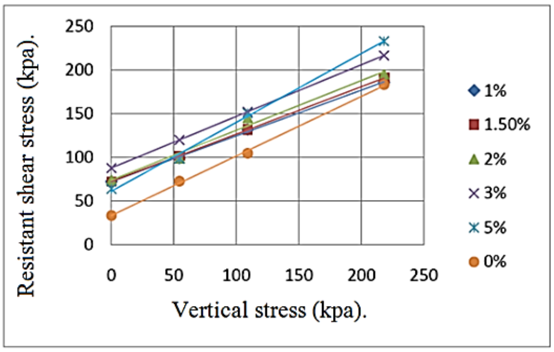


Figure 7- Chart for determination of shear strength parameters for composite soil or polyvinyl alcohol

According to Figure 8, the adhesion value is the highest for the mixing percentage of 3% and the angle of internal friction is the highest for the mixing percentage of 5%.

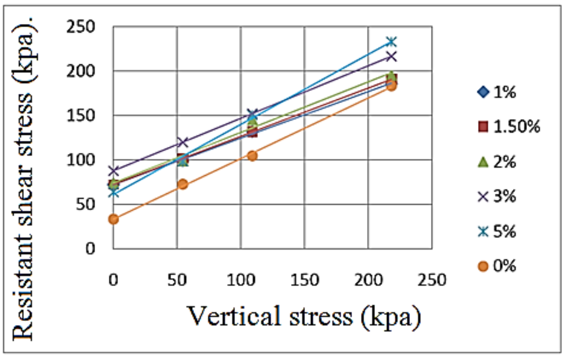


Figure8- Comparative diagram of shear stress for mixing percentages of polyvinyl alcohol material

Figure 9, obtained from the Moore-Coulomb rupture stress relationship, shows that the highest shear stress for shear stresses less than 118.5 kPa corresponds to the mixing percentage of 3, and for stresses higher than that, it corresponds to the mixing percentage It is 5. And this is because the adhesion is the highest for 3% mixing and the internal friction angle is the maximum for 5% mixing. The results obtained from the soil chemistry test, which is given in parts 5-4, show that in the mixing ratio of 3%, the amount of sodium has decreased compared to the control soil, and the amount of calcium has increased compared to the control soil, and as a result, the resistance The soil shear increases. Figure 9 shows the diagram of shear changes against horizontal displacement on the optimal percentage of mixing (3%) and under vertical stresses of 54.5, 109, and 218 kPa. ,

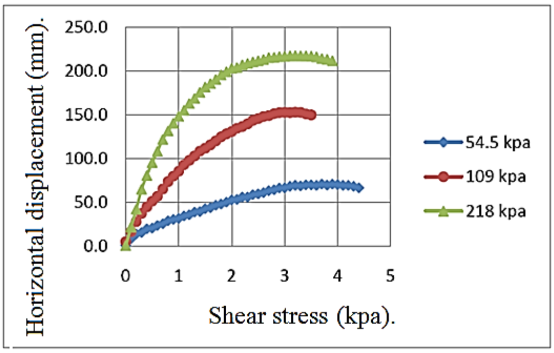


Figure 9- Comparison chart of changes in shear stress against horizontal displacement on soil or optimal mixing percentage (3%)

12-2- Polyvinyl acetate

A fertile index test was done on 6% of the mentioned different mixing of polyvinyl acetate material on the studied soil. The results are shown in Figure 15.

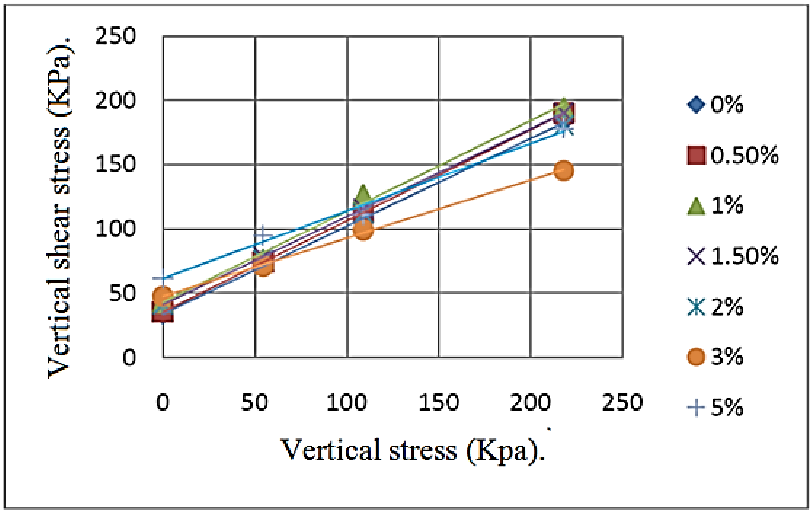


Figure 10- Shear resistance parameter determination diagram for composite soil or polyvinyl acetate

As can be seen from the above results and graph, the highest adhesion is related to the mixing percentage of 1% and the highest internal friction angle is related to the mixing percentage of 5%.

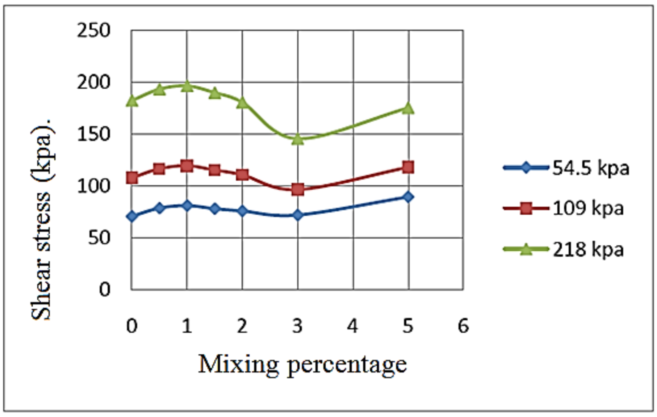


Figure 11- Comparative diagram of shear stress for mixing percentages of polyvinyl acetate material

Figure 16, obtained from the Moore-Coulomb fracture stress relationship, shows that the highest shear stress occurs at a mixing percentage of 1%. The results obtained from the soil chemistry test given in parts 4-5 show that in the mixing ratio of 1%, the amount of sodium has decreased compared to the control soil and the amount of calcium has increased compared to the control soil, and as a result, the shear strength The soil goes up. Figure 16-4 shows the diagram of shear changes against horizontal displacement on the optimal percentage of mixing and under vertical stresses of
54.5, 109, and 218 kPa. ,

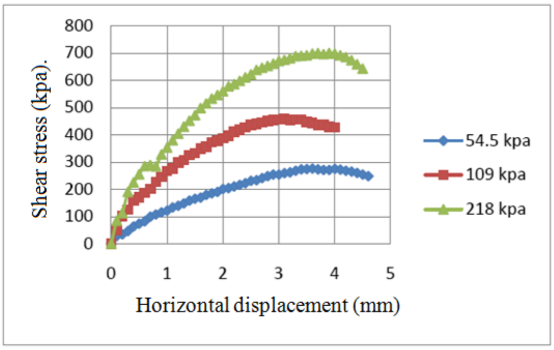


Figure 12- Comparative diagram of changes in shear stress against horizontal displacement on soil or optimal mixing percentage (1%)

CONCLUSION

The purpose of this research is to stabilize Fertile soil using polymer materials and investigate the parameters of shear resistance and erodibility of the soil combined with these materials. In other words, by adding different percentages of these materials, ¿what changes occur in the mechanical properties of the soil? Among the most important results of this research, the following can be mentioned:

1- In the experiment to determine the Fertile index
- Polyvinyl alcohol decreased the Fertile index, which in the mixing ratio of 1.5% reduced the Fertile index by 29%. ,
- Polyvinyl acetate reduced the Fertile index and in the mixing ratio of 5% of the soil, it was placed from the extremely Fertile group to the soil group with low Fertile. In this mixing ratio, the Fertile index decreased by 92%. ,
2- In the shear resistance test
- Polyvinyl alcohol increases shear resistance parameters and the optimal mixing percentage for shear stresses less than 118.5 kPa is 3 and for stresses higher than that, the mixing percentage is 5. ,
- The optimal mixing percentage for this material is 1%, and in this mixing percentage, the adhesion value increased by 27%, and the value of the internal friction angle increased by 3%. ,
According to the results obtained from the present research, the following suggestions are recommended:
- A study on the uniaxial behavior of Fertile soils by adding these materials
- Using cement together with these materials for stabilization
- Examining the time factor in the properties of these materials
- The study of erodibility in other mixing ratios of materials
- Studying these materials on other soils

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