COMPRESSIVE STRENGTH AND SWELLING PROPERTIES OF RANDOMLY DISTRIBUTED FIBER REINFORCED CLAYEY SOIL [+]

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Abstract:

This paper describes an experimental investigation on the compressive strength and swelling properties of clay reinforced with metal fiber.

Different percentages of fibers mixed with soil were used to prepare specimens to be tested. The result of this study showed that both peak strength and strain at failure increased with increasing fiber content while swelling pressure and swelling potential decreased with the increase of fiber content. The suitable fiber content was found to be 8%.

المستخلص:

تبحث هذه الدراسة في خواص المقاومة الانضغاطية والانتفاخ الحر لنمـــاذج مـــن التربـــة الطينيـــة المسلحة بالالياف المعدنية . لقد تم استخدام نسب مختلفة من الالياف لغرض مزجها مع التربـــة الطينيـــة وتحضير النماذج المطلوبة منها .

لقد اظهرت نتائج هذه الدراسة ان المقاومة الانضغاطية للنماذج الطينية المسلحة بالالياف المعدنية قد زادت بازدياد نسبة الالياف الممزوجة معها بالاضافة الى الزيادة الحاصلة في قيمة الانفعال عند الفـــشل . اما بالنسبة لضغط الانتفاخ فقد قل بشكل واضح عند زيادة نسبة الالياف الممزوجة مع الطين . وقد تبـــين من النتائج ان نسبة الالياف المناسبة عمليا للمزج مع هذا النوع من الترب الطينية هي ٨% .

Introduction:

The basic concept of Reinforced Earth is introducing reinforcements (such as metal strips or rods, geotextile strips or sheets) into the soil to carry the tension developed by the applied loads.

The use of fiber reinforcement nowadays has been suggested for various geotechnical applications. When mixing a predetermined amount of fiber with soil at particular moisture content, the soil matrix will gain sufficient tensile strength and cohesion.

One of the earliest workers on fiber reinforced soil studied the stress-deformation response of dry sand reinforced with geotextile fabric layers as opposed

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to randomly distributed synthetic and natural fibers[l]. They found that the increase in triaxial strength with fiber content varied linearly up to a fiber content of 2% by weight, and thereafter approached an asymptotic upper limit. The bearing capacity of circular footing constructed on fiber reinforced lateritic soil was also studied [2]. The results showed that the inclusion of 2% synthetic fiber to the soil would increase the bearing capacity by 38%.

The engineering behavior of cemented sandy soil reinforced with randomly distributed glass fiber was studied by some workers [3]. Their results indicated that fiber reinforcement might increase the compressive strength of cemented soil but definitely reduces soil stiffness. They also showed that the increase in compressive strength was found to be more pronounced for longer fiber length. The strength properties of clay and sand reinforced with randomly distributed fibrillated fibers were also investigated [4]. The test results of their study showed that the addition of fibers to clay and sand specimens significantly increased the compressive strength. They also indicated that by reinforcing the two selected soils with 25 mm long fibrillated fibers; the optimum fiber content was 0.3% of the dry unit weight of the soil specimen.

Nylon fibers were used to reinforce silty clay soil [5]. They studied the relative strength gain in terms of unconfined compression and concluded that the effect of addition of nylon fibers is significantly higher on the residual strength of soil compared to the effect of peak strength. The results obtained from their study also showed that the strain at peak strengths increases with the increase of the amount of fibers.

Recently, the fiber reinforcement was used in waste containment soil liners [6].They studied the role of fiber reinforcement in reducing crack development in compacted clay samples and their effect on the hydraulic conductivity. The maximum crack reduction observed in this study was approximately 90% for a fiber content of 0.8%. The result of this study also showed that the hydraulic conductivity of clay liners increased with increasing fiber content.

The main objectives of this preliminary study are to investigate the strength characteristics and swelling behavior of clayey soil reinforced with randomly distributed metal fibers.

Materials and Experimental Methods:

Materials Used:

The soil used in this study was brought from Al-Kindy district in Mosul City (a city to the north of Iraq). Geologically this region consists of a sequence of sedimentary rocks (Limestone and Gypsum) with Marl.Usually the upper part of this formation consists of consolidated clay layer of more than 4.0 m thickness [7],[8]. The samples of the clayey soil used in this study were taken from this layer.

The main index properties of the clayey soil used in this study are stated in the following table:

Table (1): Index Properties of the Soil Used

Max. Dry Density (γd)	**16.98kN/m^3**
Optimum Moisture Content (O.M.C)	18%
Liquid Limit (L.L.)	50%
Plasticity Index (P.I.)	28%
Shrinkage Limit (S.L.)	13%
Linear Shrinkage (L.S.)	16%
Specific Gravity (Gs)	2.72
Clay Content	39%

The clayey soil used in this study composed of Montmorollonite, Palygorskite, Illite and Kaolinite, while the non-clay minerals are Quartz, Calcite and Gypsum.

The index properties mentioned above indicated that the soil used in this study could be classified as (Inorganic Brown Silty Clay with High Plasticity «CH»).
The fiber used in this study was metal fiber of low Carbon Steel (0.2%) which has the following properties :

Table (2): Properties of the Fiber Used

Designation	**SAE 1015**
Tensile strength	560 MPa
Young s Modulus	200 GPa
Specific gravity	3.8
Resistance to corrosion	Weak
Dimensions (l,w,t) (mm)	(15.1,2.9,0.36)

Moulding and specimens preparation:

The specimens of the first series were tested using the unconfined compression machine. All the specimens were of 3.7 cm diameter and 7.4 cm high. They were prepared by mixing moist soil (w.c. =15%) with different percentages of fibers (0%, 1%, 2%, 3%, 4%, 6%, 8% and 10%). The soil-fiber mixture was compacted into three equal layers in the mould until it reached the desired dry density (γd=16.1 kN/m^3). Compacting effort was applied until each portion of the soil filled the mould to the required fraction of height. The surface of each compacted layer was scoured in order to provide a reasonable bond between layers.

The specimens used in the second series of the tests were of 6.35 cm diameter and 2.54 cm thick , these specimens were prepared by compacting the soil-fiber mixture directly into the odeometer ring by static compaction. All specimens used in this series were prepared at dry density of 16.1 kN/m^3 and moisture content of 15%; they were tested by free swell test using odeometer apparatus [9],[10] .

Testing Method

In order to quantify the increase in the strength of the soil due to addition of fibers, a series of unconfined compression tests were performed.All these tests were performed according to standard specification of (ASTM D2166-66).

The free swell tests, which represent the second series, were conducted on soil-fiber mixture in order to find the effect of fiber content on the swelling properties of the soil. These tests were performed according to the standard specification of (ASTM D2435- 65T) .

Discussion of the Results:

Several soil specimens with and without metal fibers were tested in unconfined compression machine to study the peak strength and failure strain of soil-fiber mixtures. Fig. (1) shows the effect of fiber content on the peak strength of clay reinforced with different percentages of metal fibers. It is clearly shown in this figure that the unconfined compressive strength of the soil increased with increasing the amount of fiber. Similar observations were found by [4],[5].

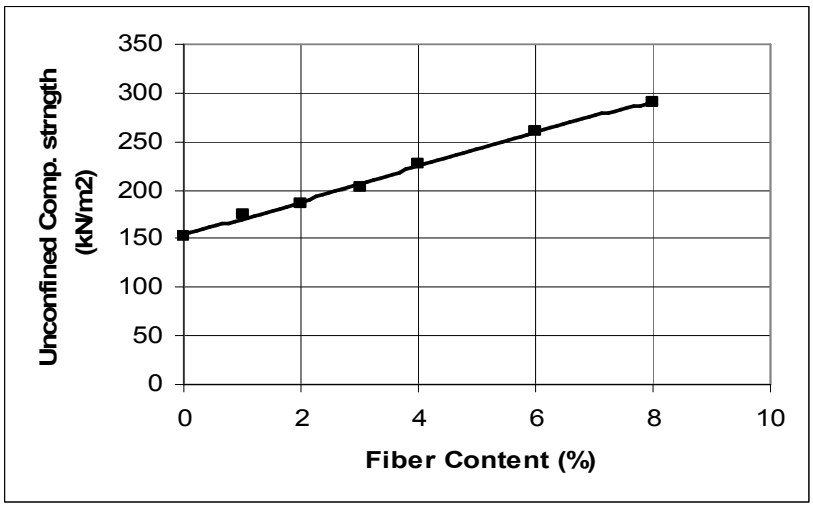

Fig. (l): Effect of fiber content on the unconfined compressive strength of clay

The variation of failure strain with fiber content was shown in Figure (2). We can conclude from this figure that the strain corresponding to peak strength increased with the increase of fiber content. This means that the soil-fiber mixture became more ductile. Similar finding was introduced by [4].

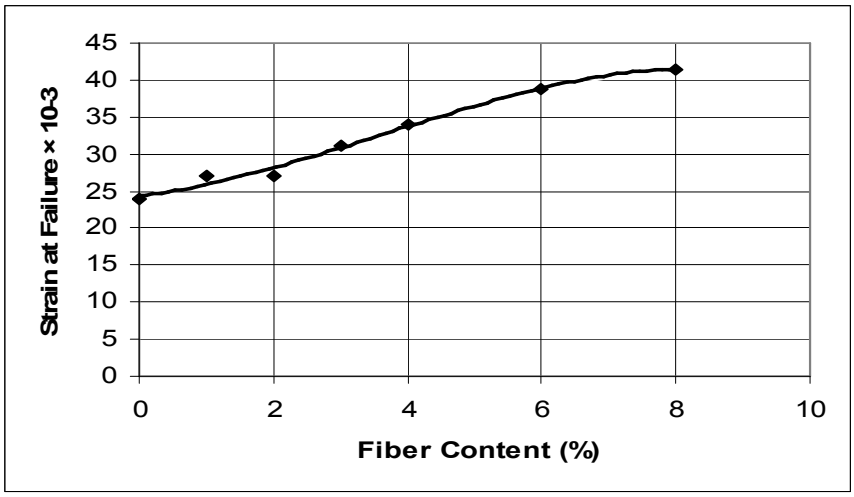

Fig. (2): Variation of failure strain with fiber conte

The increase of peak strength and failure strain of reinforced clay can refer to the increase of cohesion and friction angle values due to the inclusion of fibers.

Summary of peak strength values and failure strain is shown below:

Table (3): Summary of Peak Strength Values and Failure Strain

% Fiber	0	1	2	3	4	6	8
Peak Strength (qu) (kN/m^2)	153	175	187	202	227	261	290
Strain at Failure	0.024	0.027	0.027	0.031	0.034	0.039	0.041

The free swell tests, which represent the second series of the tests, were conducted on clay specimens reinforced with different percentages of metal fibers. Figure (3) shows the effect of fiber content on the swelling pressure of the clay. We can clearly notice in this figure that as the fiber content increases, the swelling pressure of the mixture decreases until it reaches about 20% of its original value at fiber content of 10%. This means that adding 10% of metal fibers to this type of expansive clayey soil can eliminate about 80% of its original swelling pressure. Referring to figure (3), it also shows that at 8% fiber content; the swelling pressure was only 25% of its original value. Thus, from the economical point of view, we can say that the suitable fiber content to be used practically with this type of soil is 8%.

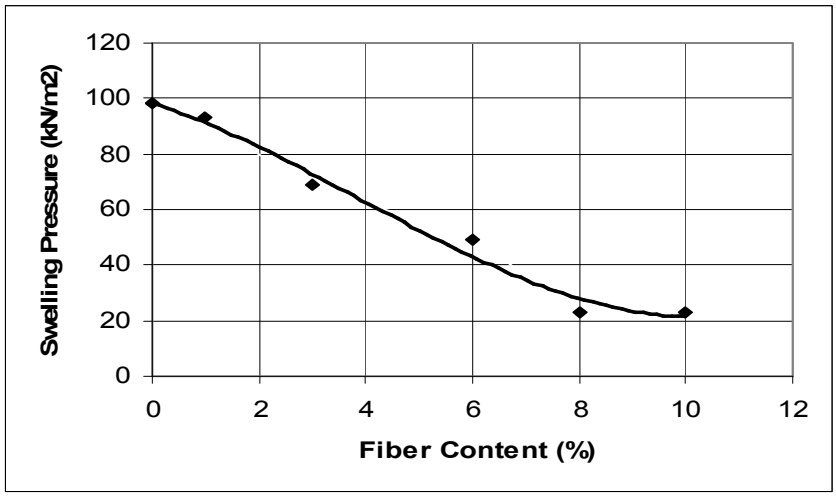

Fig. (3): Effect of fiber content on the swelling pressure of reinforced clay

The effect of fiber content on the swelling potential of the clay is clearly shown in figure (4). It can be noticed in this figure that the swelling potential of the clay has also decreased with increasing the fiber content.

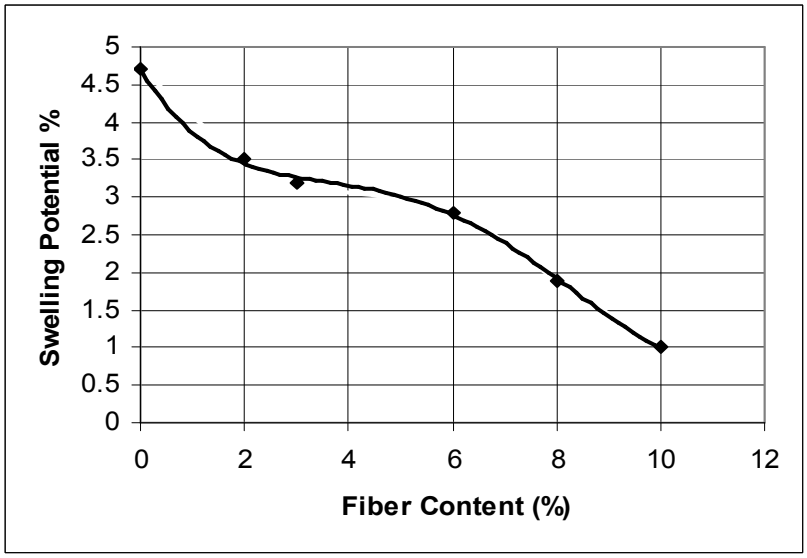

Fig.(4): Effect of fiber content on the swelling potential of reinforced clay

Conclusions:

The following conclusions can be stated from the results of this study :

1- The unconfined compressive strength of the clay -fiber mixture has increased with increasing the fiber content.

2- The specimens of clay -fiber mixtures were more ductile than pure clay specimens .

3- Adding 10% by weight metal fibers to expansive clayey soil eliminates about 80 % of its original swelling pressure .

4- The practical fiber content for the clayey soil used in this study is 8% .

Recommendations for future works:

In order to complete the results of this study , the next work must contain :

1- The effect of corrosion of the metal fibers after different periods of time on the strengh of soil- fiber mixtures .
2- Theeffect of coating the metal fibers with cutback asphalt (for corrosion resistance)on the strength of soil- fiber mixtures .

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