Experimental Investigation of the Effect of Microsilica on the Uniaxial Compressive Strength and Rupture Strain of Fine Sand

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Abstract*:* In many areas, natural soil does not have necessary resistance, some additives such as cement and microsilica are added to increase their resistance. In this research, the effect of microsilica on the strength and physical characteristics of fine sand stabilized with cement in sand samples containing cement and microsilica will be discussed. For this purpose, samples of fine sand with three different ratios of cement (2, 4, and 6 percent of soil weight) and four different ratios of microsilica (0, 0.5, 1, and 1.5 percent of soil weight) were mixed with optimal moisture, after Two curing periods of 1 and 7 days were subjected to compression and uniaxial compressive strength tests. The results of the experiments indicate that with the increase in the amount of cement and microsilica, the optimum moisture content in the density increases, the specific weight of the mixture of sand, cement and microsilica increases by adding these materials up to a certain amount, but after that it begins to decrease. . With increasing processing time, uniaxial compressive strength and rupture strain both increase. With a curing time of 1 day, for a fixed cement ratio, the compressive strength of sand-cement increases with the increase of microsilica up to about 20% of the cement weight, but after that, the resistance ratio decreases.
With a curing time of 7 days for a constant cement ratio, the compressive strength increases with the increase of microsilica. It is also observed that in both curing times for different cement ratios, with the increase in the amount of microsilica, the relative deformation of the fracture increases.

Keywords: Microsilica, cement, fine sand, uniaxial compressive strength, axial strain, curing time.

1. Introduction

Most of the time, the natural soil available in construction operations does not have the necessary resistance to bear the load of the desired structure on itself. In this case, the existing soil should be replaced with a more suitable soil, and due to the high cost of this method, other methods are used as needed, for example, if the soil is very loose, after the construction of the structure, there will be a lot of settlement from It will show itself. In such a case, it is necessary to compact the soil before constructing the building to increase its specific weight and, as a result, its shear strength. By using other methods such as adding cement materials, stabilization, the desired properties can be created in the soil. If these methods are used correctly, in addition to increasing the quality of the soil, they also have many economic benefits [1, 2].

Determining the type of stabilizing substance or substances as well as their amount is very important in achieving stabilization goals [3, 4]. In cement-stabilized soils, the type of soil, the amount of cement, the specific gravity of the stabilized and compacted soil, the quality of the mixture of cement and soil, the conditions for making the mixture, and the processing time have a great effect on the technical characteristics. The strength of cement-stabilized soils, such as cement concrete, increases over time [5].

To increase the strength of concrete, there are various mineral materials, the most effective of these materials are pozzolanic materials such as microsilica. The particles of these materials are 50 to 100 times smaller than cement particles and act as fillers for concrete components and not only cause adhesion between cement particles but also increase adhesion between cement and aggregate [6].

On the other hand, experiences have shown that a hydrated cement with large amounts of calcium hydroxide, Ca(OH)2, cannot contribute to the development of resistance, and even on the contrary, large calcium hydroxide crystals at the interface between aggregate and paste are a weak point. It shows greatness. By adding microsilica, this calcium hydroxide is converted into resistant components called hydrated calcium silicate (C-S-H) under the pozzolanic reaction. With the increase of microsilica, large amounts of calcium hydroxide are converted into hydrated calcium silicate [7]. claimed that an increase of 20% of microsilica (relative to the weight of cement) will convert almost all calcium hydroxide resulting from cement hydration into stable hydrated calcium silicate compounds [6].

Many researches have been done on the effect of cement on soil resistance, but there is limited research on the joint effect of cement and microsilica on soil resistance. Among the works done in this field, the following can be mentioned:

Das et al [8] investigated the behavior of a synthetic cemented sand by conducting a series of Brazilian tensile tests and uniaxial strength. The results of their experiments showed that as the degree of cementation increases, the tensile and compressive strength of the cemented samples increases and their breaking strain decreases.

Coop and Atkinson [9] investigated the behavior of synthetic cemented sand in the laboratory. The results of their tests showed that the maximum strength of cemented sands is affected by the direction of the stress path, drainage conditions and all-round pressure.

Bahar [10] discussed the performance of stabilized and compacted soils. He stabilized the soil both under compaction and with cement and briefly reported the effect of each on shrinkage, compressive strength, tensile strength and water resistance. The results of his experiments showed that the best method of stabilization of the tested soil, which provides compressive strength and durability at a reasonable cost, can be a combination of mechanical compaction and chemical stabilization with cement to achieve the desired level of hardness.

Usluogullari [11] investigated the strength, modulus and CBR of artificially hardened sand. He examined the mechanical characteristics of samples containing 3% cement which were cured for 7 days. According to the results of his tests, the strength of hardened sand varied from 8 to 40 psi. He also presented a linear relationship between modulus and resistance rate and CBR value.

Kalkan [12] investigated the effects of microsilica on permeability and swelling pressure, compressive strength of natural clay layer. His experiments showed that the clay compacted with microsilica has a very low permeability and swelling pressure and a very high compressive strength compared to the row of clay samples.

Massoud Mekarchian et al [13] investigated the effect of humidity on swelling in the said soil by conducting swelling tests on clay stabilized with lime and microsilica in the vicinity of sulfate. They showed that the use of microsilica along with proper humidity reduces the destructive effect of sulfate and swelling.

Mehdi Tashkar et al. conducted uniaxial compressive strength and consolidation tests on soil samples stabilized with lime and microsilica. They showed that by adding microsilica, the resistance of samples against freezing and melting increases.

Gholam Moradi et al [2] investigated the swelling and properties of marl soil stabilized with lime and microsilica. By conducting uniaxial compressive strength and CBR tests, they showed that adding microsilica to lime-stabilized soil reduces swelling, increases compressive strength, and increases CBR.

2- Research method

In the current research, the studied soil is a type of fine sand whose characteristics are presented in table (1).

Table (1) characteristics of fine sand used in the experiments

soil name	Cc	Cu	***Dmax (mm)***	***Gs (gr/cm3)***	Optimum humidity (%)	***γdmax (gr/cm3)***
SP	***1/4***	***3/89***	***0/8***	***2/66***	***11/9***	***1/89***

The cement used in the experiments is type 2, which is a product of Sofian Cement Factory, and also microsilica produced by Iran's Ferrosilis Factory was used.

In order to perform the standard proctor compaction test (ASTM D698-78), mixtures of sand with cement and microsilica additives were prepared and tested in the proportions indicated in table (2). To prepare uniaxial compressive strength test samples (UCS) to create sufficient access of microsilica to cement, first, cement and microsilica were mixed in the proportions according to table (2), then together with soil and optimal humidity inside a mold with a diameter of 3.3 cm meters and height of 8 cm, with a density of 98%, and after two treatments of 1 and 7 days, they were subjected to uniaxial compressive strength test.

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3. Results and Discussion

The results of the tests performed on sand-cement-microsilica cylindrical samples are presented in table (2). These results are discussed below.

Table (2) ratio of cement, microsilica and optimal moisture percentage, specific weight, breaking stress, samples

7days processing	1day processing	Maximum specific weight gr/cm3	Optimum humidity percentage	Microsilica ratio (%)	cement ratio (%)
Rupture stress Kg/cm2	Rupture stress Kg/cm2				
2/65	-12Feb	1/932	12/53	0	2
3/44	2/57	1/938	12/74	0/5	
4/90	-16Mar	1/951	12/90	1	
5/67	2/82	1/962	14/13	-05Jan	
5/88	3/70	1/956	12/78	0	4
-22Aug	3/95	1/958	12/98	0/5	
-20Sep	5/00	1/967	13/22	1	
-28Nov	4/93	1/970	13/47	-05Jan	
6/82	4/63	1/961	13/36	0	6
9/89	4/74	1/965	13/56	0/5	
11/34	5/39	1/972	Dec-14	1	
Jul-14	6/70	1/974	14/48	-05Jan	

1.3. The effect of additives on compaction properties of soil

As can be seen, with the increase of cement and microsilica, the optimal humidity increases according to figure (1). The reason for this is the rise of the specific surface due to the increase in fineness and also the chemical reaction with the increase in the amount of cement materials, which causes the need for more moisture.

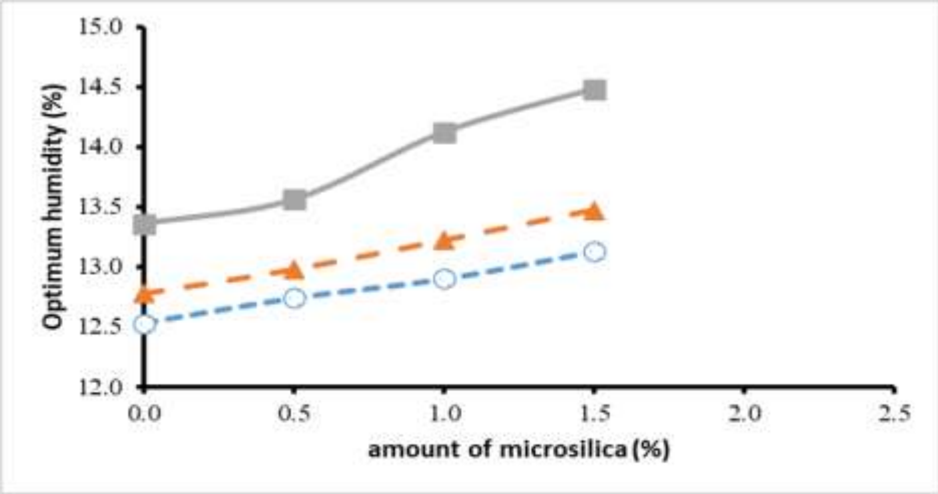

Figure (1) The effect of increasing the amount of microsilica on the optimal moisture content of mixed soil with different proportions of cement.

In figure (2), the maximum dry weight of the samples is compared. As can be seen in this figure, the specific gravity of the mixed soil samples increases with the increase in the amount of cement and microsilica because the cement paste and microsilica increase the viscosity of the mixture. According to this figure, with the increase in the amount of cement and microsilica, the rate of increase in dry specific weight of mixed soil increases, but in high proportions of cement, with the increase of microsilica, the rate of increase in maximum dry weight decreases. The increase in specific weight in the first part is due to the increase in viscosity between the grains, but in the second part, the amount of fine grains increases greatly, and as a result, the effect of the viscosity caused by the cement paste and microsilica between the grains is reduced and the result is the opposite. In other words, if the viscous paste of cement and microsilica is increased again, a decrease in specific weight will be observed; Of course, another reason for reducing the maximum dry weight increase rate is the accumulation and pelletization of fine soil grains due to the presence of cement.

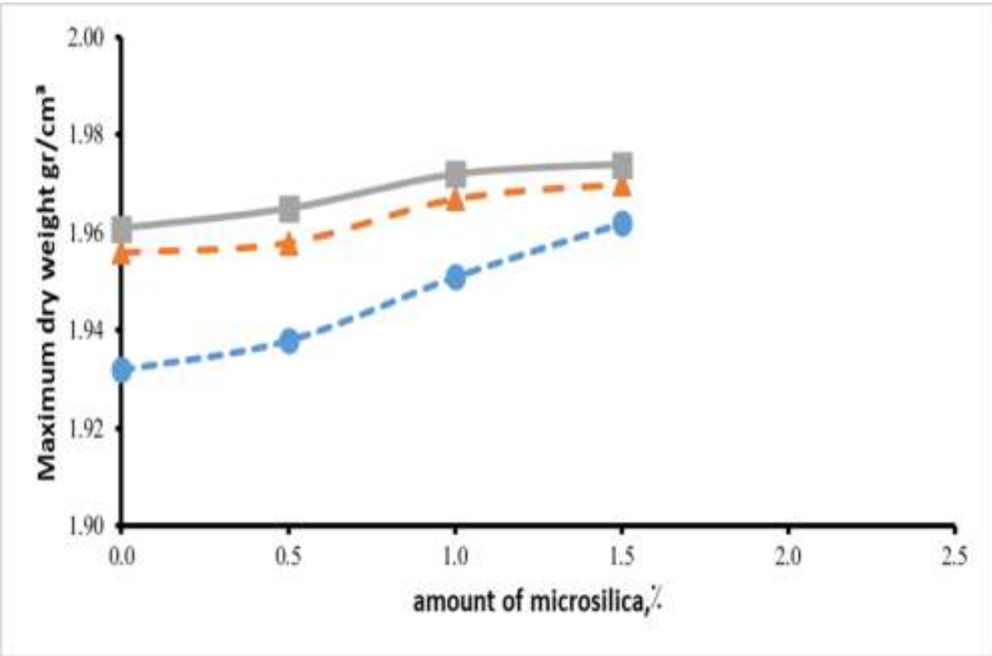

Figure (2) The effect of increasing the amount of microsilica on the maximum dry weight of soil mixed with different proportions of cement.

2.3. The results of uniaxial tests

1.2.3. The effect of additives on the compressive strength of mixed soil samples with 1-day processing

The results of uniaxial compressive strength tests for the samples in 1 day processing are presented in Table (2). These results are compared in figures (3), (4) and (5). According to Figure (3), in samples with a cement ratio of 2%, with the increase of microsilica up to 1%, the uniaxial compressive strength of the samples increases. In the proportion of microsilica, 1.5% considering that the amount of microsilica present is much more than the amount required to react with calcium hydroxide of cement paste (up to 20% of cement weight) and excess microsilica cannot perform a pozzolanic reaction, so it only has It has the property of filling and increases the fineness of the samples, this fineness along with the moisture inside the samples reduces the compressive strength of the samples.

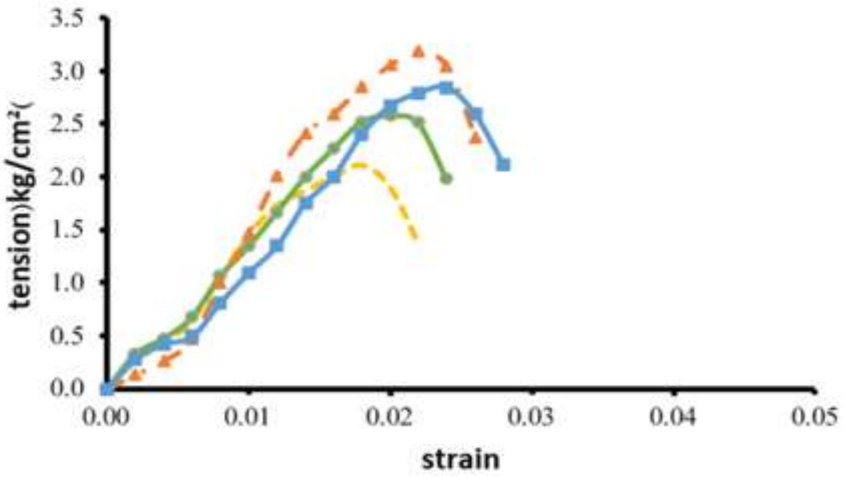

Figure (3) Stress-strain diagram for sand samples mixed with 2% cement and different ratios of microsilica with 1 day curing.

In the mixed samples with a cement ratio of 4% with 1-day processing, the compressive strength of the samples has an upward trend with the increase of microsilica. As can be seen in Figure (4), in this ratio of cement, the compressive strength of the samples with 1% and 1.5% microsilica is almost the same.

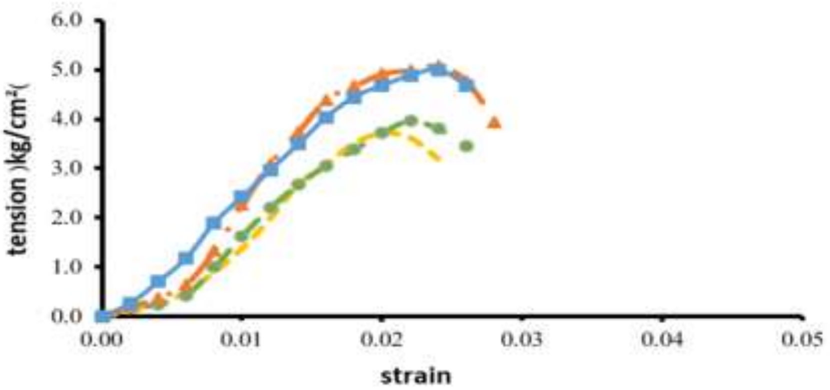

Figure (4) stress-strain diagram for sand samples mixed with 4%

Cement and different proportions of microsilica in 1-day processing.

In the mixed sand samples with 6% cement ratio (Figure (5)), increasing the amount of microsilica up to 1.5% ratio is almost in the required level (maximum 20% of cement weight) to carry out the pozzolanic reaction, so the major part of microsilica Added, it reacts with calcium hydroxide and forms stable calcium silicate and increases compressive strength. A small amount of microsilica in these samples has a filling state.

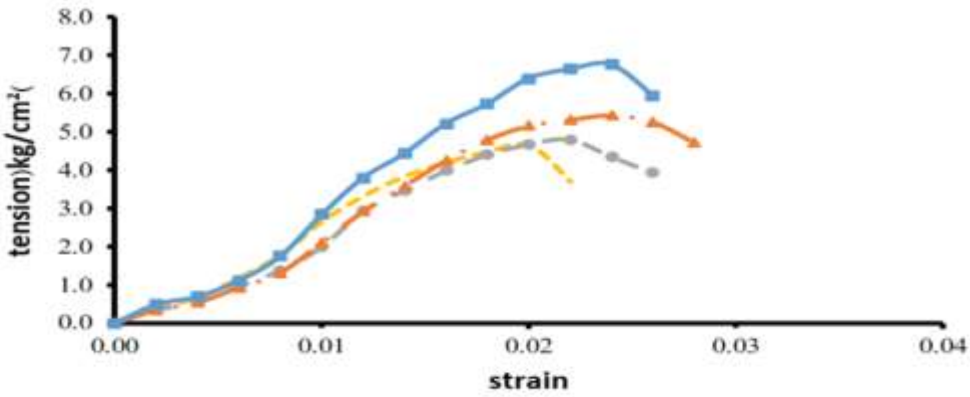

Figure (5) Stress-strain diagram for sand samples mixed with 6% cement and different proportions of microsilica in 1 day processing.

2.2.3. The effect of additives on the relative deformation of mixed soil samples in 1-day processing

In the 1-day processing of the samples for the cement ratio of 2% (Figure (3)) with the increase of the microsilica ratio, an increase in the relative deformation of the samples occurs in the maximum compressive strength because the majority of the added microsilica due to the low The presence of cement is not able to perform the pozzolanic reaction and only causes the increase of the fine grain in the sample.

In samples with cement ratios of 4 and 6% (Figures 4 and 5), with the increase of microsilica ratio, the relative deformation of the samples occurs at the maximum compressive strength. In these proportions of cement, taking into account that more pozzolanic reaction between cement and microsilica and as a result becoming harder requires the passage of more time than 1 day processing, therefore, in these proportions, the strain increase in the maximum compressive strength is observed.

3.2.4. The effect of additives on the compressive strength of soil samples

The mixture is processed for 7 days

The summary of the results of the compressive strength of the samples after 7 days of processing is presented in table (2), the corresponding graphs are also seen in figures (6), (7) and (8). According to these diagrams, with the increase of microsilica, the deformation of all samples increases. According to figure (6), it can be seen that with the increase of microsilica, the compressive strength of the samples mixed with 2% cement increases, according to this figure, the samples with 1.5% microsilica have the highest compressive strength. In these samples, the amount of microsilica present is more than the amount required to react with cement (up to 20% of cement weight). This excess amount of microsilica increases fineness in the sample due to its filling property, and with the passage of time and decrease in humidity, it increases adhesion and increases compressive strength.

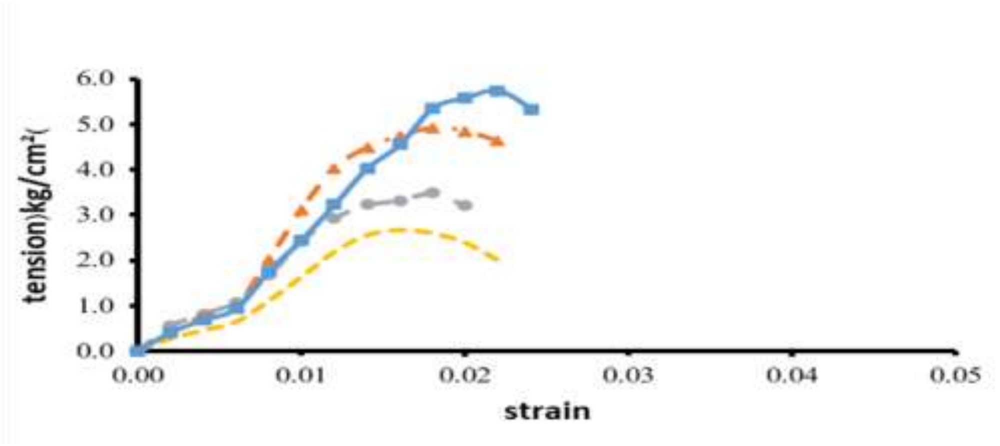

Figure (6) Stress-strain diagram for sand samples mixed with 2% cement and different ratios of microsilica with 7 days curing.

Figure (7) indicates that with the increase of microsilica, the compressive strength of samples with 4% cement increases. For the samples with microsilica ratio of 0 and 0.5%, this increase is due to the pozzolanic reaction of microsilica, but in the samples with microsilica ratio of 1 and 1.5%, part of the increase in resistance is related to the pozzolanic reaction and part is also due to the increase It is fineness that leads to adhesion.

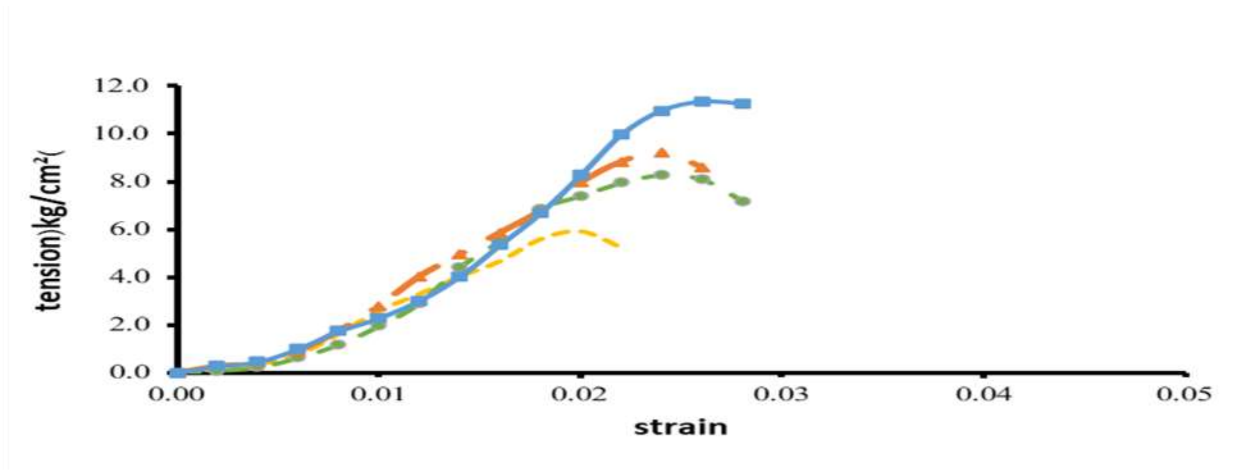

Figure (7) Stress-strain diagram for sand samples mixed with 4% cement and different proportions of microsilica with 7 days curing.

In figure (8) also, with the increase of microsilica, an increase in compressive strength can be seen. In this case, almost all the increase in strength is due to the pozzolanic reaction of microsilica, because the amount of microsilica in the samples is approximately 20% of cement and less than that. Only in the sample with microsilica ratio of 1.5%, there is a small amount of increase in strength, due to the fineness of microsilica and the adhesion caused by it.

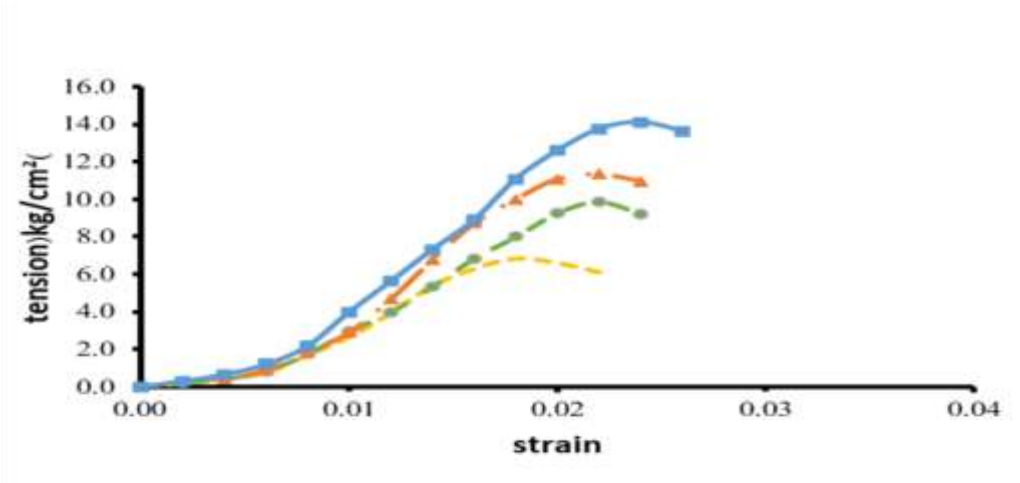

Figure (8) Stress-strain diagram for sand samples mixed with 6% cement and different proportions of microsilica in 7 days processing.

4.2.3. The effect of additives on the relative deformation of mixed soil samples in 7-day processing

As can be seen from figures (6), (7) and (8), for all samples of soil mixed with cement (2, 4 and 6 percent), the relative deformation in the maximum compressive strength increases with the increase of microsilica. find In the mixed sand samples with a cement ratio of 2%, the adhesion caused by fine microsilica particles along with the effect of a small amount of pozzolanic reaction between cement and microsilica causes an increase in the relative deformation in the maximum compressive strength of these samples. In mixed sand samples with a cement ratio of 4% with an increase of microsilica up to about 1%, the effect of the pozzolanic property of microsilica is more dominant than the effect of its filling property in increasing the relative deformation of the samples, with a further increase of microsilica, the effect of its filling property is also dominant. increase.

5.2.3. Investigating the effect of increasing time and adding microsilica on the strength of sand samples stabilized with cement

According to figures (9), (10) and (11), it can be seen that in all proportions of cement and microsilica, with increasing the processing time and creating enough time for the reactions of cement with sand and cement with microsilica, the compressive strength increases. Uniaxiality occurs in mixed sand samples.

Also, figure (9) indicates that in samples containing 2% cement ratio with 1 day curing, with the increase of microsilica to an amount of more than 1%, the uniaxial compressive strength decreases because the increase of microsilica is more than the requirement of direction. Carrying out the pozzolanic reaction only increases fineness.

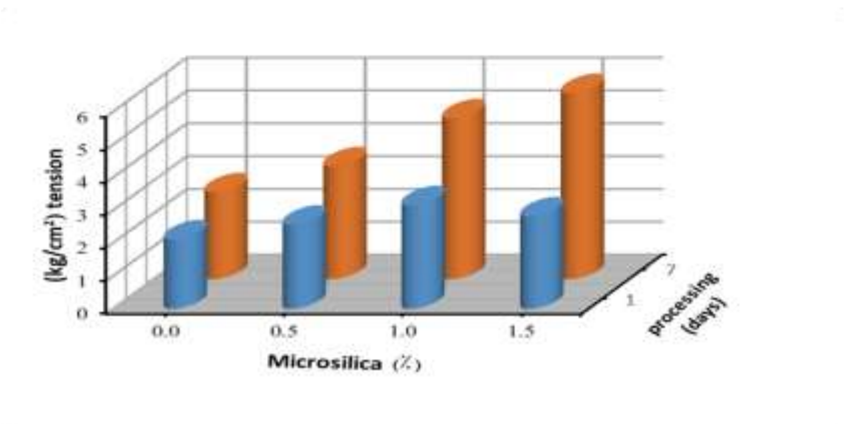

Figure (9) Comparison of uniaxial compressive strength of mixed sand samples with 2% cement ratio and different amounts of microsilica with different curing times

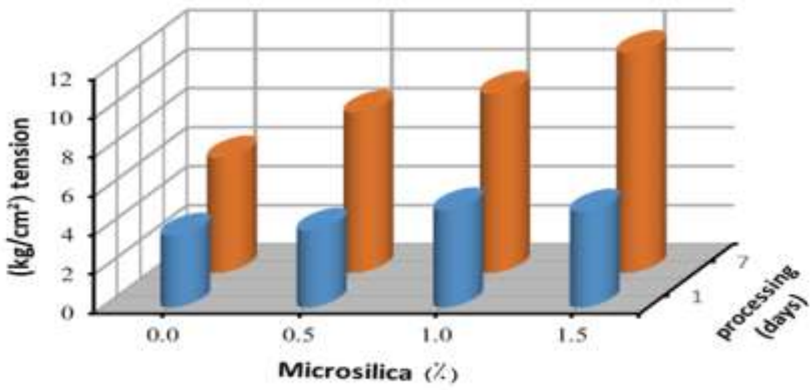

Figure (10) Comparison of uniaxial compressive strength of mixed sand samples with 4% cement ratio and different amounts of microsilica with different processing times

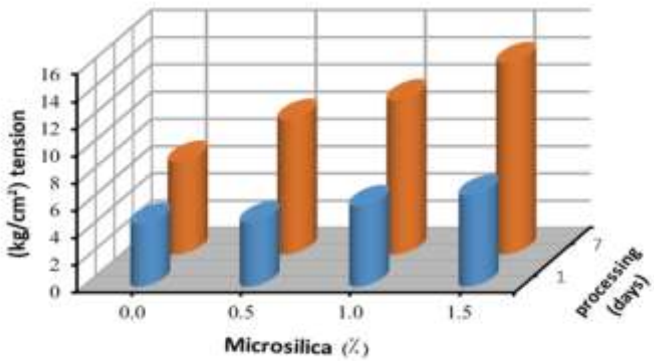

Figure (11) Comparison of uniaxial compressive strength of sand sample Mixture with a cement ratio of 6% and different amounts of microsilica with different loading times

1. **Conclusion**

With the increase of cement and microsilica up to a certain amount, the percentage of optimal moisture and the maximum dry specific weight of sand increases, but after this value, the maximum dry specific weight decreases.

With the increase of microsilica up to 20% of the weight of cement, the uniaxial compressive strength of the sand sample with different proportions of cement increases.

In sand samples mixed with cement, the addition of microsilica in an amount slightly more than about 20% of the weight of cement with 1-day processing will decrease the compressive strength, but with 7-day processing, it will lead to an increase in compressive strength.

By comparing the compressive strength of 1-day and 7-day samples, it can be seen that in sand samples containing only cement and without microsilica, most of the strength is obtained on the first day.

The studied sandy soil obtains the major compressive strength with a cement ratio of 4%. With the increase of processing time, the compressive strength in samples with this cement ratio (4%) has a higher rate of increase.

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