Evaluation of geotechnical properties of soil contaminated with different percentages of petroleum substances and mixed with different percentages of cement and lime

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Abstract

Today, the key role of soil in maintaining the foundations of structures and their stability (from structures such as residential buildings to earthen dams and huge concrete dams) is not hidden from any of the specialists and experts. This issue has caused attention and investigation in recent years by knowing the polluting factors and then eliminating or minimizing their reactions with soil compounds. The most important pollutants of urban soils are heavy metals and petroleum substances, which reduce the quality of the soil and, as a result, reduce its desired geotechnical function. These materials gradually accumulate in the soil due to their low mobility, and this accumulation leads to the disintegration of the soil granulation, reducing the bearing capacity and stability in the soil. The main purpose of this study, which was carried out by laboratory method, was to evaluate the geotechnical properties of soil contaminated with different percentages of petroleum substances and mixed with different percentages of cement and lime at the ages of 7 and 28 days. The results of the FESEM test for the S39 sample at the age of 28 days showed that this sample has a connected layered (sheet) structure and has assumed a more coherent and homogeneous state than other samples. Also, according to the images, the free space of the sample has been greatly reduced and thus the friction between the plates has increased. The small string compounds formed in this sample have caused the depth of the holes to be reduced favorably.

Keywords: geotechnical, contaminated, petroleum, residential, cement, lime, coherent, test, transportation, leakage

1. Introduction

With the progress of the industry and the increase in human need for fossil fuels, especially petroleum and hydrocarbon materials, pollution related to these industries has been inevitable. Extraction, transportation, storage and all different processes on petroleum products can cause crude oil leakage, contamination of soil, water and other natural resources with chemical and petroleum substances [1]. Penetration of various oil particles in the soil causes adhesion between oil particles and soil, which makes useful soil microorganisms unusable [2]. It has been proven that crude oil contains heavy metals and chemicals that have polluted an area of about 235 million hectares of the earth [3]. Penetration of these materials in the soil and underground water prevents the permeability of the soil, the air does not reach the lower layers, the pollution of the underground water and also its persistence in the soil causes the loss of compressive strength in the direction of the instability of the durability properties of the soil. [4]. Therefore, according to the research done by other researchers, soil pollution with petroleum materials will cause a change in the geotechnical characteristics of the soil, which means that crude oil leakage from pipes, tanks and refineries related to the oil industry, as well as natural eruption of oil in the areas Its susceptibility and penetration into the soil around and under the foundations of structures, in addition to damaging environmental effects such as groundwater and sea water pollution, also causes changes in the geotechnical characteristics of the soil. These changes in granular soils are in the form of changes in physical properties and in cohesive soils in the form of changes in soil texture and structure. The issue of stability and resistance of oil-contaminated soils is important for foundations of structures, oil tanks, oil transfer pipes, stability of soil slopes, etc. [5]. On the other hand, with the increasing demand for crude oil in the world, oil pollution has become inevitable. As a result of discoveries, production and transportation, we will witness more and more pollution of existing soils, especially in oil-rich areas such as the south of Iran.

In fact, when the soil is contaminated with petroleum hydrocarbons, the soil structure, chemical and physical characteristics, biological characteristics of the soil including soil organic matter, density, porosity, soil respiration process, mass transfer, etc. will change. Also, geotechnical parameters, such as the boundaries of the sheet, density, resistance, change with oil penetration [6]. Things that happen after an oil spill in the soil: some of it evaporates and goes into the air, biodegradation, adsorption on the surface of soil particles, transfer to groundwater, exchange with hydroxyl agent and other clay groups, reaction with soil organic components. Like humic acids, the reaction with soil organic solutions and the formation of sediment and the insolubility of pollutant derivatives are other things that occur in oil-contaminated soil compounds. Of course, the remaining and stability of the oil pollutant in the soil takes place in two stages. The initial phase is short and ends quickly, and the second phase is long and disappears slowly, which can affect the geotechnical characteristics of the soil and its stability in order to withstand external forces such as the construction of civil structures and the loosening of the foundations of structures.

The main purpose of this study is to investigate the geotechnical properties of soil contaminated with oil and mixed with different percentages of cement and lime. Amir Reza Gudarzi and colleagues in the year (2022); In this research, they studied the effect of the combination of industrial waste and lime on the hydromechanical behavior of clays. The results showed that compared to lime, the presence of slag, especially GGBS, has little effect on the geomechanical characteristics of the soil. On the other hand, it was found that the mixture of lime and slag (LAS) caused a sharp decrease in water retention potential and soil settlement control and significantly increased the bearing capacity so that the compressive strength of these samples increased more than 75 times [7].]. Sivapulaya et al. in (2021); In an article, they addressed the improvement of divergent soils (soil with gypsum) using ash and lime. The study was conducted on the resistance behavior of the soil in different periods of 90 days and the mechanism was determined through pH, mineralogy, microstructures and chemical compounds. The strength of the soil and ash combination was improved by adding lime up to 4% and in the 28-day curing period. Also, by adding 1% of gypsum to the soil-ash-lime mixture, the strength of the mixture increases after 14 days of treatment [8]. Elaha Khosravani and colleagues in (2020); They investigated the geotechnical parameters of soil contaminated with petroleum derivatives. The results showed an increase in adhesion, a decrease in the internal friction angle and compressibility. They found these results useful for finding solutions for soil amendment [9].

2. Research method

This research study was done in a laboratory. The samples examined in this research will be as described in the following table:

Table 1- representative of the studied samples

Lime mixed with soil (in term of percentage)	**Cement mixed with soil (in term of percentage)**	**Crude oil mixed with soil (in term of percentage)**	**Sample (Sample Abbreviated Title)**
3	6	3	**S36**
9	9	3	**S39**
9	9	7	**S79**

In this study, field emission scanning electron microscopy and uniaxial resistance at the ages of 14 and 28 days have been investigated as follows:

A) FESEM test to determine the layered (sheet) structure and to determine the microstructures of soil samples contaminated with different percentages of oil.

b) soil sample contaminated with different percentages of oil, once with amounts of 3, 6 and 9% of cement and once with amounts of 3, 6 and 9% of lime, stabilized and the uniaxial strength of the prepared samples was evaluated and in Finally, the optimal mixing plan is introduced in this article, which was done in a laboratory.

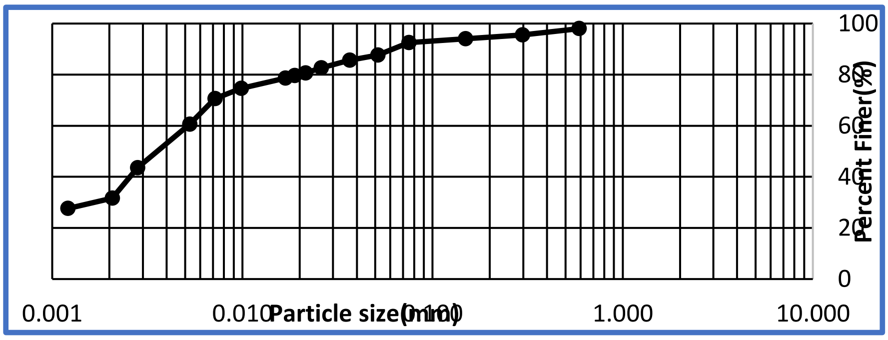
3. Specifications of consumables

3-1. Characteristics of the soil used

The soil used in this research was the soil obtained from the mine of Masjid Suleiman in Khuzestan province, which was passed through a grade 8 sieve. After checking the Etterberg limits on the prepared soil, the clay index of the soil (26.5) was obtained, and finally this soil is classified as clay with high plasticity CH.

Figure 1- Sample of spent clay passed through sieve No. 8

3-1-1.Semi-logarithmic curve of clay granulation



3-1-2. The result of Etterberg limit test on the used soil

Table 2- Etterberg limits test on the studied soil

clay	Soil
CH	Soil classification system
54.3	(LL)
27.8	(PL)
26.5	(PI)

3-2. Specifications of lime used

The lime used in this research is quicklime, which is powdered and white in color, and in order to better mix and create a reaction with clay, it has been given a passing grade of 60 through a sieve.

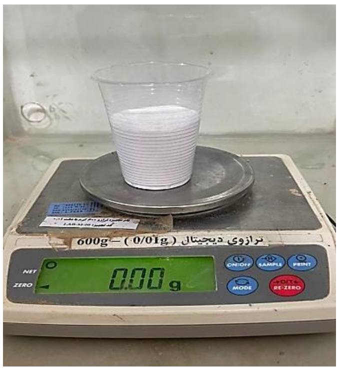


Figure 2- A sample of spent lime passed through sieve No. 60

3-3. Specifications of the cement used

Type II Portland cement was used in this research.

Figure 3 - Type 2 Portland cement

3-4. Crude oil used

The oil used in this research was desalinated crude oil from the Ahvaz field, the Asmari layer exploited by the oil-rich regions of the south.

4. Preparation of studied samples

Samples are prepared for storage and processing by standard density test. In this test, the desired soil is combined with relevant materials (with predetermined percentages) and distilled water (usually between 15 and 25% by weight, so that the finer the soil, the higher the percentage of water used), and then We give time to the solution. The obtained mixture is poured into the mold in three steps so that a third of the mold is filled each time, and 25 blows are applied to it with a special compaction hammer to compact the soil. After the completion of soil compaction, the mold (the upper part of the mold) is returned, then the surface of the mold is leveled with a tool such as a spatula.

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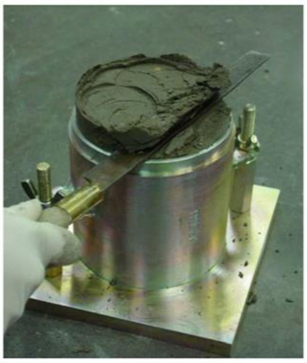


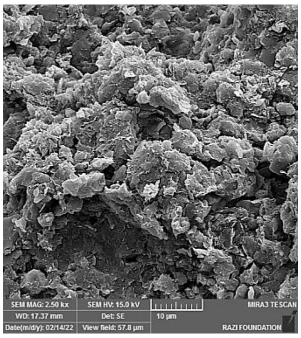
Figure 4- Leveling the dense sample

After this step, the desired soil is ready for sampling. Sampling of dense soil is done in such a way that the sampling mold is inserted into the dense sample by an oil jack and the soil, which is compressed, enters the sampling molds. In fact, smaller elements are taken from compacted soil and each of the smaller samples are taken out of the mold with a jack.

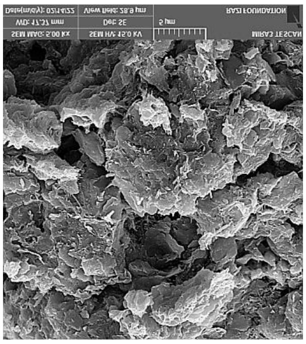
5. Laboratory analysis of samples

5-1. FESEM test results (age 14 days)

A) Sample S36 (soil mixed with 3% crude oil and 6% cement):



First image of FESEM test for sample S36 at the age of 14 days



Second image from FESEM test for sample S36 at the age of 14 days

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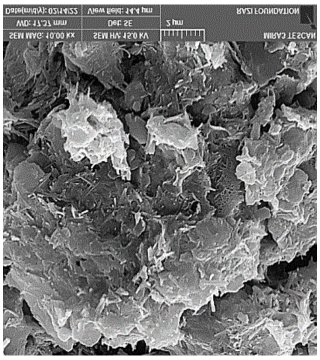
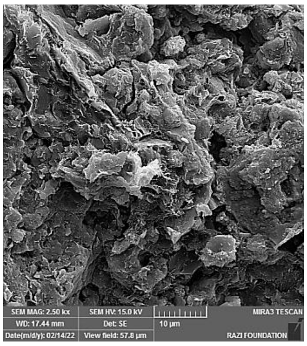
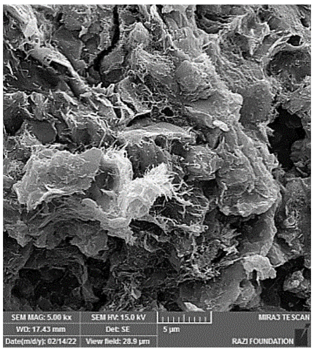


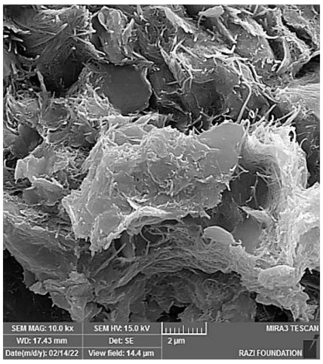
Third image of FESEM test for sample S36 at the age of 14 days



Fourth image of FESEM test for sample S36 at the age of 14 days



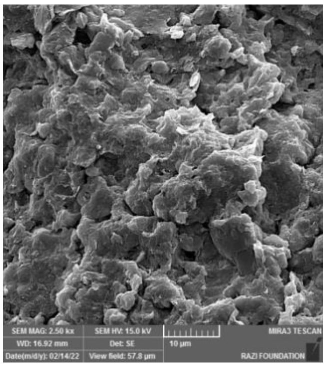
fifth image of the FESEM test for the S36 sample at the age of 14 days



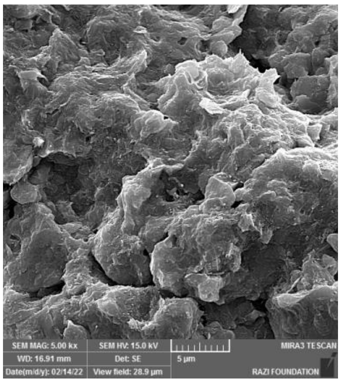
Sixth image of FESEM test for S36 sample at 14 days old

According to the above images from the FESEM test for the S36 sample at the age of 14 days; The sample has a relatively discrete layered (sheet) structure and no cohesion is visible in the S36 sample at the age of 14 days. Also, according to the pictures, the empty space of the sample has not decreased much, and the friction between the plates has also decreased. Acceptable string compounds can be seen in the images, which caused deep holes in the sample to be relatively reduced. The results obtained in this section are in line with the research done by Bifkadu (2018).

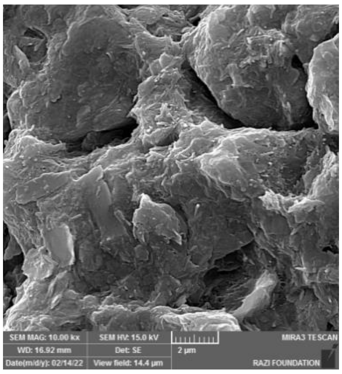
b) Sample S39 (soil mixed with 3% crude oil and 9% cement:



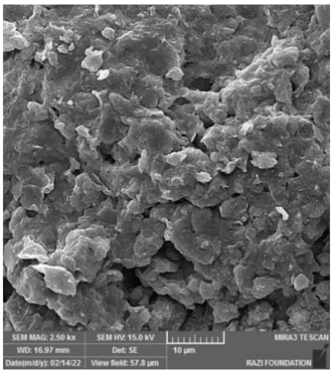
First image of FESEM test for sample S39 at the age of 14 days



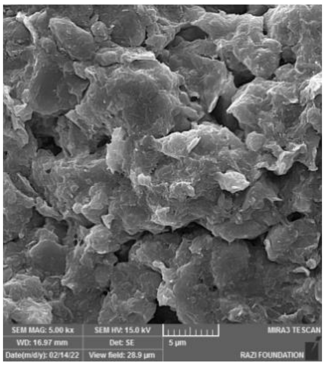
Second image from FESEM test for sample S39 at the age of 14 days



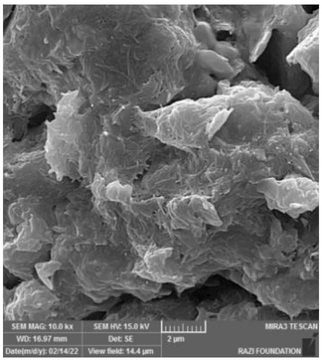
Third image of FESEM test for sample S39 at the age of 14 days



Fourth image of FESEM test for sample S39 at 14 days of age



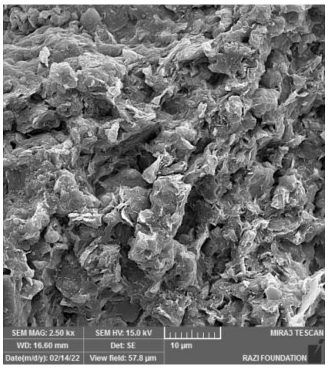
The fifth image of the FESEM test for the S39 sample at the age of 14 days



Sixth image of FESEM test for S39 sample at 14 days old

According to the above images from the FESEM test for the S79 sample at the age of 14 days; The sample has a relatively discrete layered (sheet) structure and no cohesion is visible in the S36 sample at the age of 14 days. Also, according to the pictures, the empty space of the sample has not decreased much, and the friction between the plates has also decreased. String compounds are not seen in the images, which caused deep holes to remain in the sample. The results obtained in this section are consistent with the research conducted by Liao (2019) and Bifkado (2018).

c) Sample S79 (soil mixed with 7% crude oil and 9% cement):



The first image of the FESEM test for the S79 sample at the age of 14 days

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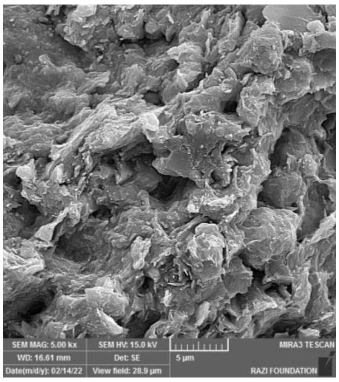
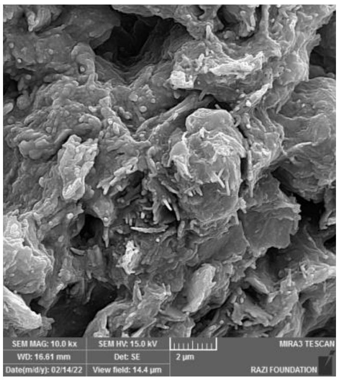
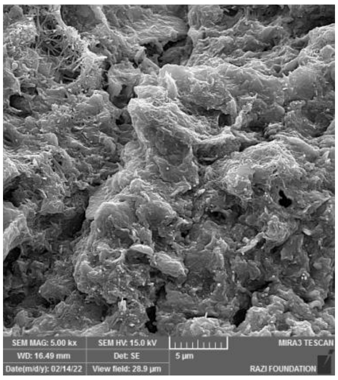


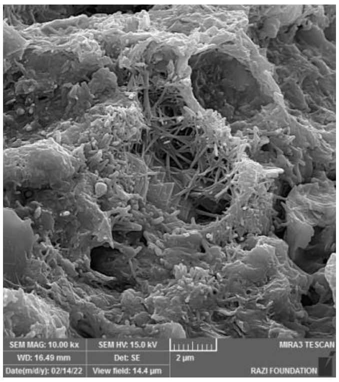
Second image from FESEM test for sample S79 at the age of 14 days



Third image of FESEM test for S79 sample at the age of 14 days



Fourth image from FESEM test for S79 sample at 14 days old



Fifth image of FESEM test for S79 sample at 14 days old

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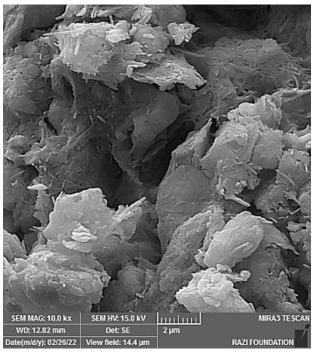
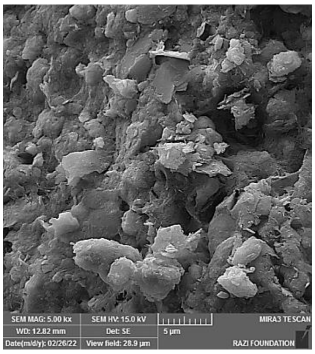
According to the above images from the FESEM test for the S79 sample at the age of 14 days; The sample has a relatively discrete layered structure and has become more coherent than the S36 sample at the age of 14 days. Also, according to the pictures, the empty space of the sample has not decreased much, and the friction between the plates has also decreased. String compounds are less visible in the images, which caused deep holes to be created in the sample. The results obtained in this section are in line with the research done by Bifkadu (2018).

5-2. FESEM test results (age 28 days)

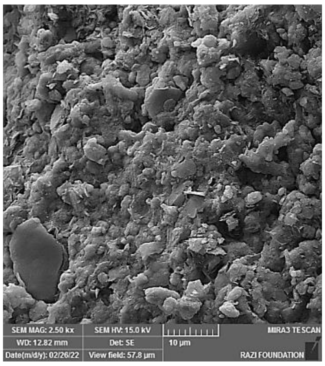
A) Sample S36 (soil mixed with 3% crude oil and 6% cement):



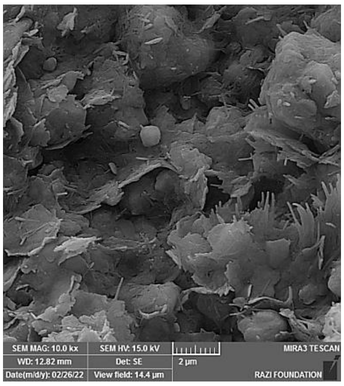
First image of FESEM test for sample S36 at the age of 28 days



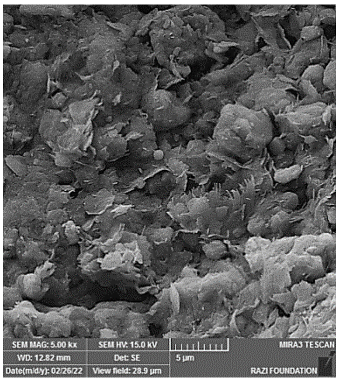
Second image from FESEM test for sample S36 at the age of 28 days



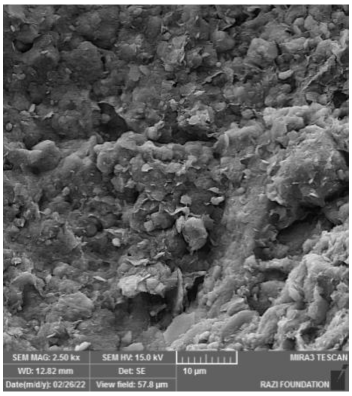
Third image of FESEM test for sample S36 at the age of 28 days



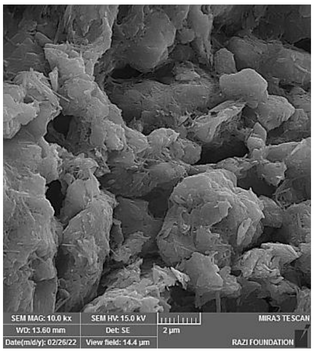
Fourth image from FESEM test for S36 sample at 28 days old



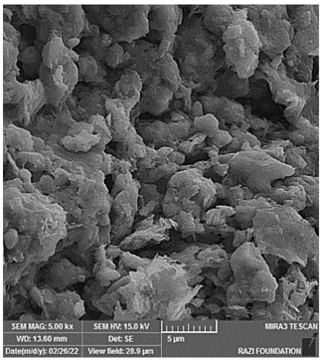
The fifth image of the FESEM test for the S36 sample at the age of 28 days



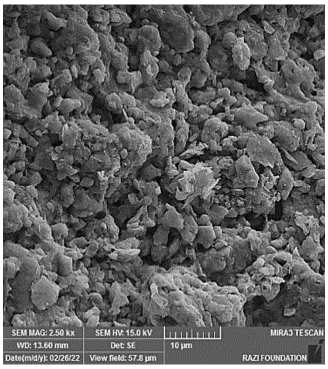
Sixth image from FESEM test for S36 sample at 28 days old



seventh image of FESEM test for S36 sample at 28 days old



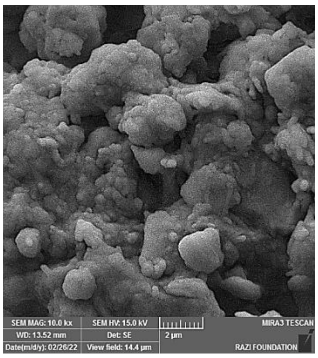
Eighth image of FESEM test for S36 sample at 28 days old



ninth image from FESEM test for S36 sample at 28 days old

According to the above images from the FESEM test for the S36 sample at the age of 28 days; The sample has a layered (sheet) structure connected to each other and has taken a more cohesive state than the 14-day sample. Also, according to the images, the empty space of the sample has been relatively reduced and thus the friction between the plates has increased. The homogeneity of the sample can be seen, while some string compounds can be seen in the images, which caused the depth of the holes to decrease relatively. The results obtained in this section are in good agreement with the research conducted by Liao (2019) and Bifkado (2018).

b) Sample S39 (soil mixed with 3% crude oil and 9% cement):



Third image of FESEM test for S39 sample at 28 days old

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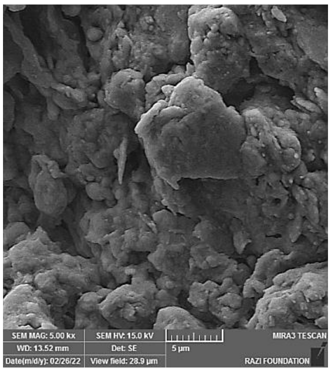
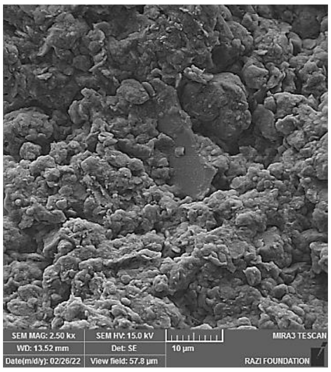
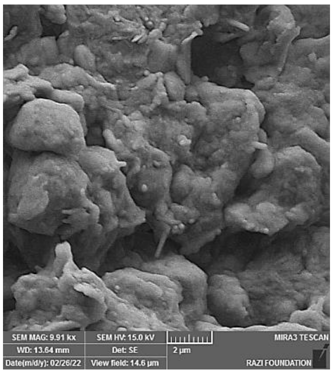


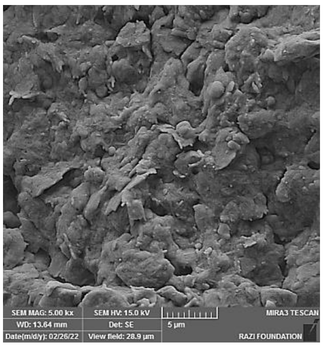
Second image from FESEM test for sample S39 at the age of 28 days



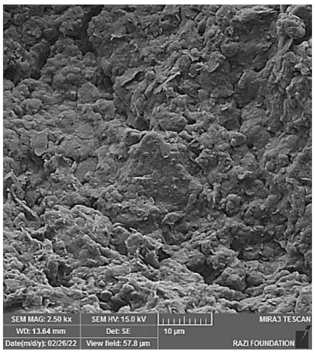
First image of FESEM test for sample S39 at the age of 28 days



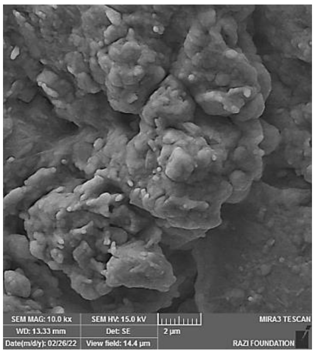
Fourth image from FESEM test for sample S39 at 28 days old



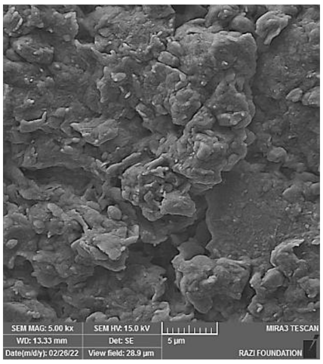
Fifth image of FESEM test for S39 sample at 28 days old



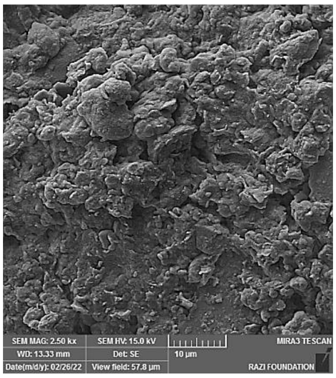
Sixth image from FESEM test for S39 sample at 28 days old



seventh image from FESEM test for S39 sample at 28 days old



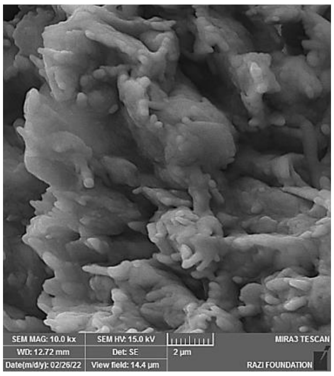
Eighth image from FESEM test for S39 sample at 28 days old



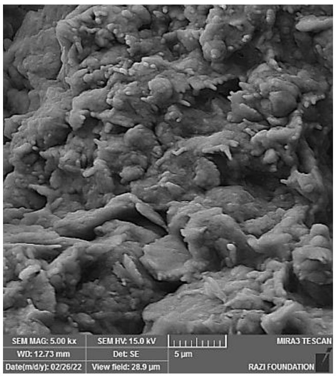
Ninth image from FESEM test for S39 sample at 28 days old

According to the above images from the FESEM test for the S39 sample at the age of 28 days; The sample has a layered (sheet) structure connected to each other and has taken a more coherent and homogeneous state than other samples. Also, according to the images, the free space of the sample has been greatly reduced and thus the friction between the plates has increased. Small stringy compounds can be seen in the pictures, which caused the depth of the holes to decrease favorably. It is worth mentioning; New cement compositions have also been created in the sample. The results obtained in this section are consistent with the research conducted by Liao (2019) and Bifkado (2018).

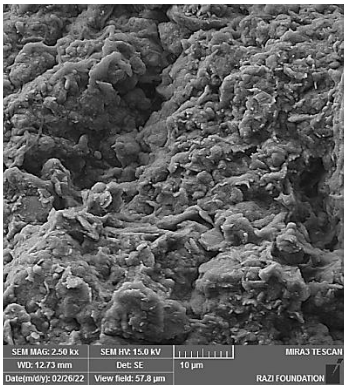
c) Sample S79 (soil mixed with 7% crude oil and 9% cement):



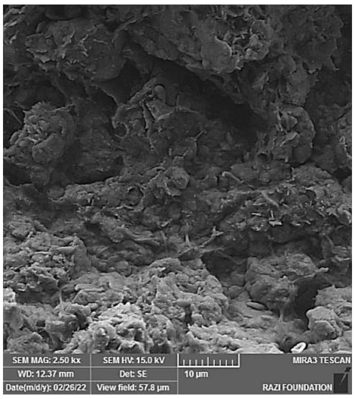
First image of FESEM test for S79 sample at the age of 28 days



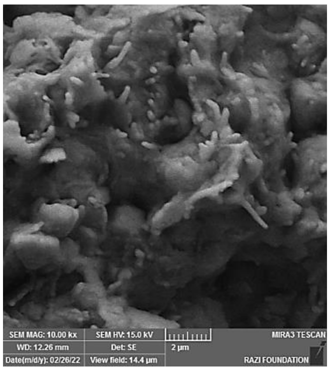
Second image of FESEM test for S79 sample at the age of 28 days



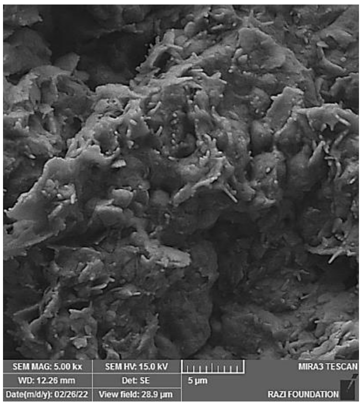
Third image of FESEM test for S79 sample at the age of 28 days



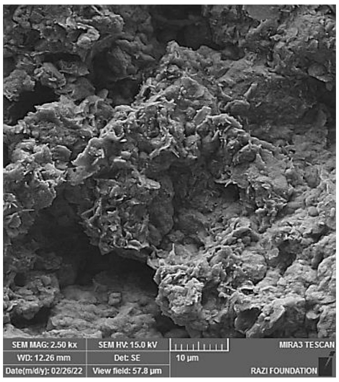
Fourth image of FESEM test for S79 sample at the age of 28 days



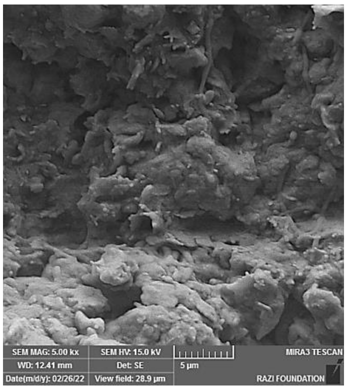
Fifth image of FESEM test for S79 sample at the age of 28 days



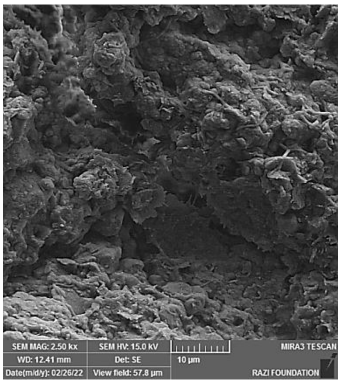
Sixth image of FESEM test for S79 sample at the age of 28 days



Seventh image of FESEM test for S79 sample at the age of 28 days



Eighth image of FESEM test for S79 sample at the age of 28 days



Ninth image of FESEM test for S79 sample at the age of 28 days

According to the above images from the FESEM test for the S79 sample at the age of 28 days; The sample has a relatively interconnected layered (sheet) structure and has a coherent state, but it is less coherent than the S39 sample. Also, according to the images, the empty space of the sample has decreased and thus the friction between the plates has increased. Very few string compounds are seen in the images, which caused the depth of the holes to decrease. It is worth mentioning; New cement compositions are also created scattered in the sample. The results obtained in this section are in line with the research conducted by Liao in 2019.

6.Evaluation of uniaxial strength of soil samples contaminated with different percentages of oil and stabilized with added percentages of lime

Table 3- Uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 3% lime

oil	0%	4%	7%	10%
1 day	4.14	4.46	4.54	3.64
14 day	8.19	14.52	13.81	12
28 day	10.63	17.55	17.81	15.45

Based on the obtained results, the uniaxial resistance in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 3% lime at the age of 14 days for mixing soil with 4% oil is equivalent to 14.52 kg. per square centimeter and for mixing soil with 7% oil, it is equal to 13.81 kg/cm2 and the uniaxial resistance for mixing soil with 10% oil is equal to 12 kg/cm2, which shows that with the increase in percentage Mixing oil with stabilized soil with 3% lime, (from 4% to 10% oil) and at the age of 14 days, the amount of uniaxial strength decreases in terms of kilograms per square centimeter, and the maximum uniaxial strength is equal to 14.52 kg/cm2 at the age of 14 days, was created in a soil sample containing 3% lime mixed with 4% oil.

Also, based on the results obtained from the above table, the amount of uniaxial resistance in kg/cm2 at the age of 28 days for mixing soil with 4% oil is equal to 17.55 kg/cm2 and for mixing soil with 7% oil. Equivalent to 17.81 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, equivalent to 15.45 kg/cm2 has been obtained. which shows that by increasing the percentage of mixing oil with soil stabilized with 3% lime (from 4% to 10% oil) and at the age of 28 days, the amount of uniaxial strength in kilograms per square centimeter after a relative increase , has faced a significant decrease and the highest uniaxial strength equal to 17.81 kg/cm2 at the age of 28 days was created in the soil sample containing 3% lime mixed with 7% oil.

Table 4- Uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 6% lime

oil	0%	4%	7%	10%
1 day	2.89	3.71	3.66	3.65
14 day	8.19	14.78	12.62	12.55
28 day	10.8	18.55	18.91	16.54

Based on the results obtained; Uniaxial strength in kilograms per square centimeter of the soil sample contaminated with different percentages of oil and stabilized with 6 percent lime at the age of 14 days for mixing the soil with 4 percent oil, equal to 14.78 kg per square centimeter and to For mixing soil with 7% oil, it is equal to 12.62 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, it is equal to 12.55 kg/cm2, which shows that by increasing the percentage of mixing oil with Soil stabilized with 6% lime (from 4% to 10% oil) and at the age of 14 days, the amount of uniaxial resistance decreases in terms of kg/cm2 and the maximum uniaxial strength is equal to 14.78 kg/cm square at the age of 14 days, was created in a soil sample containing 6% lime mixed with 4% oil.

Also, based on the results obtained from the above table, the amount of uniaxial strength in terms of kg/cm2 at the age of 28 days for mixing soil with 4% oil is equal to 18.55 kg/cm2 and for mixing soil with 7% oil. Equivalent to 18.91 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, equivalent to 16.45 kg/cm2 has been obtained. which shows that by increasing the percentage of mixing oil with soil stabilized with 6% lime, (from 4% to 10% oil) and at the age of 28 days, the amount of uniaxial strength in kilograms per square centimeter after a relative increase , has been faced with an insignificant decrease and the highest uniaxial strength equal to 18.91 kg/cm2 at the age of 28 days was created in the soil sample containing 6% lime mixed with 7% oil.

Table 5- Uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 9% lime

oil	0%	4%	7%	10%
1 day	4.52	3.81	3.28	2.5
14 day	5.94	15.04	15.34	9.39

28 day	7.5	16.31	15.71	15.85

Based on the obtained results, the uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 9% lime at the age of 14 days for mixing soil with 4% oil is equivalent to 15.04 kg. per square centimeter and for mixing soil with 7% oil, equivalent to 15.34 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, equivalent to 39.9 kg/cm2, which shows that Increasing the percentage of mixing oil with soil stabilized with 9% lime, (from 4% to 10% oil) and at the age of 14 days, the amount of uniaxial strength in kg/cm2 after a relative increase for 7% oil , decreases strongly and the highest uniaxial strength equal to 15.34 kg/cm2 at the age of 14 days was created in the soil sample containing 9% lime mixed with 7% oil.

Also, based on the results obtained from the above table, the amount of uniaxial strength in terms of kg/cm2 at the age of 28 days for mixing soil with 4% oil is equal to 16.31 kg/cm2 and for mixing soil with 7% oil. Equivalent to 15.71 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, equivalent to 15.85 kg/cm2 has been obtained. which shows that by increasing the mixing percentage of oil with soil stabilized with 9% lime (from 4% to 10% oil) and at the age of 28 days, the amount of uniaxial strength in kg/cm2 decreases significantly. And the highest uniaxial resistance equal to 16.31 kg/cm2 at the age of 28 days was created in the soil sample containing 9% lime mixed with 4% oil.

Evaluation of uniaxial strength of soil samples contaminated with different percentages of oil and stabilized with cement additive percentages.

Table 6- Uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 3% cement

oil	0%	4%	7%	10%
1 day	7.2	6.5	6.1	5.2
14 day	12.9	12.9	12.7	11.9
28 day	33.1	26.2	22.5	21.1

Based on the obtained results, the uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 3% cement at the age of 14 days for mixing soil with 4% oil is equivalent to 12.9 kg. per square centimeter and for mixing soil with 7% oil, equivalent to 12.7 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, equivalent to 11.9 kg/cm2, which shows that Increasing the mixing percentage of oil with stabilized soil with 3% of cement, (from 4% to 10% of oil) and at the age of 14 days, the amount of uniaxial strength decreases in terms of kilograms per square centimeter, and the maximum uniaxial strength is equal to 9 12/kg/cm2 at the age of 14 days, in a soil sample containing 3% cement mixed with 4% oil.

Also, based on the results obtained from the above table, the amount of uniaxial strength in kg/cm2 at the age of 28 days for mixing soil with 4% oil is equal to 26.2 kg/cm2 and for mixing soil with 7% oil. Equivalent to 22.5 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, equivalent to 21.1 kg/cm2 has been obtained. which shows that by increasing the mixing percentage of oil with stabilized soil with 3% cement, (from 4% to 10% oil) and at the age of 28 days, the amount of uniaxial strength in terms of kilograms per square centimeter decreases significantly. and the highest uniaxial strength equal to 26.2 kg/cm2 at the age of 28 days was created in the soil sample containing 3% cement mixed with 4% oil.

Table 7- Uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 6% cement

oil	0%	4%	7%	10%
1 day	8.6	7.5	7.2	5.6
14 day	24.5	20.1	19	22.4
28 day	43	47.5	40.4	34

Based on the obtained results, the uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 6% cement at the age of 14 days for mixing soil with 4% oil is equivalent to 1.20 kg. per square centimeter and for mixing soil with 7% oil, equal to 19 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, equal to 22.4 kg/cm2, which shows that with increasing percentage Mixing oil with soil stabilized with 6% cement, (from 4% to 10% oil) and at the age of 14 days, the amount of uniaxial strength in kg/cm2 after a relative decrease, for 10% mixing with Oil increases significantly and the highest uniaxial strength equal to 22.4 kg/cm2 at the age of 14 days was created in the soil sample containing 6% cement mixed with 10% oil.

Also, based on the results obtained from the above table, the amount of uniaxial strength in kg/cm2 at the age of 28 days for mixing soil with 4% oil is equal to 47.5 kg/cm2 and for mixing soil with 7% oil. Equivalent to 40.4 kg/cm2 and the uniaxial strength for mixing soil with 10% oil is equivalent to 34 kg/cm2. which shows that the sample containing 6% cement is the most favorable among other samples. Also, with the increase of mixing percentage of oil with soil stabilized with 6% of cement, (from 4% to 10% of oil) and at the age of 28 days, the amount of uniaxial strength in terms of kilograms per square centimeter has significantly decreased. and the highest uniaxial strength equal to 47.5 kg/cm2 at the age of 28 days was created in the soil sample containing 6% cement mixed with 4% oil.

Table 8- Uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 9% cement

oil	0%	4%	7%	10%
1 day	13.2	8.5	7.3	6.6
14 day	33	27.4	26.1	25.7
28 day	49.5	36.6	32.2	28.6

Based on the obtained results, the uniaxial strength in kilograms per square centimeter of soil samples contaminated with different percentages of oil and stabilized with 9% cement at the age of 14 days for mixing soil with 4% oil is equivalent to 27.4 kg. per square centimeter and for mixing soil with 7% oil, equivalent to 1.26 kg/cm2 and uniaxial resistance for mixing soil with 10% oil, equivalent to 25.7 kg/cm2, which shows that Increasing the mixing percentage of oil with stabilized soil with 9% cement, (from 4% to 10% oil) and at the age of 14 days, the amount of uniaxial strength decreases in kg/cm2. In this case, the sample that showed the highest uniaxial resistance was related to the soil sample without oil, which was equal to 33 kg/cm2.

Also, based on the results obtained from the above table, the amount of uniaxial resistance in kg/cm2 at the age of 28 days for mixing soil with 0% oil is equal to 49.5 kg/cm2 and for mixing soil with 4% oil. equivalent to 36.6 kg/cm2 and for mixing soil with 7% oil, it is equivalent to 2.32 kg/cm2 and the uniaxial resistance for mixing soil with 10% oil is equivalent to 28.6 kg/cm2 . which shows that by increasing the mixing percentage of oil with stabilized soil with 9% cement (from 4% to 10% oil) and at the age of 28 days, the amount of uniaxial strength in kg/cm2 decreases significantly. found and the highest uniaxial strength equal to 49.5 kg/cm2 at the age of 28 days was created in the soil sample containing 9% cement mixed with 0% oil.

7.Conclusion

Based on the laboratory studies conducted in this research, the results obtained are as follows:

1) from FESEM test for sample S39 at the age of 28 days; The sample has a layered structure (sheets) connected to each other and has become more coherent and homogeneous compared to other samples (S36 and S79) at different ages. Also, according to the results of the tests, the empty space of the sample has been greatly reduced and thus the friction between the plates has increased. Small string compounds can be seen in the images, which has caused the depth of the holes to decrease favorably. New cement compositions have also been created in the sample.

2) Uniaxial resistance in kilograms per square centimeter of the soil sample contaminated with different percentages of oil and stabilized with 3% lime at the age of 14 days for mixing the soil with 4% oil, equivalent to 14.52 kg per square centimeter And for mixing soil with 7% of oil, it is equivalent to 13.81 kg/cm2 and the uniaxial resistance for mixing soil with 10% of oil is equivalent to 12 kg/cm2, which shows that with the increase in mixing percentage of oil with Stabilized soil with 3% lime decreases the squared uniaxial strength

3) In the soil sample containing 3% lime, the highest uniaxial strength equal to 14.52 kg/cm2 was created at the age of 14 days and mixed with 4% oil.

4) In the soil sample containing 3% lime, the highest uniaxial strength equal to 17.81 kg/cm2 was created at the age of 28 days and mixed with 7% oil.

5) In the soil sample containing 6% lime, the highest uniaxial strength equal to 14.78 kg/cm2 was created at the age of 14 days and mixed with 4% oil.

6) In the soil sample containing 6% lime, the highest uniaxial strength equal to 18.91 kg/cm2 was created at the age of 28 days and mixed with 7% oil.

7) In the soil sample containing 9% lime, the highest uniaxial strength equal to 15.34 kg/cm2 was created at the age of 14 days and mixed with 7% oil.

8) In the soil sample containing 9% lime, the highest uniaxial strength equal to 16.31 kg/cm2 was created at the age of 28 days and mixed with 4% oil.

9) In the soil sample containing 3% cement, the highest uniaxial strength equal to 12.9 kg/cm2 was created at the age of 14 days and mixed with 4% oil.

10) In the soil sample containing 3% cement, the highest uniaxial strength equal to 26.2 kg/cm2 was created at the age of 28 days and mixed with 4% oil.

11) In the soil sample containing 6% cement, the highest uniaxial strength equal to 22.4 kg/cm2 was created at the age of 14 days, mixed with 10% oil.

12) By increasing the mixing percentage of oil with stabilized soil with 6% cement and at the age of 28 days, the uniaxial strength has decreased significantly.

13) In all the samples containing different percentages of oil with the ages of 14 and 28 days, the highest uniaxial strength equal to 47.5 kg/cm2 was created in the soil sample containing 6% cement mixed with 4% oil.

14) in all the samples stabilized with lime and stabilized with cement (containing different percentages of oil and free from oil mixture) from the ages of 14 and 28 days, the sample that has shown the highest

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uniaxial strength is related For the sample of soil without oil at the age of 28 days and stabilized with 9% cement, which is equivalent to 49.5 kg/cm2.

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