Influence of PPF on leaching and subsidence of Gypseaus soils

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ABSTRACT

Gypsum soils are found in various places, including Iraq. The problems created by gypsum soils are due to the presence of gypsum salts, which dissolve in water and affect the engineering qualities of the soil over time, causing several problems that can finally lead to collapse.

This study aims to assess the effect of PPF on the soaked gypseous soil. The tests were carried out on three types of gypseous soil with varying gypsum content and properties, mixed with varying PPF contents (0, 0.25%, 0.5%, and 1%) at 12 mm length.

By the compaction results, polypropylene fiber increases the optimum moisture while reducing the maximum dry density.Also, adding (0.5 % PPF) has produced an efficiency percentage of 69.9_74.8% in reducing collapsible potential. For the leaching model test The model test results we found through the leaching process showed that the effect of fibers in stabilizing the soaked gypsum soils was apparent by preserving their engineering structure and preventing deformations and collapses. Whereas untreated soils became brittle and collapsed under the influence of their weight, this reduced the volume by 1795.2 cm3 after 80 days of leaching with water, while the treated soil volume decreased by only 210.5 cm3.%. The current study's findings point to polypropylene fiber improvement as an environmentally friendly technique for enhancing the engineering characteristics of gypseous soil

Keywords: Leaching_ Gypseaus Soils _ Polypropylene Fiber (PPF)_ Model Test_ Collapse

1. Introduction

Gypsum soils are distributed in several regions of the world, including Iraq. The problems caused by gypsum soils have been noticed as a result of the presence of gypsum salts, as they cause a continuous change with time in the engineering properties of the soil as a result of the dissolution of these salts upon contact with water, which causes many problems that can ultimately lead to collapse [1]. So, Engineers must treat gypsum soil to reduce its influence on structures. Several strategies increase gypseous soil behavior, such as compaction for shallow layers and injection for deep layers of big or buried structures. also Can use deep foundations like piles by distributing load to stable layers beneath collapsible ones[2]

Furthermore, chemical stabilization uses cement, sulfur, a crylate, and sodium silicate to treat collapsible soils. Despite improving soil folding behavior, they can be hazardous and pollute groundwater and soil [2], [3]. However, there are several factors to consider while deciding on a suitable technique, including construction details, economic factors, and the degree of collapse.

Several initiatives to address the soil problem have recently been documented using geofibers for soil stabilization and improvement. Due to the low cost and ease of deploying technology, the light weight of the additive (i.e. geofibres), and history of successful cases, geofibers are popular among practitioners. Geofibers improve shear modulus, liquefaction resistance, particle entanglement, and load-bearing capacity in granular or non-cohesive soils [4].

Geofiber These are typically fibers integrated into soils to form a perfect reinforcement system for fixing slope failure, reinforcing pavement subgrade, stabilizing foundations, and enhancing backfill for retaining walls. By working well with the soil already there, geofibers help create a soil reinforcement system with much better engineering features [5].

Fibers available for use in construction can be classified as natural fibers (e.g., coir fibers, jute fibres, etc.), synthetic fibers (e.g. polypropylene fibers, polyester fibers, etc.), and waste fibers (old/used tire fibers, used plastic fibers, etc.)(nonhazardous type) materials[6]. Previous research has shown that using natural fibers in poor soils can improve the soil's mechanical behavior even with a modest amount of fiber. Waste materials and synthetic fibers boost soil strength by enhancing friction interlocks and bonds between soil particles[7]. Furthermore, fiber can make construction projects more cost-effective and environmentally friendly. Because fibers may be derived from waste goods like old tires, used plastic, etc., their utilization can help resolve waste disposal difficulties; otherwise, these wastes can occupy a large amount of landfills[8]. Several researchers have looked at the shear strength of fiber-reinforced soils and found that it significantly improves the soil's shear strength and ductility. Specifically, fibers boost the soil's peak shear strength while the post-peak decrease in shear strength is limited [9].

According to standard Proctor tests, adding jute fibers at a rate of 0–1% by weight of dry soil raises the optimal water content of clay with low plasticity and lowers the maximum dry unit weight [10]. The modified Proctor tests carried out by (AbdulRahman et al.) indicate that the presence of 1% polypropylene fiber (PPF) by weight of dry soil causes the maximum dry density of reinforced gypsum soil to decrease[11]. Also (Ali1a et al.) found that the maximum dry density of reinforced soil with PPF slightly decreased by 2.8% [12].

[13] was performed Oedometer tests investigated the effect of glass fibers on collapsible soil. Glass fiber with 0, 3, 4, 5, and 6 % was utilized to treat laboratory remolding soil, The study shows that glass fiber treatment reduces soil collapse. (AbdulRahman et al.) were evaluated (PPF) effect on gypsum soil with a 39% gypsum concentration and 6 mm fiber lengths. The results of the odometer test are shown for the gypseous soil after mixing with PPF. The collapse potential was significantly reduced, from 13.9% to 0.96% for (0 to 1%) fiber content [11].

[14] were evaluated the possibility of using fibers to reduce collapsible soil potential alone or in conjunction with Portland cement. Polypropylene fibers in various ratios (0, 0.1, 0.2, 0.5, and 1 percent) lengths of 12 mm were mixed with a cement soil mixture. The cement content is available in three concentrations (0, 1, and 5%). Odometer tests were carried out to determine the effect of a fiber and cement mixture on the collapse characteristics of treated collapsible soil. The results showed that increasing the fiber content from 0% to 1% with 0% cement content reduced the collapse potential from 13.68% to 6.83%. Also, fibers can be used to reduce cement content while maintaining the same results, with a combination of 0.2 percent fibers and 1 percent cement being as effective as using 5 percent cement for treatment without fibers in terms of CP reduction.

Though previous studies have shown that geofiber is a sustainable material for improving the geotechnical properties of a wide variety of soils, applying geofiber to treat gypseous soil is A little bit. So, this research looks at what happens to the properties of gypseous soil when polypropylene fiber is added, especially when the soil is wet, by carrying out tests in the lab, such as the collapsibility tests and the leacgine model test.

2. Materials and methods

2.1 Soil

The soil used in this research was collected from three locations in the Salah-Aldin Governorate and was representative of three types of disturbed natural gypseous soil. The samples were taken from a depth of 0.5 to 2 meters below the earth's surface. The first one was brought from Tikrit University, which has a gypsum content (56%) and is defined as (soil 1). The second variety is from AL'Dour, has a medium gypsum content (36%), and is known as (soil 2). Finally, the third is from Al 'Alam, but its low gypsum content (21%) is referred to as (soil 3). Fig (1) displays the soil samples' grain-size distribution curve, and The USCS categorizes these soils as "poorly graded sand," which is the lowest soil quality level (SP). Table (1) to Table (3) presents gypseous soils' physical and chemical properties and the test standards

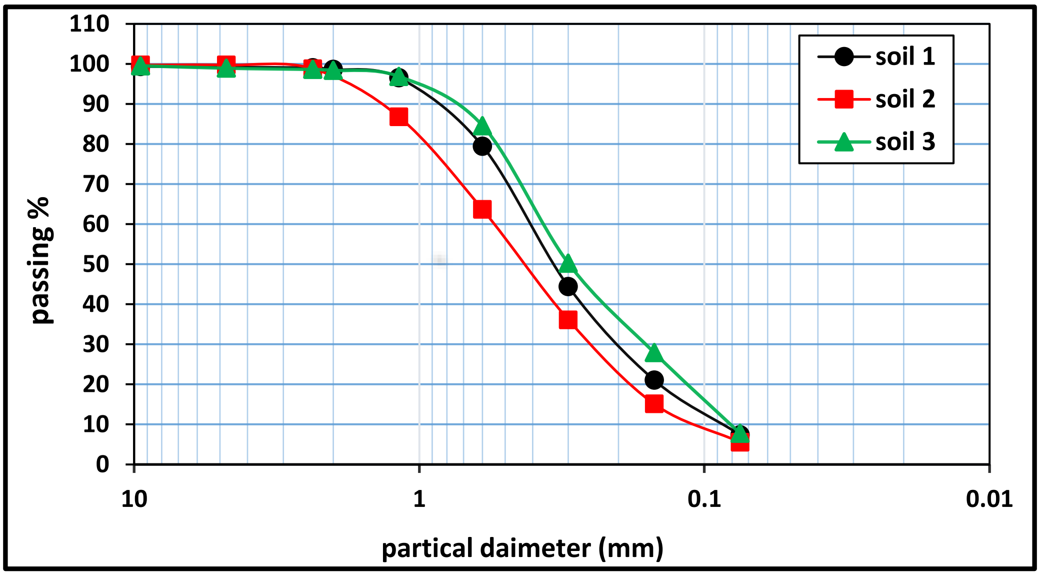


Figure 1: The grain-size distribution curve

Table 1: Gypseous soils tests with their Specification

Property	Specification
Grain size distribution	ASTM D422 [15]
Specific gravity	ASTM D854 [16]
(LLand PL)	BS 1377:2A-ASTM D4318 [17][18]
Compaction test	ASTM D1557 [19]
Field density	ASTM D1556 [20]
Chemical tests	BS 1377-3 [21]

Table 2: Physical properties of gypseous soils

Soil symbol	Specific gravity (Gs)	Atterberg's limits		Grain size distribution		Compaction test		γf KN/m³
		LL%	PL%	Cu	Cc	$\gamma_{d\,max}$ kN/m³	O.M.C %	
Soil 1	2.36	92.2	N.P-SM	4.86	1.11	17.65	11.75	12.17
Soil 2	2.46	34.2	N.P-SM	5.10	1.07	17.49	13.31	13.34
Soil 3	2.51	32.9	N.P-SM	4.63	0.84	18.91	10.45	14.05

Table 3: Chemical properties of gypseous soils

properties	**Soil1**	**Soil2**	**Soil3**
Total soluble salts (T.s.s)%	64.41	37	25.31
Organic matters (O.M)%	0.015	0.048	0.091
PH value	7.88	7.81	7.78
Gypsum content %	57	36	21

2.2. Polypropylene Fiber (PPF)

Polypropylene fiber is a polymeric fiber and is one of the most recent members of the rapidly growing thermoplastic polymer family are prepared using the melt spinning technique, which consists of two manufacturing stages: (1) extrusion of a fiber and (2) subsequent thermal and mechanical stretching of the fiber. In this process, a viscous fluid is extruded through a multihomed die or spinneret, forming a fine-diameter fiber [22].

Table (4) shows the properties of the (PPF) which was brought from the Sika Company and is depicted in plate (1).

Table 4: The properties of polypropylene fiber

property	value
Colour	transparent fibers
Density	0.91 g/cm3
Length	12mm ± 1mm
diameter	0.032 mm
Tensile strength:	600-700 Mpa
Elastic Modulus	3.000-3.500 Mpa
Elongation	20-25 %
Chemical Base	100% virgin polypropylene
Melt point	160°c
Ignition point	365°c

Plate 1: Polypropylene fiber (PPF) used in the present research

3. Experimental program

3.1. Sample Preparation

The soil was prepared using samples passing through sieve No.4, then oven dried for 48 hours at 45 °C., then moved to a mixing container. The required amount of water is added to the specimen, and the batter is then carefully mixed by hand to ensure that it is homogeneous.

For fiber-reinforced samples, at this point, the required percentage of fiber is added to the wet soil, expressed as a percent of the total dry weight of soil, and manually mixed into the wet soil in small increments. Because it was observed that if the fibers were mixed into dry soil, it would cause segregation or the floating tendency of fibers, then it was mechanically mixed. Before the tests, the prepared mixtures were kept for 24 hours in airtight bags so that the moisture would be evenly spread throughout the sample.

3.2 Testing Program

3.2.1 Compaction test

Maximum dry density and optimal moisture content for compacting the three soil types were determined using a modified proctor test (ASTM D1557). it was dried at 45 °C for 48 hours, eliminating the possibility of water crystallization being lost from the gypsum, allowing an accurate determination of its moisture content.

3.2.3 Collapse tests

Oedometer devices were conducted in accordance with (ASTM D5333-03)[23]. The soil's collapse potential (CP). was evaluated using a test proposed by (Knight, 1963) and known as the collapse test or the Single Oedometer Test (CP)..The severity of the collapse potential indicated is shown in Table 5.

Table 5: Collapse identification (after Jennings, J. and Knight, 1975)[24]

Severity	No problem	Moderate	Trouble	Severe	Very severe
CP (%)	0-1	1-5	5-10	10-20	>20

3.2.4 Leaching Model Test

The impact of wetting on the behavior of gypsum soil's pristine surface was studied in a model experiment. The model consists of the following parts, As can be seen in Plate 3.6

1. The glass container is 150mm, 250mm, 300mm in dimensions, and 10mm in thickness. To show the actual situation of how to drain the water from gypsum soil in sit., we made holes in the model's base.
2. For a representation reality of the gypsum soil's exposure to rainwater, irrigation, or other water sources, the container's water supply faucets must be located at the container's top and connected to a water tank until the water reaches the model's surface.
3. A gravel layer (7) cm thick is placed on the container's bed to make the water dissipate. then (3) cm thick layer of graded sand is put on top of the gravel layer to keep soil from getting through the holes in the bottom container and to act as a filter for the gypsum soil.
4. To prevent the soil specimen from shifting and to prevent the filter from mixing with the gypsum soil, a layer of filter paper was placed on top of the previous layers.

It was decided to create two model assessments. The first model was evaluated on untreated gypsum soil (1), and the second was evaluated on the same soil treated with 0.5% of the dry weight of the PPF. Both untreated and fiber-treated soil samples were generated with the same dimensions (150 mm x 150 mm x 250 mm) and a density equal to 83% of the maximum dry unit weight. The soil was compacted inside the model to a total thickness of (15 cm) using a hammer, The specimen was compacted into five equal layers. Each layer is 3 cm thick. The changes that will occur to the gypsum soils in the model are checked every (7,15,22, 31, 38, 50,60,70, and 80) days .

4. Results And Discussion

4.1. Compaction tests

Figures (2) and (3) show the changes in maximum dry density and optimum moisture content (OMC) with PPF, respectively. It has been noticed that the maximum dry density drops and the optimal moisture content rise with the increase in the gypsum content of the soil.

Results showed that as PPF concentration was raised, maximum dry density decreased and OMC increased. the density of ppf-treated soil 1 decreased from 17.65 to 17.19 kN/m3, and the (OMC) increased from 11.75 to 12.85% when PPF content increased from 0 to 1%. While in PPF-treated soil (2), it is seen that with a rise in ppf content from 0 to 1%, the ($\gamma dmax$) decreases from 17.49 to 16.94 kN/m^3 and the (OMC) increases from 13.31 to 14.18 %. For soil (3), increasing the PPF content from 0 to 1% reduces density from 18.91 to 18.37 kN/m3 while increasing the (OMC) from 10.45 to 11.54%.

Increases in fiber content are related to decreases in dry density, as demonstrated above. Because fiber has a lower specific gravity value (0.91 gm/cm3) than some of the soil particles it replaces [12].

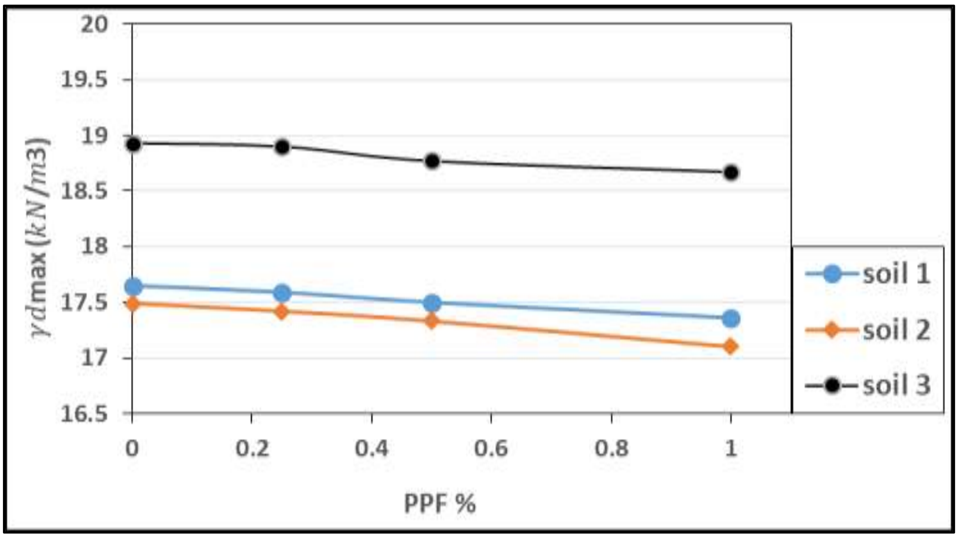


Figure 2: Maximum dry density of PPF-treated soils

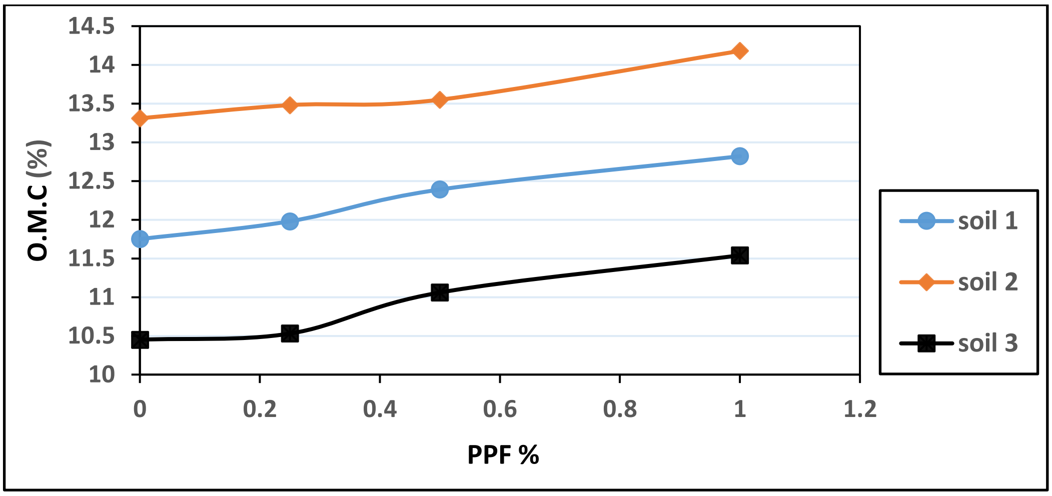


Figure 3: Optimum moisture content of PPF-treated soils

4.2 Collapsibility of PPF-Treated Soils

Collapse behavior in gypseous soils was evaluated using a single oedometer. The results of collapse experiments conducted on three different gypseous soil types are summarized in Table 6; the data show the relationship between effective stress (log v) versus the void ratio (e). The highest value of collapsible potential for soil with a high gypsum content (soil 1) was 6.75%, and it is classified as (Trouble)by (Jennings, J. and Knight, 1975). Soil (2) had a collapse potential of 4.8%, while soil (3) was only 3.3%, That was categorized as (Moderate) of collapse.

The collapse test results for three varieties of PPF-treated gypsum soil are depicted in Figure (4).

The addition of 0.5% PPF content reduced the collapse potential of soil (1) from 6.875% to 2.03%, representing a 69% efficiency percentage in decreasing collapse potential. and the soil classification was changed from problem to moderate. The collapse potential of soil 2 was decreased to 1.3% after being treated with 0.5% PPF, with a 72.9% efficiency percentage, while the collapse potential of soil 3, which had a low gypsum concentration, was reduced to 0.83% and reached the "No Problem" level. with a 74.8% efficiency percentage in lowering the collapsible potential. Figure (5) shows the effect of gypsum concentration on collapse potential.

The presence of fibers increases the cohesiveness of soil particles and provides another type of link that resists the inundation of collapsible soil. As a result, limits volume change by preventing soil particles from sliding relative to one another, which may be attributed to a reduced collapse potential [14][25]

Table 6: Summary of the results of the Collapse test

PPF (%)	Soil 1	Soil 2	Soil 3
	Collapse potential %	Collapse potential %	Collapse potential %
0	6.75	4.8	3.3
0.25	3.808	2.69	1.03
0.5	2.03	1.3	0.83
1	2.34	1.375	1.18

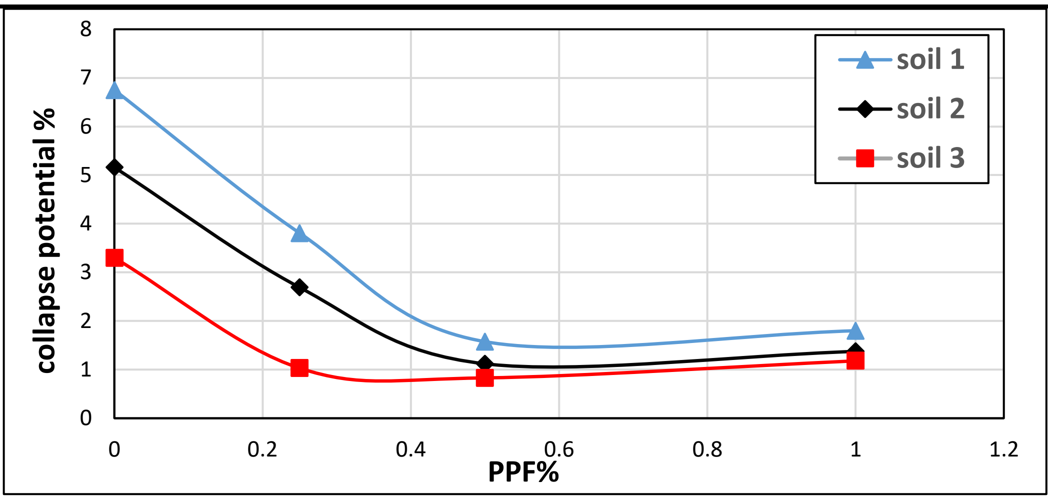


Figure 4 : Effect of PPF content on collapse potential

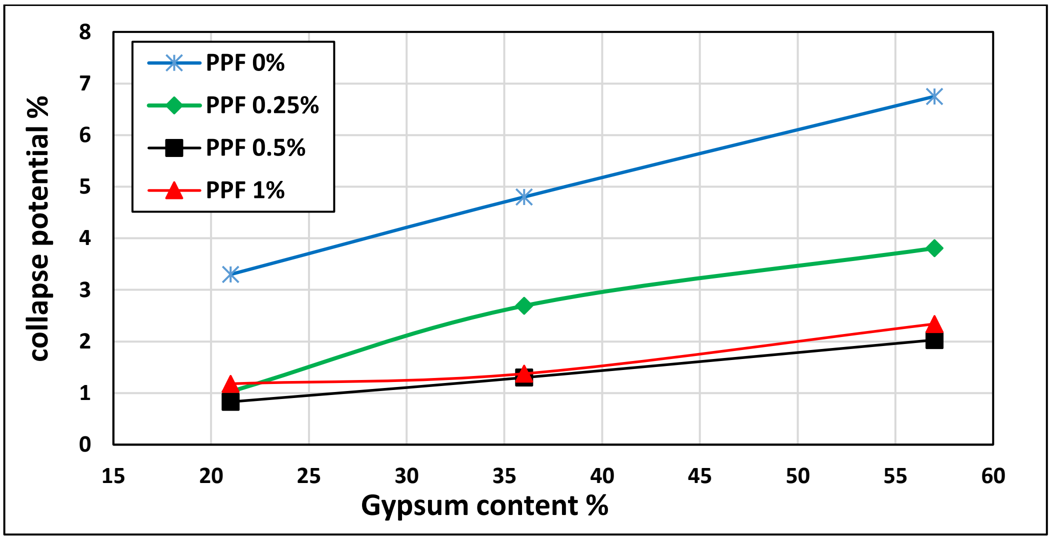


Figure 5: Influence of gypsum content on collapse potential for PPF-treated soils

4.3 Leaching Model Test

Gypseous soils have a high bearing capacity, little settlement, and negligible creep, As mentioned earlier, these are all desirable engineering features. However, once wet, the structure becomes weak and it begins to fall due to the arrangement of soil particles, which may cause it to collapse under the effect of the initial weight and without any extra external loads[26]. As a result, local soils can be improved to the point where they can be utilized in a certain project without problems significant in the future . **Plate (2)** depicts a model that was fabricated to investigate PPF to stabilize the soaked gypsum soil.

After the model has been set up, water is poured over both the treated and untreated gypsum soil from above, and the soil remains submerged in water for the test duration. Through this process, the water will drain from the holes in the model's base and may be washed the soil from the gypsum. Time-Volume variation during each testing period is depicted in Figure (6) for both the treated and untreated models.

During the initial week of testing, the untreated specimens showed voids and deformations. A contrast to this is that the treated specimens showed no visible deformation while still maintaining its original form, as can be seen in **Plate (3).**

The voids and deformations on the untreated model's upper and front surfaces widened after 22 days of tests, and the deformation was shaped as a semicircle, as shown in **Plate (4).** Due to this, the volume of untreated soil in the model reduced from 5625 cm3 to 5214.1 cm3

after 0 and 22 days, whereas the volume of treated soil did not change.
Submerging the specimens in water causes the holes and deformations in the untreated model to increase. The model's top surface develops fractures and voids after being examined for 31 days. There is a clearer indication of this trend after 38 days of testing, at which point the volume has decreased to (4987.02 cm3 and 4683.33 cm3) after 31 and 38 days of the test, respectively. Whereas the Fiber-treated soil experienced reduced volume change over the same examination periods, some gaps did occur in the model's front surface while the soil structure was preserved from deformations.
After 50 days of examination, the untreated soil began to collapse, as represented by the fall of some part of soil from the sides of the model into the holes formed in the specimen

Plate (5) display the testing results after 70 days, It can be observed that the untreated gypsum soil experienced a continuously increasing collapse. also, deformation and cavities showed up on top of the model, and the soil became brittle and loose, causing a drop in volume to 3938.83 cm3. This is because the gypsum dissolves, removing the cementation between the soil particles, and since the wetting process is continuous, the gypsum dissolves continually, increasing the structural collapse due to the breaking of the soil particle connection [27].At the end of the examination period, which lasted for 80 days, the volume change stabilized. the untreated model's volume reduced to 3829.8 cm 3, whereas the treated model's volume decreased from 5625 cm 3 to 5414.5 cm 3 At (0_80) days, and it was noticed that the soil decreased by one level due to the fiber reinforcement in the soil as illustrated in **Plate (6),** The final improvement in the rate of volume for treating gypsum soils with PPF was 88.2%.
Through this examination, we found during the soaking process of the specimens that water did not easily permeate treated soil. It stops for more than one day at the soil's surface This is because the PPFcloses the flow channels and decreases the voids between the soil particles. In addition, provides the type of bond that resists the inundation of collapsible soil and adds to the cohesion of the soil particles. It also wraps the particles so that water does not soak up through the soil. This was observable from the model's solidity and cohesion [11].This is found to be contrary to the case of untreated soil where, over hours, the water was completely penetrating the model due to the many gaps and voids formed by gypsum dissolution.

Plate 2: (a) PPF-treated gypsum soil 1 (b) natural gypsum soil 1

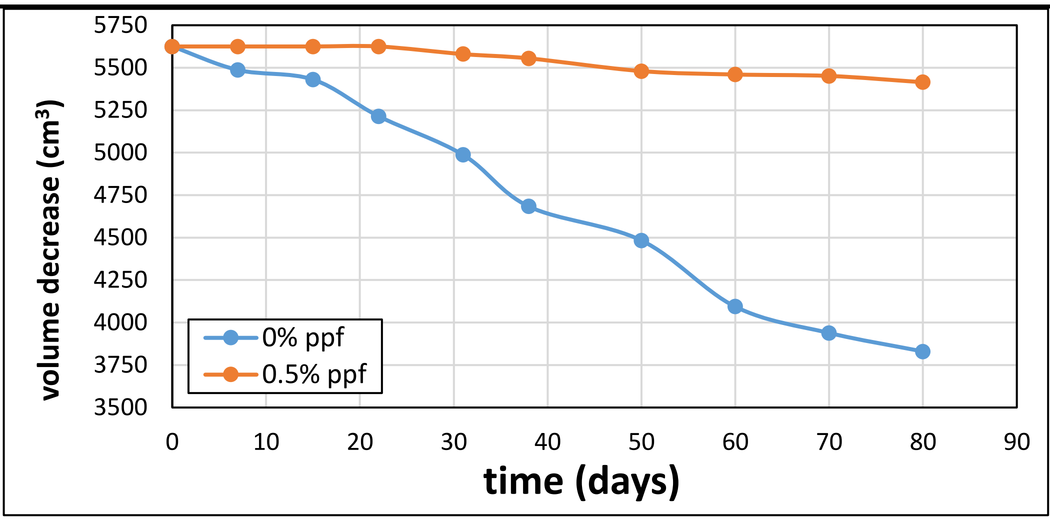
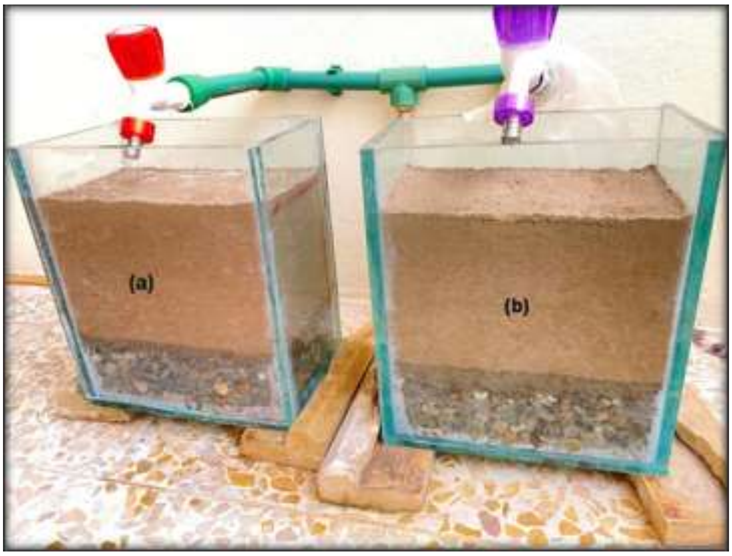


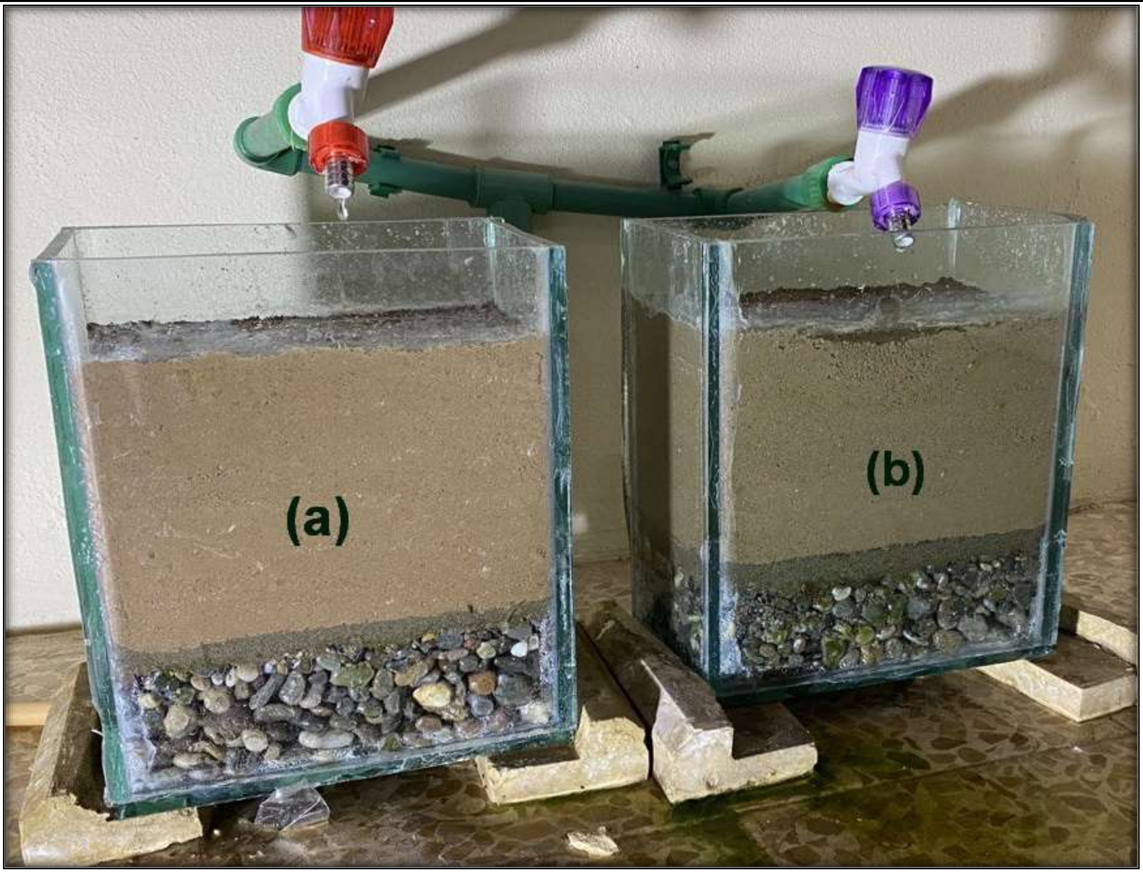
Figure 6: time-Volume change relationship for the treated and untreated soil 1



Front view

Top view

Plate 3: The model's test after **7** (days) (a) PPF-treated gypsum soil: (b) natural gypsum soil



Front view

Top view

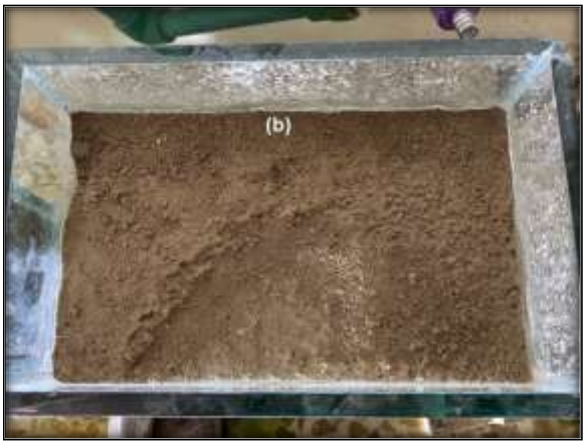
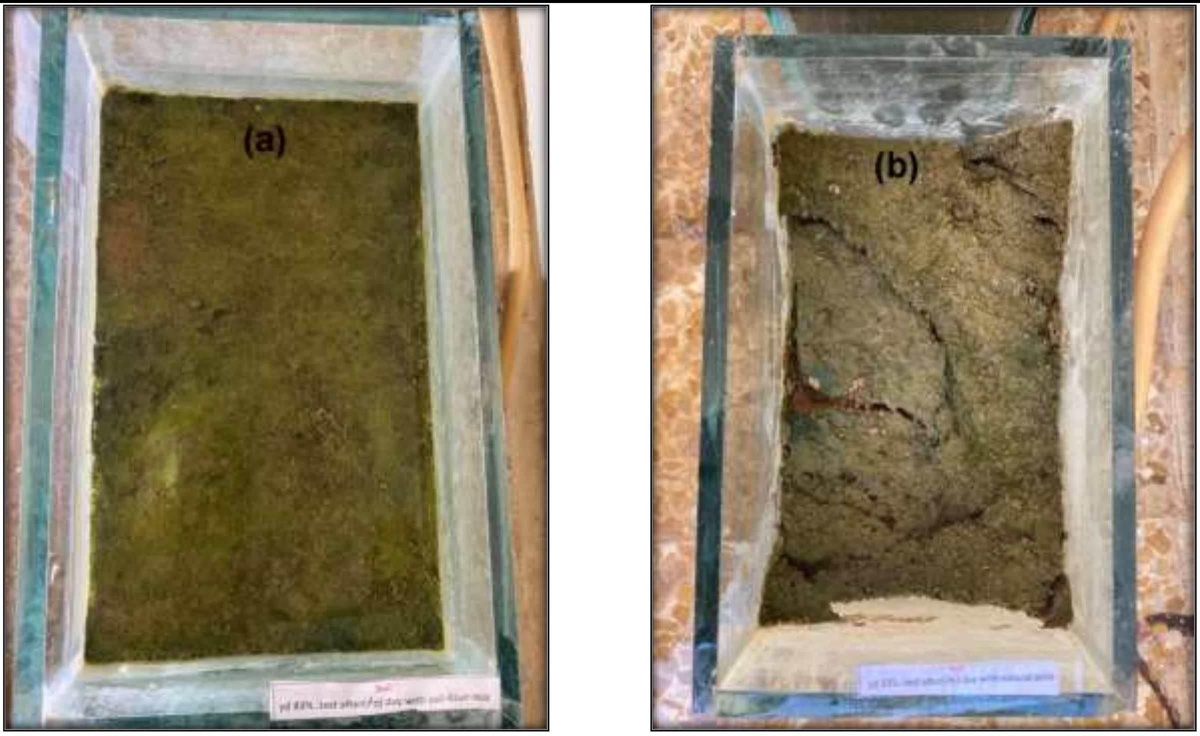


Plate 4: The model's test after **22** (days) (a) PPF-treated gypsum soil: (b) natural gypsum soil



Top view
Front View

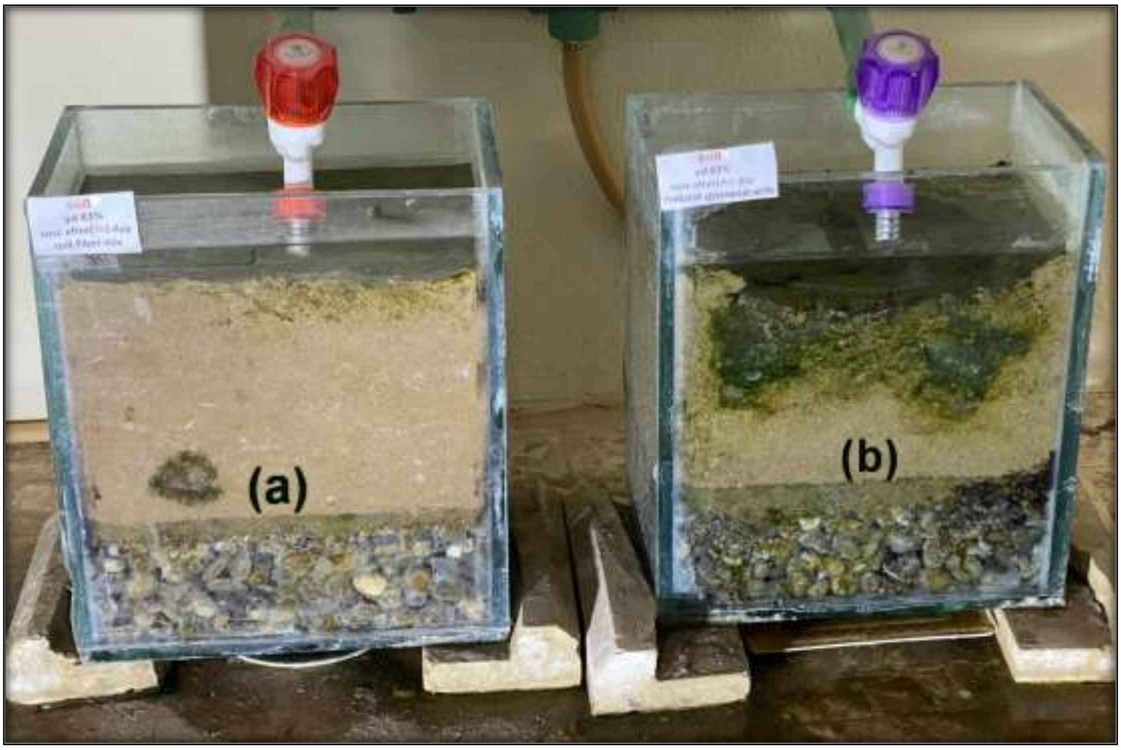
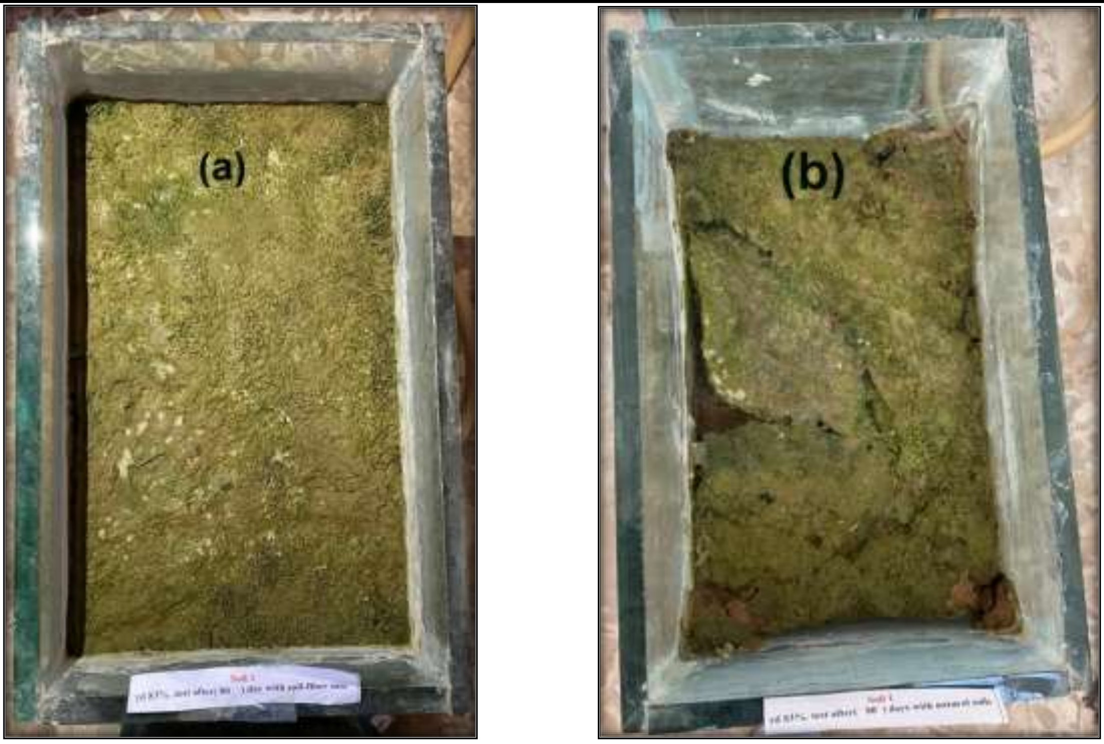


Plate 5: The model's test after **70** (days) (a) PPF-treated gypsum soil: (b) natural gypsum soil



Top view

Front view

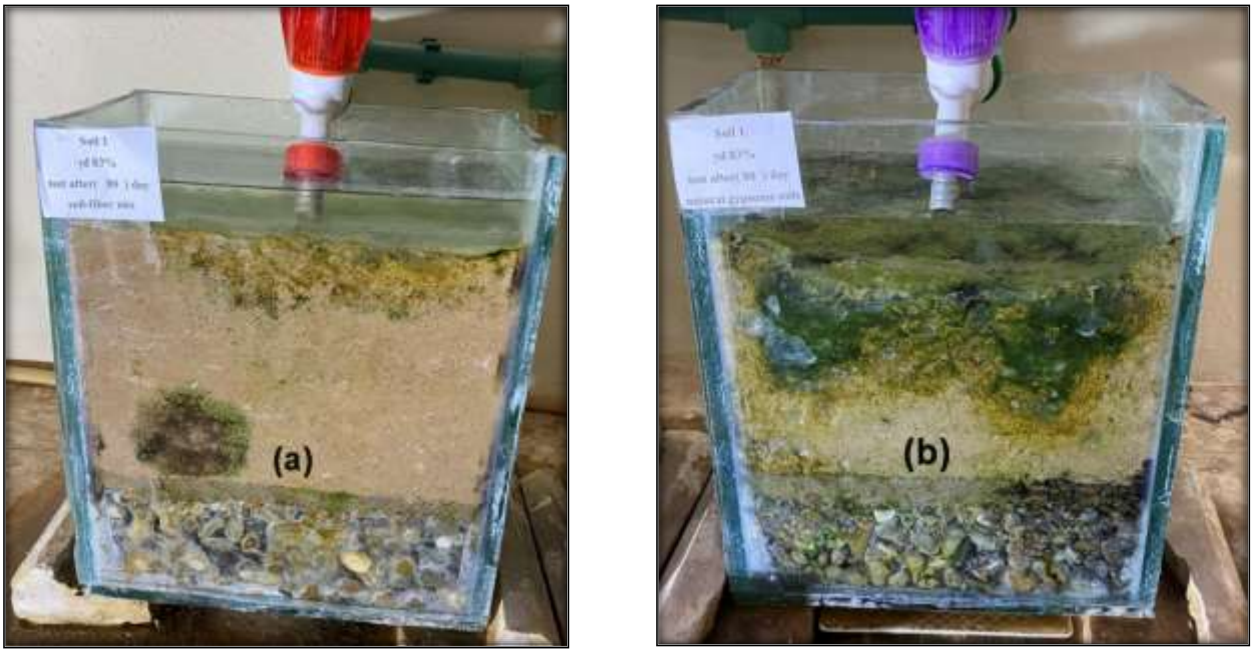


Plate 6: The model's test after **80** (days) (a) PPF-treated gypsum soil: (b) natural gypsum soil

5. Conclusions

This research has studied the effect of (PPF) on leaching gypsum soil. The obtained results can lead to the following conclusion.

1. Maximum dry density drops from 18.91 to around 16.94 KN/m3 as PPF concentration rises, whereas optimum moisture content rises from 10.45% to 14.18%.
2. By adding 0.5% PPF to gypsum soil, the collapse potential is reduced by more than 69.9-74.8%
3. The model tests showed the fibers' efficiency by stabilizing saturated gypsum soil. Compared to untreated soil, PPF-treated soil had less deformations, gaps, and volume changes. Untreated gypsum soil lost 28% of its volume after 80 days, while PPF-treated soil lost about 28% of its volume.
4. (PPF) is cheap and efficient, so it may be used to enhance wide regions at a decent cost. On the other hand, it is environmentally friendly because it can solve significant waste disposal problems.

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