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# The Study Effect of Parameters of Shear Strength at the Sand with Geofoam by Using Laboratory Tests

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**Abstract**

In general, geosynthetics is a comprehensive title to describe thin and flexible plates that are inside the soil mass or in connection with soil materials with various purposes such as reinforcement, isolation, moisture insulation, erosion control, playing the role of filter, drainage, and are being used. Nowadays, the use of new materials to improve the bearing capacity of soil is widely used. geofoam is made in light and large parts for different applications, such as reducing the lateral pressure of the soil, etc., and it acts as an insulator against heat and heat in earthen structures or pavements. This material is often made of polyester material and has many advantages. geofoam blocks are a type of geosynthetics and have good performance and replace the embankment behind the retaining wall or road pavement layers. The main goal of the present research is to investigate the effect of geofoam particles on the improvement of the bearing capacity of sandy soils. The amount of geofoam particles is 0.05%, 0.10%, 0.15%, and 0.18% by weight of the studied materials. To evaluate the impact of geofoam particles on the geotechnical parameters of sandy soils. Mixed with geofoam, laboratory tests of density, direct shear (under the effect of vertical stresses of 1.5, 2.5, and 3.5 kg/cm2), and permeability have been performed. The results obtained from the research show that, in general, adding 20% by weight of geofoam to the studied materials, has improved the maximum dry weight, reduced permeability, and increased shear strength. Although, geofoam particles are more effective in angular sandy soil than granular sand.

Keywords: Sand; Geofoam Grains; Angle of Internal Friction; Cohesion; Direct Shear Test; Permeability

## Background

A plate product, made of polymer materials, which is used together with soil, stone, or any material related to geotechnical engineering as a basic component in man-made projects and structures. The word geosynthetic consists of two parts "geo" meaning earth and "synthetic" meaning synthetic. In better words, the term artificial earth refers to the use of these materials in construction projects related to earth, soil, and stone and their man-made nature. geosynthetics are materials that are made using different types of polymers along with the progress of the petrochemical industry, and their use as a new material in water and soil projects has been welcomed. geosynthetics are mainly the product of synthetic polymers that are derived from crude oil. These materials are made artificially from rubber and plastic materials and are produced with different shapes and properties depending on the type of application and expected performance.

Due to its wide application, speed of execution, and reasonable price, the production, and consumption of these materials are growing rapidly. In general, geosynthetics is a comprehensive title to describe thin and flexible plates that are inside the soil mass or in connection with soil materials with various purposes such as reinforcement, isolation, moisture insulation, erosion control, playing the role of filter, and drainage. Etc. are used. In many cases, these sheets may perform a combination of the aforementioned duties. The physical and mechanical properties of geosynthetics, such as strength, impermeability, erosion resistance, and most importantly, their extremely high tensile strength compared to weight, have led to a wide range of applications of these materials in construction projects. These materials are used in various fields, such as improving soil conditions, improving environmental issues, hydraulics, and hydraulic structures, and transportation. geosynthetics are widely used in industrial projects, dam construction, road construction, structures such as retaining walls, soil improvement, and other projects related to soil.

The historical history of geosynthetic materials manufacturing and use dates back to the 50s. In this decade, geosynthetics were used for the first time in America, and in the 70s, they became popular in Europe. In recent decades, the use of geosynthetics has become popular in Asian countries. At that time, woven geotextile monofilament sheets were used as filters in erosion control in the state of Florida, USA. Bob Ebert was the first person to propose the first plans for the use of geosynthetic materials in water and soil projects, and for this reason, he is known as the father of "geotextile". In the mid-1960s, the US Army Corps of Engineers investigated the possibility of using woven geotextiles as an alternative to filters in erosion control and slope protection systems. This organization proposed the first technical criteria for the design of geotextiles as a filter and presented a set of technical standards in this field in 1975.

The first conference on geotextiles was held in 1977 and the use of geotextiles as a filter, drainage, protection of beaches, and reinforcement of weak soils with low capacity was accepted by many experts and engineers. geofoams are the newest group of geosynthetics. geofoams are made in large and light pieces and act as insulation against heat in earthen structures or pavements. Foams are mainly used as fillers for empty spaces and joints. According to the capabilities that the manufacturers have given to the foams, these foams have a volume increase of up to 60 times in the open space and can act as water and gas insulation, as well as having high load-carrying properties. The application of geofoams is often used under foundations built on soft and loose soils, road sub surfaces, airport runway pavements, railway systems that are constantly exposed to expansion and contraction, and under liquid storage tanks. Cool drinks and steep surfaces are used.

## Introduction

Geofoam is a type of geosynthetic material that consists of foam. geofoam blocks, as one of the geosynthetic materials, have high applicability in geotechnical engineering due to their small volume weight compared to the soil volume weight, as well as high compressibility, quick and easy implementation, heat insulation, and resistance to water absorption [1]. They were used in retaining walls, and road construction projects as a light filler, reducing the stresses caused by vertical loads in the lower layers [2].

Extensive studies have been conducted in the field of using geofoam in the form of seeds or blocks to improve soil and geotechnical buildings. The first use of geofoam as a light embankment in Japan dates to 1985, and this country accounts for almost 50% of the world's consumption in this field. The use of geofoam light embankment materials as an option for bed soil modification has been considered since 1990 for the following reasons: First, the short construction time of light embankments compared to other methods of bed stabilization. Secondly, reducing the bed settlement and increasing its bearing capacity compared to the use of other materials for the construction of embankments [3].

One of the most important types of research in this field was conducted by Horvath in 1995. Based on the results of laboratory tests, he divided the stress-strain behavior of geofoam materials into four linear elastic parts, a plastic part with specific compressive yield strength, linear and hardening part, and a non-linear and hardening part [4]. According to the investigation of the behavior of geofoams with different densities, sizes, and shapes, Al-Raghi's research in 2000 shows that with the increase in the size of geofoam blocks, its modulus of elasticity increases, and the behavior of larger samples is more resistant than smaller samples [5]. Hazarika observed in his research that at the same density, with the increase in the size of the geofoam block, its compressive strength increases [6]. Saradehi Babu and his colleagues showed by conducting experiments on lightweight concrete that with the increase in the density of geofoam, the compressive strength of concrete containing geofoam grains increases [7].

Negusi showed that in unconfined pressure tests, the strength and modulus of geofoam blocks increase with the increase in geofoam density [8]. By conducting a series of direct and triaxial shear tests, Ilari evaluated the mechanical behavior of the soil geofoam mixture and its effect on reducing swelling potential and reducing the volume of swelling soils. These studies were done on sand and bentonite with different mixing ratios and geofoam particles were added to the soil with weight mixing percentages of 0.3, 0.6, and 0.9%. The results of direct shear tests showed that in mixtures with less bentonite, the maximum tolerable shear stress increases with the increase in the weight percentage of geofoam. But in clay soils, the opposite is true [9]. Aitkin et al. on an expansive soil without geofoam and the same soil with values tested different geofoam rolls and evaluated lateral and vertical swelling pressure [10].

Deng and Xiao investigated the stress-strain characteristics of the sand-geofoam mixture by conducting direct and triaxial static shear tests. They studied the effect of mixing ratio and confining pressure on the behavior of granular soil and geofoam mixture. The results of triaxial tests on three different mixing ratios (0.5%, 1.5%, and 2.5%) showed that increasing the percentage of geofoam mixing results in a decrease in shear strength and an increase in volumetric strains. The limiting pressure is also directly related to the strength of the mixture. They suggested a ratio of 0.1% as the optimal mixing percentage [11]. Najmuddin and Chanakchi investigated the effect of adding modified expanded polystyrene geofoams to the soil on compaction test indicators such as optimal moisture percentage and maximum dry density [12].

Thermal modification of geofoams is a new method presented by Kan and Demir Bogha to achieve foam with more durability, density, and resistance. The results of Kahn and Demirbogha's


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research showed that with the increase in the weight percentage of geofoam, the maximum dry weight in both compaction tests decreases linearly [13]. In the field of using geofoam in the improvement of soil materials in Iran, various studies can be mentioned. In the research conducted by Heydarian, Nejad Shirazi, and Nasahi, geofoam particles were added at the rate of 0.25, 0.4, and 0.5% by weight to sandy soils and 0.02 and 0.03% to clay soils.

The results of their studies showed that with an increase in the percentage of geofoam in sandy soil, the internal friction angle decreased, and the amount of apparent adhesion increased. Also, in clay soil, the uniaxial compressive strength shows an upward trend with the increase of geofoam [14]. In the research carried out by Nejad Shirazi, Heydarian, and Jam, the effect of geofoam particles on coarse-grained (remaining on Sieve 4) and fine-grained (passed through Sieve 4) materials were carried out. The results of their studies showed that with an increase in the percentage of geofoam in sandy soil, the internal friction angle decreased, and the amount of apparent adhesion increased.

Also, in clay soil, the uniaxial compressive strength shows an upward trend with the increase of geofoam [15]. Hasanpuri Notash and Debiri studied the effect of thickness, density, height, and several geofoam blocks on the amount of lateral pressure exerted on stone and retaining walls under static loading conditions. The results of their research have shown that the placement of geofoam blocks can significantly reduce the amount of lateral pressure of the soil mass affecting the wall [16-17].

## Materials Used in the Experiment

In the current research, the soil of the round corner and sharp corner sands studied was prepared in the city of Sanandaj in Kurdistan province located in Iran. The granulation curves of the materials are estimated according to the standard [18] ASTM D421 and [19] ASTM D422, which can be seen in figures (1-3). According to the graphs, the sandy soils under study were of the poorly grained SP type according to the unified classification method. The specific density of the studied sandy soils was measured according to the ASTM D854 standard [20] and it was estimated to be 2.63 and 2.64 for round corner and sharp corner sands, respectively.

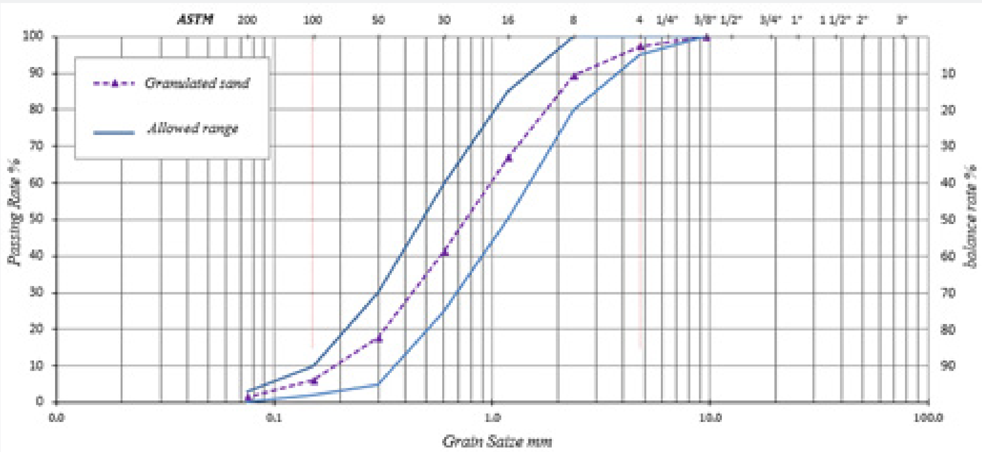


**Figure 1:** Granulation curve of Angular Aggregate studied in the experiment.

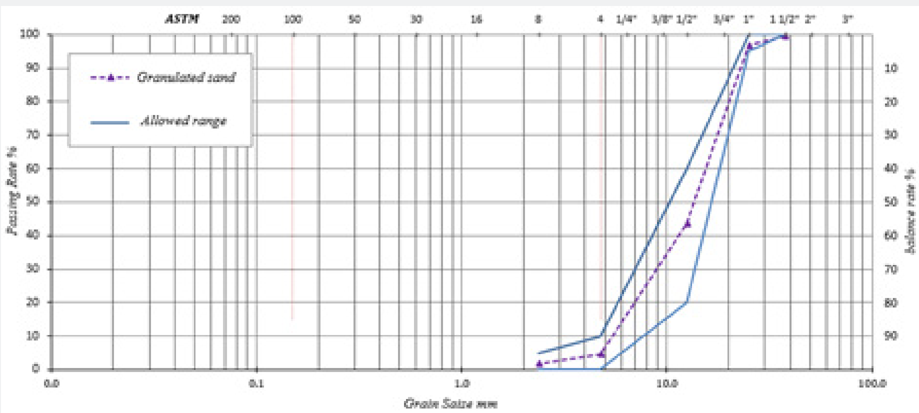


**Figure 2:** Granulation curve of Very Rounded Soil studied in the experiment.


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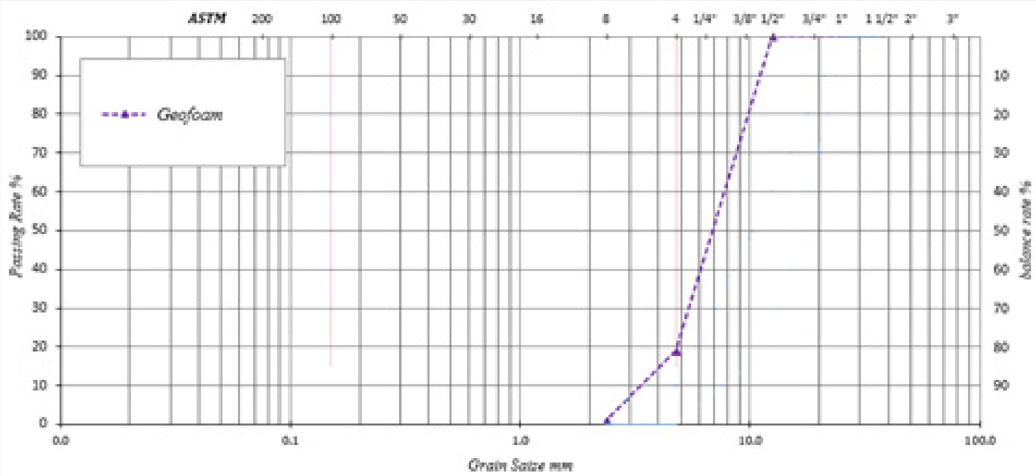


**Figure 3:** Granulation curve of Geofoam particles studied in the experiment.

## Laboratory Test

The purpose of this research is to investigate the effect of geofoam particles in improving the load-bearing capacity and technical characteristics of the round corner and sharp corner sandy soils for use in geotechnical buildings and the body of road pavement layers. In the present research, sand soil with round and sharp corner shapes has been mixed with geofoam particles in the amount of 0.05, 0.1, 0.15, and 0.18% by weight to investigate its influence on geotechnical parameters. First, the laboratory compression test was performed according to ASTM$^{D698}$ standard [21] on reinforced and unreinforced samples. ASTM$^{C305-14}$ standard [22] was used to prepare uniform and homogeneous mixture samples to evaluate geotechnical parameters. Based on this, first, geofoam particles and water (according to the optimum moisture content) were mixed inside the mixer.

Then wait for a little until some water is absorbed by the geofoam particles so that it can get better adhesion with the soil. Next, the soil particles of the studied mixture were slowly added to it in a dry state. According to the standard, the mixing operation is stopped for 30-40 seconds so that the materials absorb moisture. In the end, the operation of mixing soil materials and geofoam particles was done for 30-40 seconds with slow speed, 20 seconds of cleaning, and 55-60 seconds with medium speed.

Then, to determine the bearing capacity of pure and stabilized samples, a direct shear test based on ASTM$^{D3080}$ standard [23] in the dimensions of 15 x 15$^{cm}$ molds with low speed in vertical stresses of 52, 3.5, and 5$^{kg/cm2}$ in Optimum humidity was achieved. To investigate the effect of geofoam particles on the drainage rate of materials, a constant height permeability test was performed according to the ASTM$^{D2434-68}$ standard [24-30]. The laboratory program carried out on the studied samples can be seen according to table 1.

**Table 1:** Tests performed on test samples.

| Row | Symbol | Soil Shape | Geofoam Percentage | Density | Direct Shear Test | Permeability Test |
|---|---|---|---|---|---|---|
| 1 | T1-0 | Angular Aggregate[1] | 0 | * | * | * |
| 2 | T1-0.05 | Angular Aggregate | 0.05% | * | * | * |
| 3 | T1-0.10 | Angular Aggregate | 0.10% | * | * | * |
| 4 | T1-0.15 | Angular Aggregate | 0.15% | * | * | * |
| 5 | T1-0.18 | Angular Aggregate | 0.18% | * | * | * |
| 6 | T2-0 | Very Rounded[2] | 0 | * | * | * |
| 7 | T2-0.05 | Very Rounded | 0.05% | * | * | * |
| 8 | T2-0.10 | Very Rounded | 0.10% | * | * | * |
| 9 | T2-0.15 | Very Rounded | 0.15% | * | * | * |
| 10 | T2-0.18 | Very Rounded | 0.18% | * | * | * |

Sharp-Cornered Sand
Round-Cornered Sand


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The results obtained from the laboratory compaction test are presented in figure 4. Based on the graphs, it can be stated that by increasing the amount of geofoam to 0.18% in the sharp sand soil mass of the corner, the amount of dry weight has reached its maximum value and the optimal moisture content has reached its minimum value. Also, increasing the amount of geofoam to 0.18% has caused a maximum increase in the amount of dry specific gravity and reduced the amount of optimal moisture in corner sand. Therefore, it can be said that, in general, the effect of geofoam in the maximum dry weight and optimum humidity of sharp and rounded sands has a similar trend. The difference is that the sharp corner, compared to the rounded corner, provides the maximum dry weight [31-34].

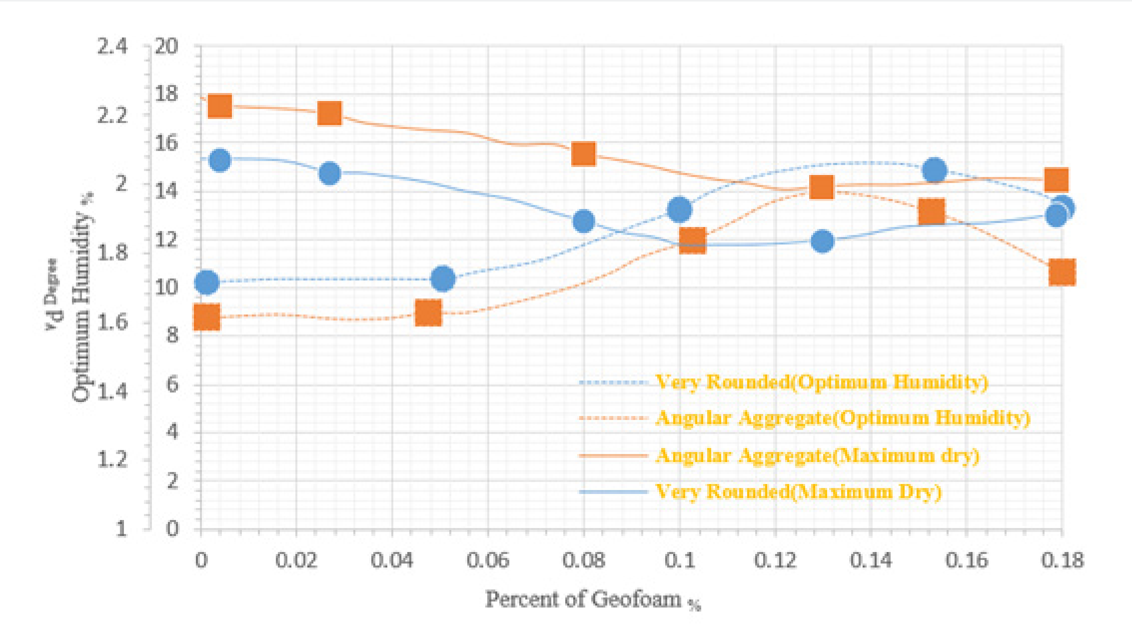


**Figure 4:** The effect of geofoam particles on the results of the compaction test.

## The Results of the Permeability Test

The results of the permeability test on sharp-cornered and round-cornered sand can be seen according to figure 5. According to the results of the experiment, it was found that with the increase in the percentage of geofoam particles, the amount of permeability decreased, and this trend is more severe in sandy soils.

## The Results of the Direct Shear Test

To study the effect of geofoam particles on the geotechnical parameters of adhesion and internal friction angle of sharp and rounded sands, a direct shear test was conducted. The results of this test can be seen according to the diagrams in figure 6. As can be seen in the figure, when 0.18% weight percent of geofoam is added to sandy soil, it causes an increase in the internal friction angle between the particles. Although this increase is 40.6% and 45.5% in the sharp corner and round corner sand soil respectively. Also, it can be seen in the figure, that geofoam particles do not have a good effect on the adhesion of sand materials. In the corner sand, increasing the number of geofoam particles has decreased the adhesion. While this process is different in the sharp sandy soil of the corner. So, adding 0.05% of geofoam to the sharp corner soil increases the adhesion, but with the increase in the presence of geofoam, the amount of adhesion decreases.

Changes in the effect of geofoam particles on the shear strength at the moment of rupture of stabilized rounded and figure sand samples are presented in the graphs in figure 7. The graphs in the figure show that when 0.05% by weight of geofoam particles is added to the sandy soil, the shear strength decreases at the moment of rupture. In the following, by increasing the amount of geofoam up to 0.18%, the carrying capacity of sandy soil goes through an increasing process. On the other hand, it can be seen in figure 7, that the effect of geofoam particles in the sharp corner sand is similar to the round corner sand. Although according to the shape of the particles, in general, it can be stated that the shear resistance in sharp-cornered sand is higher than that of round-cornered sand.


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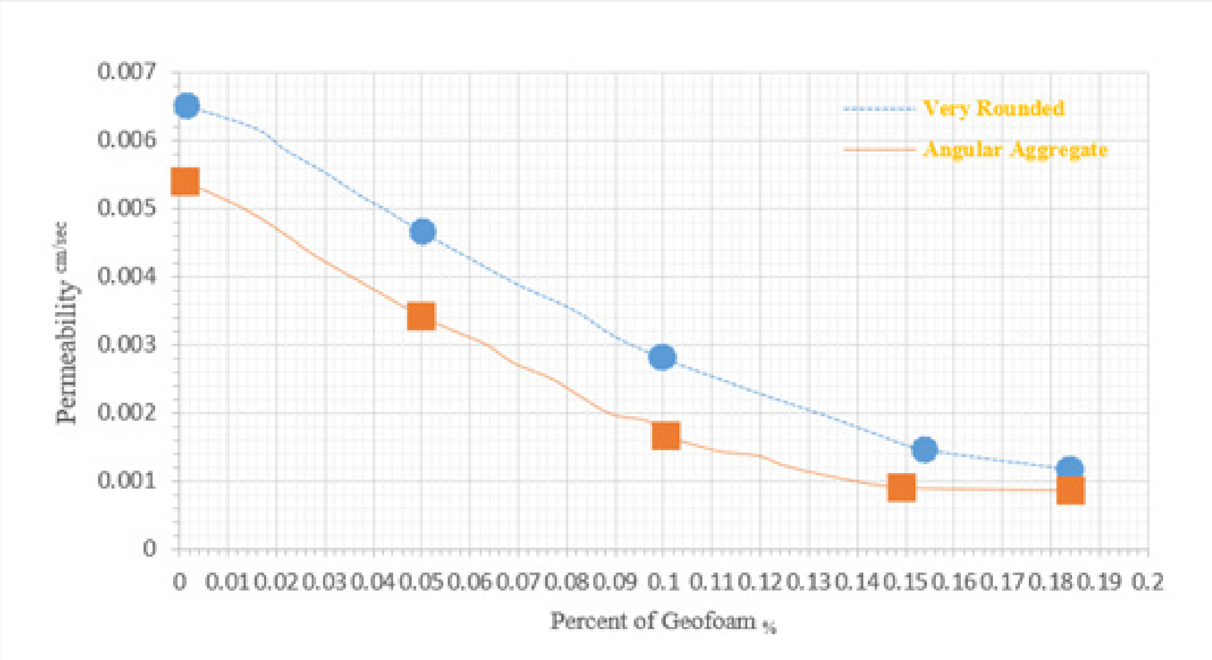


**Figure 5:** The effect of geofoam particles on the permeability of the studied materials.

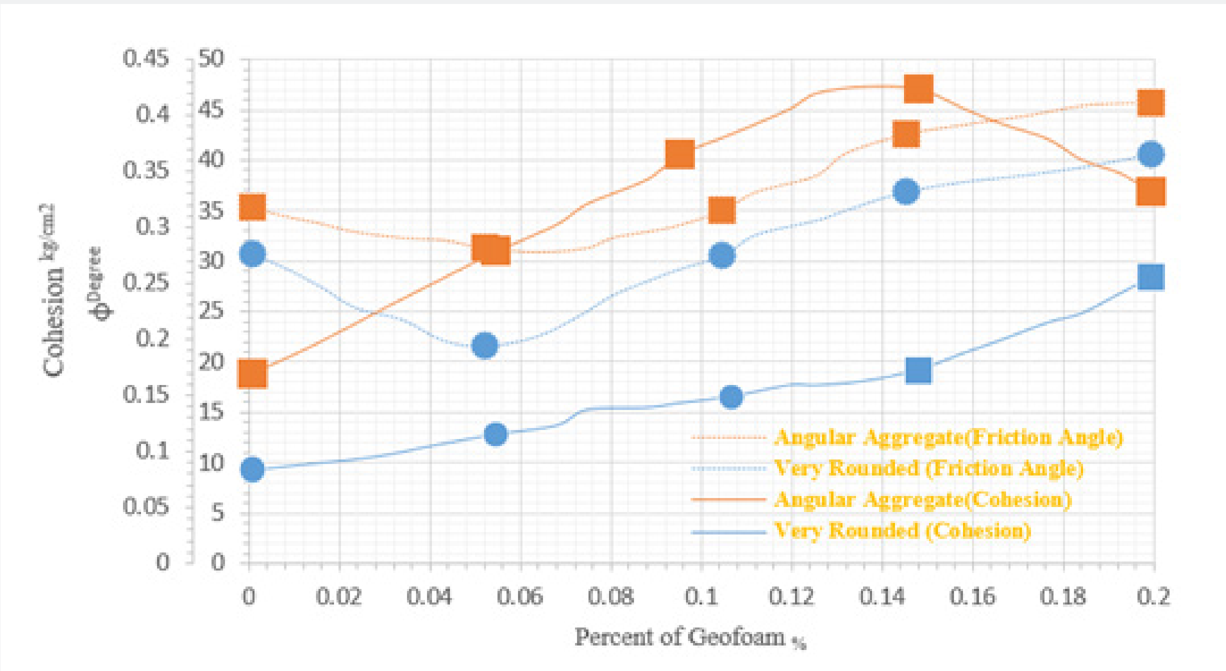


**Figure 6:** The effect of geofoam particles on the results of the direct shear test.

## Conclusion

Because the soil is a non-uniform and uncemented environment and has a compressible state due to the presence of space between the particles, it can have a lower load-bearing capacity under natural conditions. Nowadays, the use of new materials has been used a lot in improving and increasing soil load capacity, one of the most used materials in this field is geofoams from the geosynthetics family, which have a very important function in science and industry, including in embankments behind retaining


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walls or layers. There are road pavements. In general, geofoam is capable of solving geotechnical problems due to its lightweight, no volume change against water, low permeability, and relatively good resistance. In this research, the effect of geofoam particles at the rate of 0.05%, 0.10%, 0.15%, and 0.18% on the shear resistance, load-bearing capacity, and permeability of rounded and sharp-cornered sandy soils has been investigated.

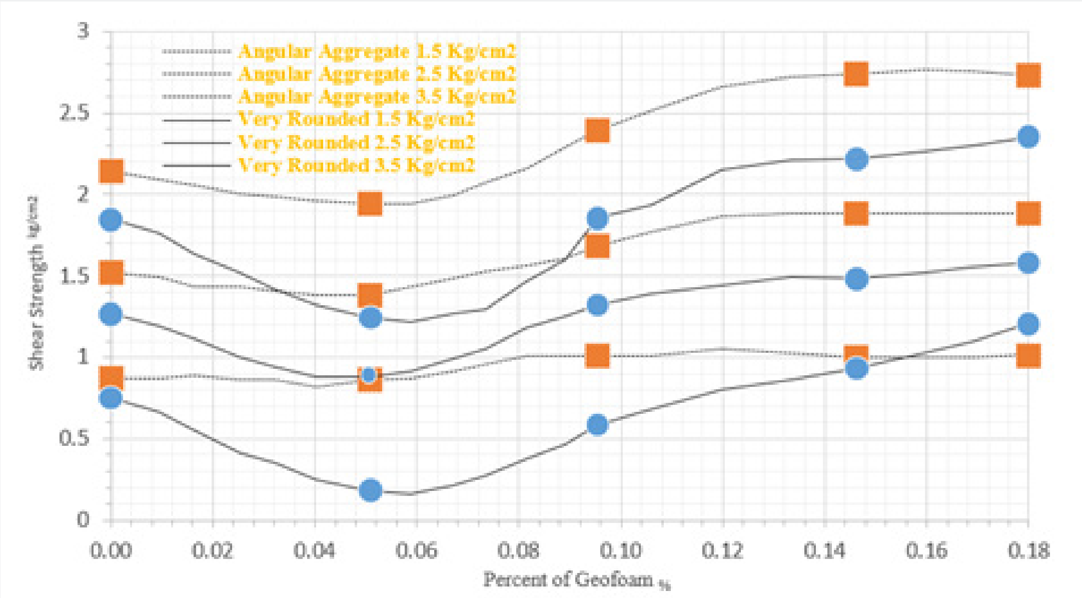


**Figure 7:** Of the effect of geofoam particles on shear strength at the moment of rupture.

According to the obtained results, it can be noted that when geofoam particles are added to the studied samples, the optimal percentage of geofoam particles in soil samples is equal to 0.15% by weight based on the results of this research. So that 0.15 percent of geofoam is added to the studied soil samples, due to the interaction that occurs between soil materials and geofoam particles, it causes a decrease in the minimum porosity ratio, an increase in the maximum dry weight, optimal humidity, and an increase The angle of internal friction between the particles decreases the permeability and thus the shear resistance. Of course, the effect of geofoam particles on sharp corner sand is much greater than on round corner sand. In the following, it is suggested to evaluate the effect of geofoam particles on the damping ratio and shear modulus in future research to accurately investigate the appropriate behavior.

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