Kufa Journal of Engineering
Vol. 12, No. 1, January 2020, P.P. 29-47
Received 26 June 2020, accepted 2 August 2020

BEHAVIOR OF SALINE SOIL STABILIZED WITH POLYPROPYLENE FIBER AND CEMENT

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HTTP://DX.DOI.ORG/10.30572/2018/KJE/120103

ABSTRACT

This research deals with a problematic saline soil, which is widespread in many cities of the world, and try to obtain a solution for the reduction in its strength due to soaking by using more than one additives.

In order to improve saline soil and to explain its effect, more than one additive were used in the research; polypropylene fiber is the major additive, which was used with cement in different percentages. Soil strength parameters were assessed by conducting direct shear test for both the natural and treated soil, which were tested under soaked condition after, submerged in water for 24 hour. The result of direct shear test showed that, for natural soil, there are large lose in the strength of soaked soil compared to that of dry soil due to the solubility of salt in soil. This decay in soil strength about (48.6%) for cohesion and (67.8%) from angel of internal friction. Meanwhile, with adding PPF to soil and under soaked state, the soil strength parameters grew significantly with the increase in the rate of fiber, where both the soil cohesion and angel of internal friction increase. Soils, treated with (1.5%) polypropylene fibers as well as cement, their strength parameters improved significantly as cement amount increases, where the soil cohesion and angel of internal friction increase.

From experimental model which is built up to study and examine the laboratory result under complete submerged state, has a result for natural and treated soil showed improvement in bearing capacity of treated soil about 10 times compared to natural soil bearing capacity when tested under soaked condition.

KEYWORDS: Saline soil, collapsibility problem, Polypropylene fiber; direct shear under soaked condition; Physical Model Tests.

1. INTRODUCTION

In most counties of the world, collapsible soils commonly spread (for example US of America, Brazil, South Africa, China, Iraq, Kuwait and Egypt,) mainly in the regions that classified as arid or semi-arid. These nature of soils pretense impending danger to constructions erect on it as soon as became waterlogged (Tadepalli et al. 1992).

When soil are, dry and at its natural state, they have stiff and take high superficial shear strength; while, they might exhibition a volume significant decrease (collapsing, hydro consolidation, hydro compression) and reduction in shear strength when they are saturating. Such soils, that indicate this phenomenon at low stresses levels, are termed collapsible soils (Rollins and Rogers, 1994).

The water sources may be natural, for example variation in water table and rainfall, or manufactured, for instance water and sewer lines leakages and excessive-irrigation. Collapse might be attack by only water or by saturating and loads performing together. Collapsible soils reality has long been identified since World War II. However , the modern infrastructure growths in arid regions, attended by the consumption of huge water amounts and the problems of related construction permit a wide-ranging investigation of these soils. The soils collapse caused by moistening might result in displacement of (2.0% to 6.0%) from its thickness (Beckwith and Hansen, 1989). The subsidence can be huge as verified by settlements of irrigation canal (4.5 m) in California in the San Joaquin Valley/ the West Central Part of it (Bull, 1964).

Saline soils consist of soil particles enclosed by molecules of chlorides, sulfates or other speciess alts, which operates as a link agent to fill in the gaps in the dry condition. The saline soil disposal subject to the nature of salts confined in. chlorides salts, for example, is more dominant and faster soluble in water (Skalny et al., 2002).

Voids between the particles of soil would be creäted, and that cause variation in the molecular composition of soil skeleton. Which produce re-arrangement in soil particles and decreasing the soil bearing capacity for buildings created in it, which lead to increases the rate of the drop in soil shear strength and sudden and unexpected subsidence would occurs, and thus the structural problems existence for buildings and facilities constructed on. For normal buildings, it is advises to prevent such problems by use raft foundation but it is costly. However, for special and heavy structures like dams and bridges nuclear buildings, the essential appears, for treatment such collapsible soil seriously (Abduljauwad and Al-Amoudi, 1995).

Saline soils is composed from hydrated gypsum minerals $CaSO_4.2H_2O$, SiO_2, calcite $CaCO_3$ or (NaCl) food salt that covers surface of land. Due to the capillary action and heating of the ground the water table level upraised, and for these soils the water salinity increased, these factors lead to increase of the amount of sedimentation of these natures of salts as water evaporated so the water table performs an essential way to the presence of saline soil (Abduljauwad and Al-Amoudi, 1995).

2. LITERATURE REVIEW

In recent years, many reports in improvement the soil engineering characteristics that reinforcement with discrete polypropylene fibers (PPF) have been achieved for usage in geotechnical uses for civil engineering (Al-Refeaii, 1991, Yetimoglu et al., 2005; Tang et al., 2010 and Hejazi et al., 2012).

Maher and Gray, (1990) and Kumar and Singh, (2008) used PPF in soil mass to withstand tensile failure, shrinkage, cracking, acid and alkali attack, biological decay. It was stated that mixing of polypropylene fiber (PPF) into soil will be improve its engineering properties significantly (e.g. compressive - tensile - shear strengths, durability, fracture toughness) (Yetimoglu and Salbass, 2003, Yi et al., 2006 and Consolii et al., 2009). Moreover, soil reinforced with (PPF) exposes greater toughness and ductility, increases bending strength and formability and lower loss of the post peak strength, when evaluated to untreated soil (Gray and Ohashi, 1983 Attom and Tamimi, 2010). Singh et al. (2013) found that the value of CBR of the soil increased when fiber content increase. The increase in length and diameter of fiber also increased the CBR value. Abhinav Nangia, et al., (2015) found that addition of randomly distributed (PPF) improve the soil properties.

Mousa et al., (2010) compared the shear strength parameters of sandy soil mixed with two different types of polypropylene fibers. Test result exhibited that shear strength increased when fiber content increase in and with increase in aspect ratio.

These studies indicated that additions fiber increase the ultimate strength, CBR, stiffness, shear modulus, resistance to liquefaction and damping of reinforced soil (Hejazy et al., 2012).

Attom, (1997) carry out the experiment on a sandy soil to improve its properties and problems associated with weak soil by adding fiber of polypropylene. They obtain increase in angle of internal friction also in different percentage and this percentage increase with increasing of normal stress and the ductility of sand soil increase by adding fiber. The increase in aspect ratio resulted increasing in both of shear strength and angle of internal frictional.

Lee et.al., (1973) to maintain strength isotropy, randomly oriented fibers was used, the reduction of potential weak planes was the main aim of their study, and that may develop parallel to oriented reinforcement.

Esna-ashari and Asadi, (2008) to reinforce the sandy soil, cord waste fiber was used in his study. They establish that the brittle behavior of sandy soil can change significantly to more ductile with the addition of tire cord fiber as well increased both the peak strength and the internal friction angle of sand.

Rafalko et. al (2007) the polypropylene fibers used as primary stabilizer the strength a of the soil increased with increasing the dosage rate of fibers, When longer fibers used for stabilization, they have increase in the strength more than shorter fibers since the soil was ductile and bulged at high strain before failure. Although may have increases in strength resulted when addition fibers as a primary stabilizer to soft clay.

Dhiren, (2015) studied the alteration in CBR Value of Sand when mixed with Polypropylene Fiber by adding rate between 0% and 2.50% at 0.50% interval of fibers, They obtain growths by 113% for the CBR value of reinforced sand in compare with that for unreinforced sand. The 2.5% (w/w) was established as optimum fiber content. After 2.5% the adding of fiber becomes unreasonable.

Dixit, (2016) studied optimum use of polypropylene fibers to improves soil properties. They state there increased in value of cohesion and decrease in value of the angle of internal friction that conducted by using direct shear tests. With the presence of the fibers increase in value of CBR and unconfined compressive strength was observed, as result the optimum mix for design purposes can be considered as 2.25% of polypropylene fibers in the soil.

Ravi S balagoudra, Vamshi Krishna (2017) studied Soil Stabilization by adding Lime and Polypropylene Fiber Material, were many tests accompanied on Black cotton soil mixing with increments of 0.25% polypropylene fiber (PPF) up to 1% besides constant 4% lime (by weight of soil), Finally at 0.75% of PPF and by keeping 4% lime, the maximum strength was achieved.

Muske Srujan Teja, (2007) studied soil stabilization using Polypropylene fiber materials and found The parameters of shear strength for soil were achieved by direct shear test, increase in the cohesion value for fiber reinforcement of 0.05%, 0.15% and 0.25% as 34.70%, 6.090% and 7.070% respectively and the internal friction angle was increase to be 0.80%, 0.31% and 0.47% respectively.

Heba Dawood Salim, (2013) has been studied Influence of Polypropylene fibers on the stabilized soil, The results of studies, show there was an advance in the shear strength only when the rate 1% and 2%from soil weight was adding; also the effect of the consistency limit that with increasing the rate of the addition there was increasing the water content. And the dry density was increased at the adding of 1% and 2% and reducing this value at the adding of 3% with increasing of water optimization at the compaction test.

Saleem Mahmood Imariq, (2015) studied effect of adding Polypropylene fiber on the behavior of saline soil under washing and soaking. They noticed that the settlement has decreased to 62% and 52% respectively for both 1% and 3% of polypropylene percentage. These induced to a good improvement reduced the collapsibility to 62%.

3. EXPERIMENTAL TESTS AND USED MATERIALS

- Find the optimum polypropylene fiber (PPF) content by preparation and testing the soil samples with a different PPF ratio (three ratio 1%, 1.5% and 2% of PPF of the dry weight of soil) and the other soil properties have not been changed. The comparison make according to soil strength parameter under soaking condition.
- Preparation and testing the soil samples with different cement content (3%, 4%, and 6% of the dry weight of soil) combined with soil and PPF in optimum content from step 1.

3.1. The used soil.

In this work, the soil was collected from Karbala International Airport 44 km south of Karbala and accurately have this location (x=424974.7099, y=35804 72.1400).

According to the grain size distribution as in Fig. 1 and Table 1, the soil classified as poorly graded sand (SP) respect to the Unified Soil Classification System (USCS) given by (ASTM D 2487 - 9800).

Table 1. Sieve analysis properties of used soil.

Property	D10	D30	D60	Cu	Cz
Value	0.12	0.25	0.6	5	0.868056

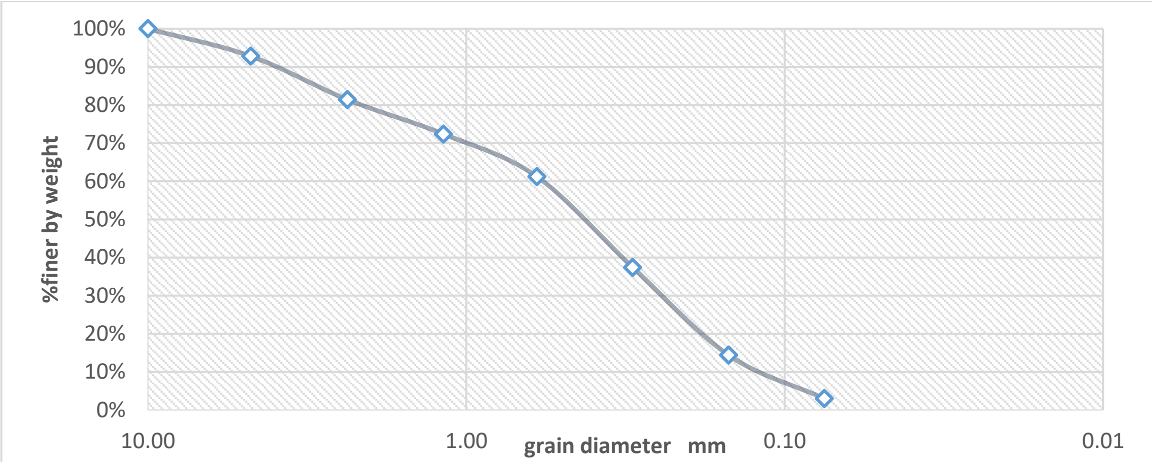

Fig. 1. Grain size distribution for used soil.

3.2. Additives

3.2.1. Polypropylene fiber

The polypropylene fibers are public material used for soils fiber reinforcement, these fibers found in the marketplace as short, discrete materials with altered aspect ratio, and it mixed randomly with soil. It is produced in two systems: Monofilament and Fibrillated. Monofilament fibers are separate, cylindrical fibers. Fibrillated fibers are flat, tape like fibers that can be described as latticework of "stems and webs" as the fibers break apart for the period of mixing and compaction. Table 2 shows polypropylene fiber properties.

Table. 2 Properties of polypropylene fiber

Property	Value
Specific Gravity	0.91g / cm³
Length	12mm
Diameter	32 Micron
Shape	Straight
Chemical Base	100% Polypropylene Fibre
Water Absorption	No Absorption
Melt Point	160°C
Ignition Point	365°C
Thermal Conductivity	Low
Electrical Conductivity	Low
Specific Surface Area Of Fibre	250m² / Kg
Tensile Strength	625-725 MPa
Module Elasticity	3500- 4000 N / mm²
Acid Resistance	High
Alkali Resistance	100%

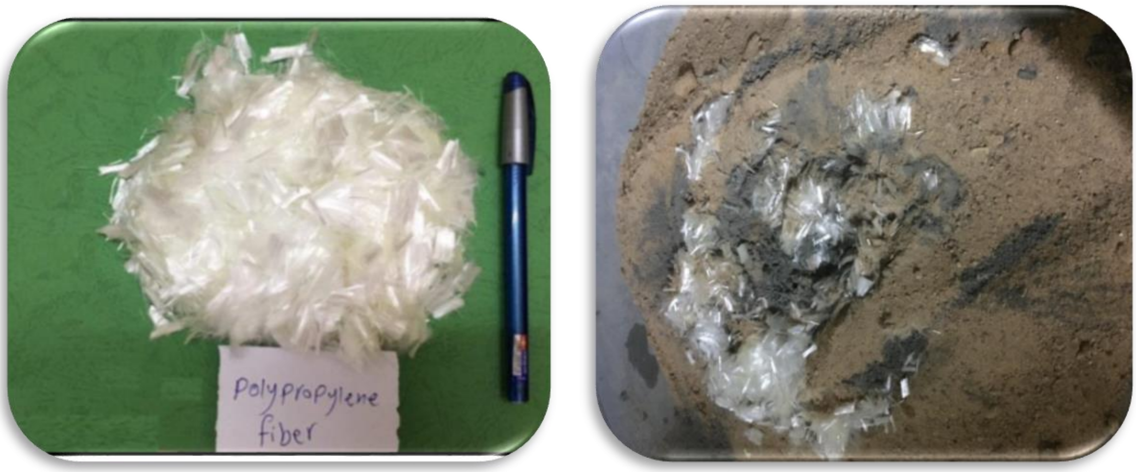

Fig. 2. Polypropylene fiber and cement mixed with soil at its natural water content.

3.2.2. Cement

The cement used in percent work is Portland cement type V (High Sulfate resistance Cement) have the properties shown in Table 3.

Table 3. Cement used in percent work.

Property	Value
Compressive Strength after 3days (MPa)	30 MPa
Compressive Strength after 7days (MPa)	35 MPa
Time of the initial setting (hour)	3:05
Time of the final setting (hour)	4:40
SiO_2 (%)	19.350
CaO (%)	65.689
Al_2O_3 (%)	3.309
Fe_2O_3 (%)	4.238
MgO (%)	1.519
SO_3 (%) `	2.119
C3A (%)	1.605
LOI (%)	1.055
Salts insoluble (%)	0.57
Losses in heating (%)	6.3238
Fineness of cement (m^2/kg)	419

3.3. Direct Shear Test

The direct shear test was performed on the reference sample and treated samples to obtain shear strength parameters under consolidated drained conditions according to (ASTM D 3080 – 03).the sample was soaked in water 24 hours for both reference and treated soil before testing the sample (Fig. 3).

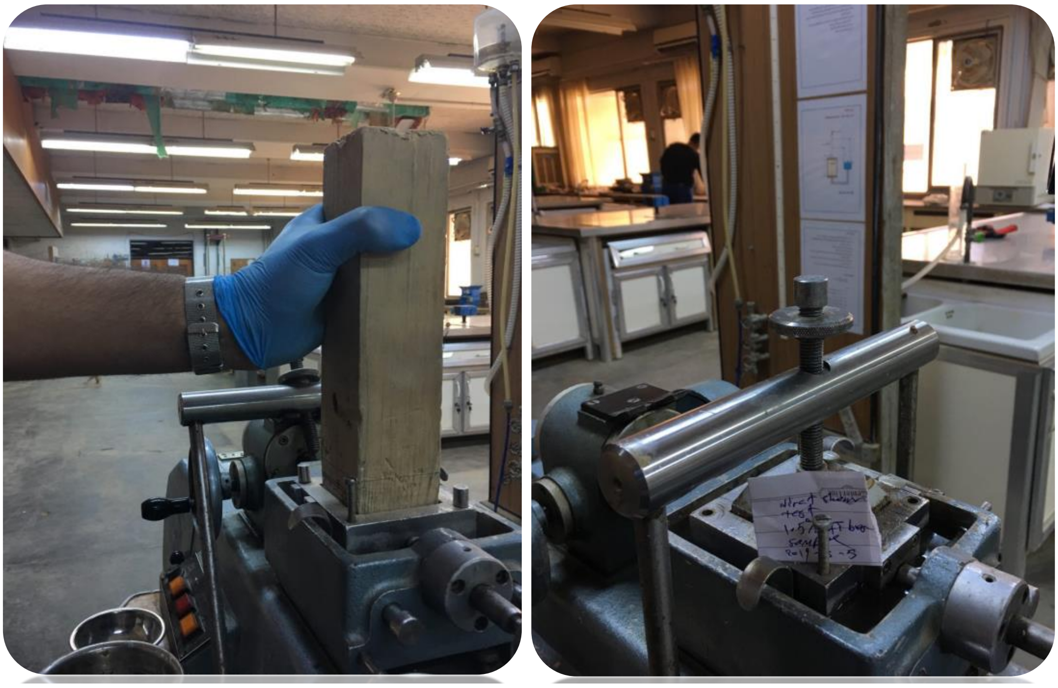

Fig. 3. Preparing soil specimens for direct shear test (tamping technique).

3.4. Physical Model Test

In order to evaluate the effect of different loading state on the untreated and treaded soil by additives, a physical model manufactured with its accessories was used as shown in Fig. 4. The model consists of steel box have adequate stiffness to support the soil weight and applied load stresses, loading frame, digital weight indicator and dial gages for measuring the vertical displacement.

3.4.1 Box container

The soil container, steel box manufactured as square section with 1000 mm in length and with 800mm in depth, three sides and box base made from plate gage (3 mm) and braced with steel Chanel frame. While the other side made from a plastic glass of (6 mm) thickness, the aim of employing glass is to get better surveillance of soil homogeneity as well reference marks developed to assist with the establishment of the required soil model.

Boundary Effects of the Sand Tank

Both stress and displacement forms in the sand can be influenced by the soil container and its side boundaries; in addition, due to the friction between soil grains and the walls of container, with depth there are reduced in the vertical stress in the sand (Kraft , 1991). To avoid side friction effect of walls; the container height and its diameter ratio must be equal to or less than one (Tarnet , 1999; Garnier , 2001 and 2002).

Parkin and Lunne (1982) operated cone penetration tests using calibration chamber. In loose sand by means of relative density (RD. less than 30 %), they proposed that boundary effects can be neglected. In addition, they exposed that as the sand relative density increases, the effect of the chamber walls come to be more noticeable. To avoid evaluating boundary effects, the results have presented that for loose sands with relative density less than (30 %), the ratio of the chamber to cone diameters must be more than (20) and (50) for dense sands have relative density equals to (90 %).

3.4.2 Loading frame

Steel lever have roller support at left end and loaded at other end, this steel member have length 2 m and the support lay in 0.14 m from point of connected road transport the load to footing.

3.4.3 Model footing

Small-scale circular footing of 0.12 m diameter used to simulate foundation on natural and treated soil system, the footing made from bronze-steel alloy.

3.4.4 Preparing soil for model

Six layers of 10cm thickness was placed by way of tamping in model box, each layer attended by an adequate dry soil weight according to relative density (RD) value for (1 m*1 m*0.1 m) layer volume.

The treated soil prepared by the same procedure above while the additive used as weight percentage for top central layers and mixed with adequate moisture content (treated soil depth about twice footing width). In each layer treated by adding cement and PPF, the soil and additive are mixing at dry state. Then add an adequate quantity of water with required mixing and transport additive soil mixture to model in planning dimensions with tamping.

In order to place the additive soil mixture in required relative density, the tamping method are used. Which are one of many methods such as compaction and the raining method using to place sandy soil in a physical test model.

The small-scale footing was fixed with final layer in center of model. The model was soaked after 28-days period of curing treated soil sample for seven days.

3.4.5 Testing procedure

The following steps carried out to study the behavior of reference and treated soil with additives by means of the bearing capacity and collapsibility of soil under static loading:

1. Sand was prepared by using tamping technique, to specify weight of soil in layer volume to catch the required relative density, the box was filled until the sand layer level reach (600) mm.
2. After placing the end layer of soil, the square footing model was placed in the center of the soil steel box.
3. The soil is soaked 28 days in water after 7-days curing period for treated soil with PPF and cement.
4. The loading rod installed at the upper surface of the footing verticality and fixed in upper end with sensor of digital weight indicator.
5. Applying the first load increment after installing dial gage with record its reading and other accessories, the period of load increment covers all elastic displacements to be accrued.
6. The applied load increments continuous until failure occur. Figs. 7 and 8 show the failure for reference and treated soil with PPF and cement respectively.

Fig. 4. Saturated soil Prepared for model test with applied the first load increment.

Fig. 5. Preparing treated soil with PPF and cement.

Fig. 6. Natural soil failure shape tested in model.

Fig. 7. Failure shape of the natural soil loaded in soaked state.

Fig. 8. Failure shape of the treated soil loaded in soaked state.

4. RESULTS AND DISSUASION

4.1. Group results

4.1.1. First group result

This group includes the natural soil direct shear test result, the dry sand of relative density (90%) and the same sample properties tested under soaked condition. The dry test result showed the soil cohesion is (37 Kpa) and the angle of internal friction about (43.5°), both the cohesion and the angle of internal friction decrease when the soil tested under soaking condition to (19Kpa) and (14°) respectively. This reduction in the soil strength parameter due to salts solubility in the soil by water. This effect clearly shown in the Fig. 9 which exposed relationship between normal stresses versus shear stress.

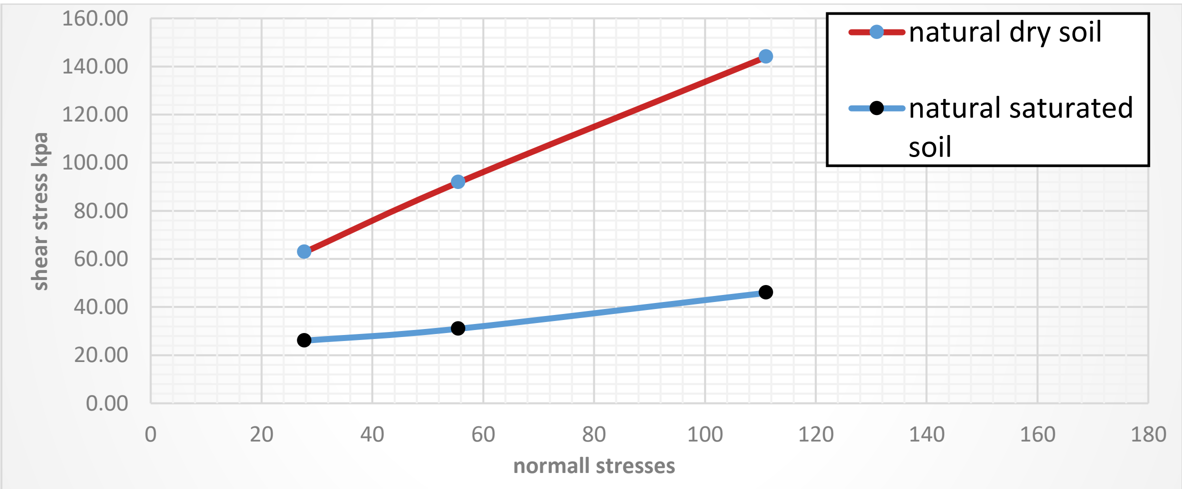

Fig. 9. Relationship between shear stress and normal stress for natural soil, from direct shear test for dry and soaked samples.

4.1.2. Second group result

This group include the result of treated soil with polypropylene fiber (PPF) in three percent of it. Where the test conducted under soaked condition, the (1.0%) PPF test result showed the soil strength parameter has increased noticeably. Where the improved soil have cohesion of (31 Kpa) and the angle of internal friction (21.8°).

The soil sample treated with (1.5%) PPF have strength parameter close to the sample treated with (1.0%) PPF Where the cohesion of (32Kpa) and the angle of internal friction (26.2°).

The third sample treated with (2%) PPF, result of tested under soaked condition show the soil strength parameter has increased significantly Where the cohesion of (40 Kpa) and the angle of internal friction (35°). This increment in soil strength due effect of reinforcement with polypropylene fiber. This effect clearly shown in the Fig. 10 below which exposed relationship between normal stresses versus shear stress for three percent of PPF.

These result are fully consistent with (Yetimoglu and Salbas, 2003; Yi et al., 2006; Consoli et al., 2009) who observed that an admix of polypropylene fiber into soil have significantly improved its engineering properties (e.g. tensile / compressive / shear strengths, fracture toughness, durability).

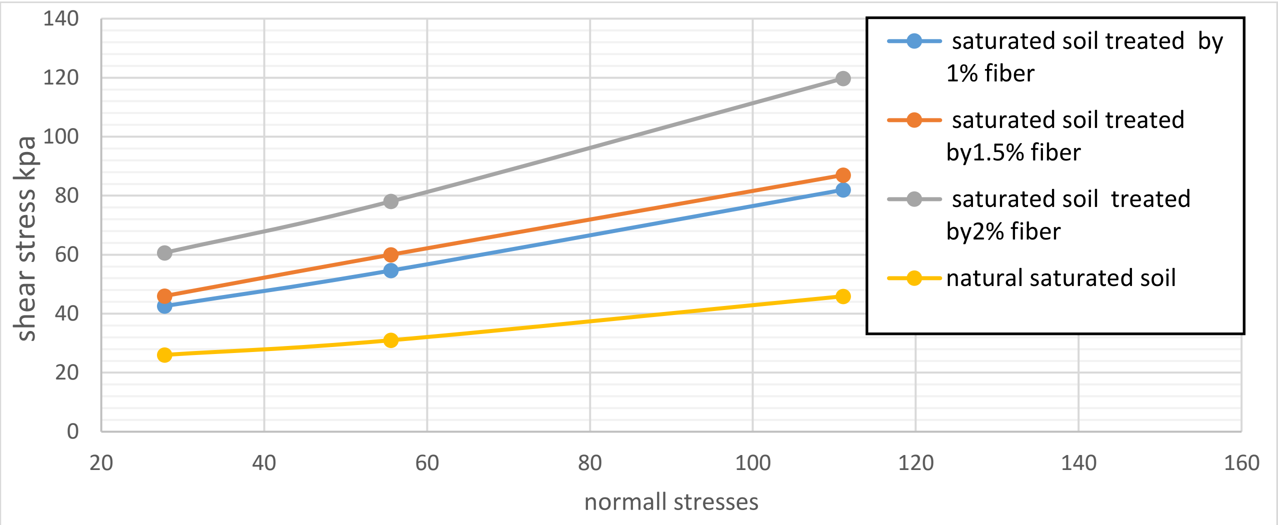

Fig. 10. Relationship between normal stresses and shear stress for treated soil with PPF, from direct shear test in soaked condition.

Study of (Muske Srujan Teja 2007) for soil stabilization using Polypropylene fiber materials was also showed fully consistent with these result and founded The shear strength parameters of soil were determined by direct shear test have significantly improved.

4.1.3. Third group result

The treated soil with polypropylene fiber (PPF) and cement was conducted in this group, these tests were performed in soaked condition as described in test method. Three samples tested which were mixed with (1.5%) PPF and with (3%, 4% and 6%) of cement.

The first soil sample which contain (3%) of cement have significantly improved in the soil strength parameters, the improved result is very close with dry soil strength parameter where the cohesion of (42Kpa) and the angle of internal friction (48.6°).

Treated soil with (4% & 6%) have a strength parameter exceeded that for dry soil where the cohesion was (50, 60Kpa) and the angle of internal friction was (50.1°, 51.8°) respectively. These results show in the Fig. 11 below which explain the relationship between normal stresses versus shear stress for the soil samples with three different percent of cement and (1.5%)PPF.

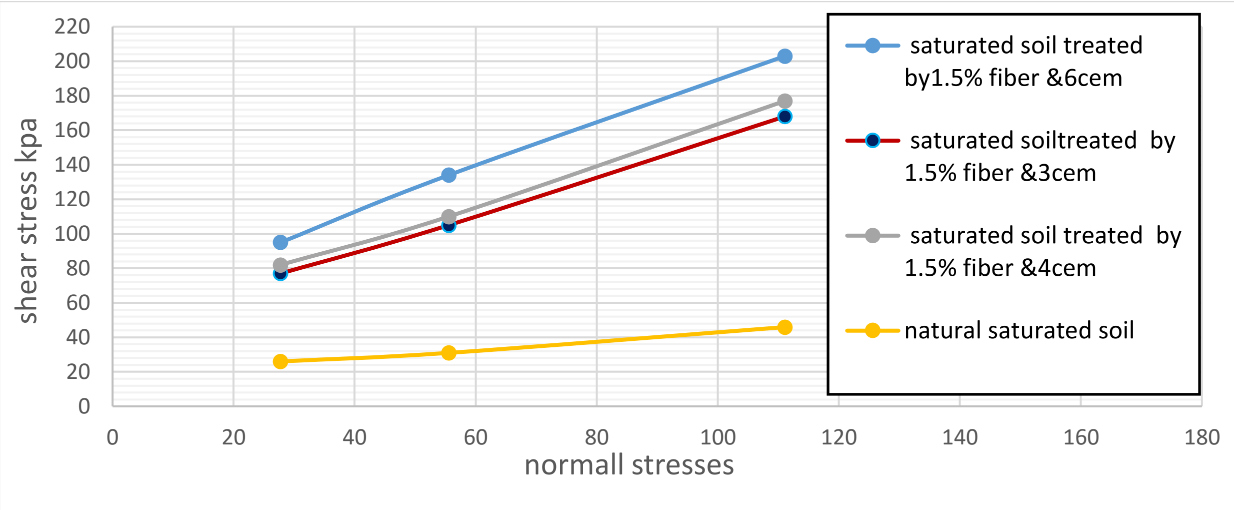

Fig. 11. Relationship between normal stresses and shear stress for treated soil with (PPF) and cement, from direct shear test in dry and soaked condition.

Table. 4. The results of shear strength parameters before and after adding the additives.

treated method	Cohesion (KPa)	angle of internal friction (degree)
soil tested in dry state	37	43.5
soil tested in saturated state	14	19
Soil mixed with 1% PPF and tested in saturated state	31	21.8
Soil mixed with 1.5% PPF and tested in saturated	32	26.2
Soil mixed with 2% PPF and tested in saturated state	40	35
Soil mixed with 1.5% PPF,3% cement and tested in saturated state	42	48.6
Soil mixed with 1.5% PPF,4% cement and tested in saturated state	50	50.1
Soil mixed with 1.5% PPF,6% cement and tested in saturated state	60	51.8

4.2. Experimental model result

Two-model result as described the model and test program in 3.4, the first one is conduct on natural soil under socked condition while the second is conduct on treated soil by (1.5 %) (PPF) and (6 %) of cement. Both samples were soaked for (28) days, as well as, the treated soil sample was cured for seven day before soaking.

4.2.1 Experimental model result for natural soil

The stress-settlement curve for loaded circular footing on natural soil show the soil displacement is slightly increase for load less than (140 kPa), and then excessive settlements create after this stress level.

From direct shear test results, the cohesion of soil was (19Kpa) and the angle of internal friction (14) when the soil tested under soaking condition. According to TERZAGHI'S BEARING CAPACITY EQUATION the soil, bearing capacity is (154 kPa); these values closes with model result.

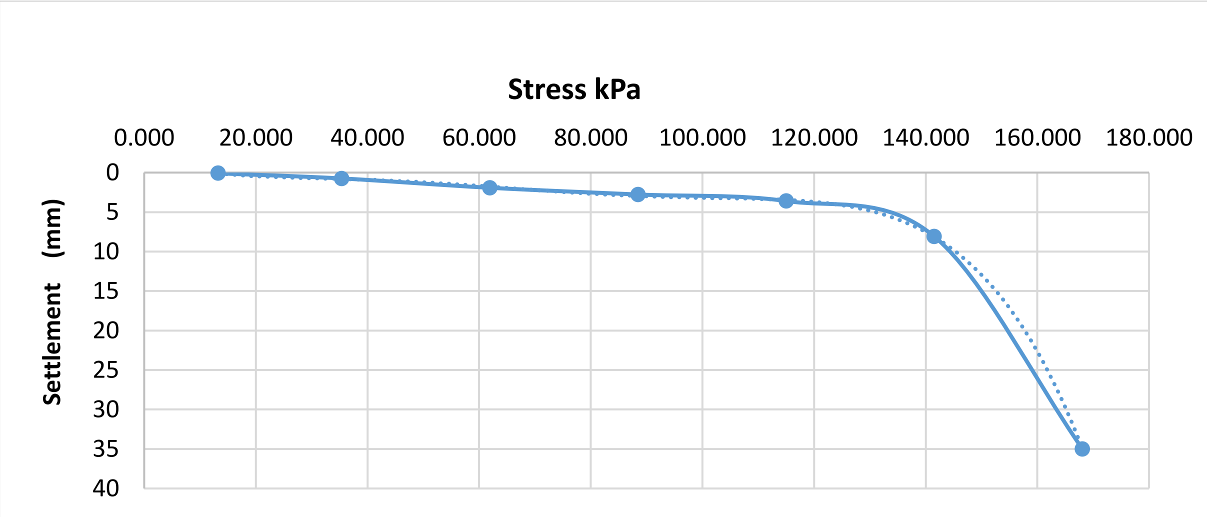

Fig. 12. Experimental model Relationship between Normal Stress versus Vertical Settlement for Natural Soil.

4.2.2 Experimental model result for treated soil

The stress-settlement curve for loaded circular footing on treated soil shown in Fig. 13. From this figure it can be seen that the soil settlement is slightly increase for stresses less than (1.6 MPa) after this level of stress excessive settlement developed.

At this level of stress (1.6 MPa) settlement about (11mm) occurs, which equals (9.2 %) of the foundation diameter.

By comparing the results shown in Figs. 12, 13, the bearing capacity of treated soil was improved about (10) times compared with that of natural dry soil when tested under soaked condition.

This significantly improved in strength of soil is due to the effect of (PPF), which distributed randomly in soil, and the bound of soil particle due to the effect of adding cement.

Soil treated with (1.5 %) (PPF) and (6 %) cement has a strength parameters exceeded that for dry natural soil, where the cohesion become (60 kPa) and the angle of internal friction reaches (51.3°) which were obtained from direct shear test, were used for this model under footing (240 mm) depth.

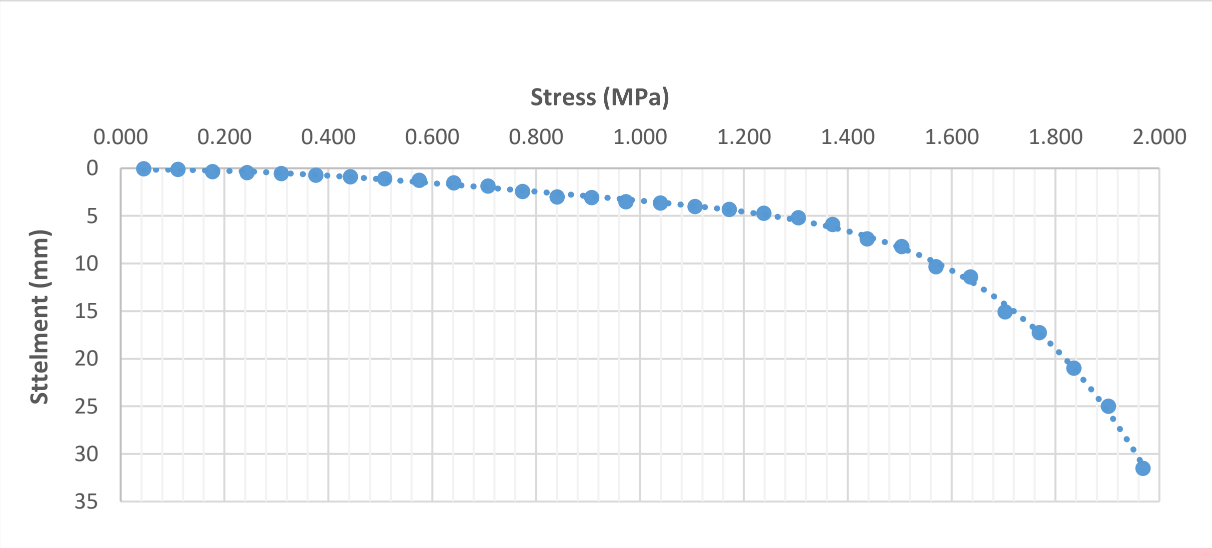

Fig. 13. Experimental model Relationship between normal stress versus vertical settlement for treated soil with (1.5 %) (PPF) and (6 %) cement.

5. CONCLUSIONS

Dependent on the results that was achieved from experimental tests, the below conclusions could be drawn:

1. From the drained direct shear test, the cohesion of soil decreases about (48.6 %) and the angle of internal friction decreases about (67.8 %) when it is tested in soaked condition compared with dry test results.
2. When the soil treated with polypropylene fibers (PPF) the soil strength parameter growth significantly, under soaked state, with increasing the rate of fiber, where the soil cohesion and angel of internal friction increase respectively by (163%, 168% and 210%) and (156%, 187% and 250%) corresponding to treated rate (1%, 1.5% and 2%) of (PPF).

3. Soil treated by cement as well as (PPF) have a strength parameter improved significantly with cement dosage increase, where the soil cohesion and angel of internal friction increase respectively by (221%, 263% and 316%) and (347%, 358% and 366%) corresponding to treated cement rate (3%, 4% and 6%).
4. From experimental model result, for natural and treated soil the bearing capacity of treated soil improved about (10) times compared with that for natural soil when tested under soaked condition.

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