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Improvement of fine soils through the incorporation of recycled is polyethylene terephthalate (PET) fibers

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ABSTRACT

One of the most widely used plastics in the world is polyethylene terephthalate (PET). The production of consumer packaging made with PET represents 36% of the global demand for plastics, this is the largest segment of demand for plastics. Synthetic textiles are the second largest application for plastics globally. The most produced synthetic fiber is PET fiber (or polyester fiber), currently representing around 60% of the total world fiber production. To mitigate the initial impact of the short useful life of PET, it is proposed to use it as a reinforcement in earthworks; Thus, allowing the use of fiber in large quantities and on a large scale in geotechnical works with long useful life, such as: embankments, cores of earth dams, etc. To observe and evaluate the mechanical behavior of a high plasticity silt soil from the Valley of Mexico which has been reinforced with PET fibers from recycled water bottles, a laboratory program was carried out, varying the fiber content from 0 to 0.7% with respect to the dry weight of the soil. The results allow us to consider the great potential that recycled PET fibers would have as an extensive improvement method for superficial deposits of crackable soft soils, with low resistance and high deformability similar to those studied. In the results, an increase in the resistance of the soil reinforced with PET fibers is observed under static and dynamic load conditions, it was also found that the PET fibers increase the tensile strength significantly in the soil and reduce the potential for cracking.

Keywords: PET fiber, cracking, fiber content, soil improvement, soft soils.

1 INTRODUCTION

Population and economic growth in various regions of the world, especially in developing countries, has led to a considerable increase in the consumption of plastic, especially for packaging and construction.

One of the most widely used plastics in the world is polyethylene terephthalate (PET). The production of consumer packaging made with PET represents 36% of the global demand for plastics, this is the largest segment of demand for plastics. Synthetic textiles constitute the second largest application of plastics globally. The most widely produced synthetic fiber is PET fiber (or polyester fiber), currently accounting for around 60% of total world fiber production (Mills, 2011).

Despite the indisputable usefulness of PET in everyday life, there is a problem around this plastic, in addition to the 700 years it takes to degrade, and it is its accelerated demand and production. The recycling rate of plastic is low compared to other materials; it is estimated that around 18% of available plastic waste (excluding synthetic fiber) is currently recycled.

These factors produce an environmental impact that is reflected in: the death of animals that are trapped inside bottles when they are thrown into rivers and oceans, floods caused by the obstruction of sewers and drainage points when they are indiscriminately discarded into the streets, decrease in the useful life of sanitary landfills due to the volume they occupy, air pollution due to the generation of greenhouse gases when they are destined for incineration, effects on human health due to the emission of toxic gases and groundwater contamination due to infiltration of leachate by the final disposal of the ashes resulting from the incineration.

To mitigate the initial impact of the short useful life of PET, some authors have proposed its use as reinforcement in earthworks; thus allowing the use of fiber in large quantities and on a large scale in geotechnical works with a long useful life; such as: pavements and paths (Hoover et al. 1982; Tingle et al., 2002; Newman and White, 2008; Chauhan et al. 2008), slope protection (Hernandez et al. 2022), cores of earth dams (Yang et al. 2019), covers and lining of landfills (Qiang Xue et al. 2014; Chaduvula et al., 2017). However, due to the little information available regarding the behavior of this improvement proposal, the use of synthetic fibers as reinforcement in the soil is not currently used despite presenting multiple benefits.

Furthermore, compared to systematically reinforced soils, soils reinforced with randomly distributed fibers have some advantages; Primarily, fiber-reinforced soil preparation mimics soil stabilization by mixing, discrete fibers are simply added and mixed into the soil, much like cement, lime, or other additives. In addition, randomly distributed fibers offer isotropy of strength and limit the possible planes of weakness that can develop parallel to oriented reinforcement (Yetimoglu and Salbas, 2003. Kumar et al, 2007. Maher and Gray, 1990).

Likewise, traditional flat reinforcements, such as geosynthetic reinforcements, when used on slopes and need anchoring and excavation, there is the possibility of failure, in addition to the difficulty in placement, the use of fiber reinforcement in these applications provides a solution. flexible. Also, compared to geosynthetic reinforcements, fiber reinforcement can be used in limited space, especially for stabilization of failed soil slopes. (Shukla, 2017).

In the same way, the use of fiber materials mixed with a clayey soil can improve the characteristics of the soil as a hydraulic barrier. The addition of fiber to the soil can lead to a stronger and more ductile material, thus minimizing shrinkage problems, the fibers act as reinforcing elements, thus reducing the occurrence and propagation of cracks. The mechanical response of the soil fiber, especially the post-crack behavior can prevent the underlying layers from undergoing a progressive crack opening process (Ehrlich et al, 2019).

Research found in the literature indicates that fiber-reinforced fine soil exhibits higher toughness and ductility and lower strength losses after peak compared to non-fiber soil (Puppala and Musenda, 2000; Kaniraj and Havanagi 2001; Ang and Loehr, 2003; Ozkul and Baykal 2006; Tang et al. 2007; Zaimoglu and Yetimoglu 2012; Maheshwari et al. 2013; Gelder and Fowmes, 2016). Additionally, large deformations in fiber-reinforced soil structures can be noted before failure occurs due to the higher extensibility characteristics, and therefore adequate corrective measures can be easily taken within the available time.

Recent studies suggest a possibility of using recycled PET plastic waste as reinforcement material to improve strength properties of soils in geotechnical works. Jin y Kalumba (2019) conducted a series of direct shear tests on composite soil-plastic samples prepared with two sandy soils and random inclusions of chips obtained from waste PET plastic bottles supplied by a local recycling factory. The experimental results revealed significant improvement in the shear strength parameters, cohesion and friction angle of the sands on addition of PET chips.

Dos Santos et. al (2021) evaluated the influence of PET fibers on the mechanical behavior of sandy soils. They performed consolidated drainage triaxial tests using a 0.5% fiber addition, followed by plate load and slope tests on the laboratory scale model for the most effective fiber. In general, the inclusion of both fibers improved the stress-strain behavior, evidenced by a higher strain energy absorbed in the reinforced soil.

Research on tensile strength in soils improved with PET fibers has shown promising results. Studies by Liu et al. (2018), Shukla et al. (2019), Babu et al. (2017), and Khera et al. (2020) demonstrated that the addition of PET fibers significantly improves soil tensile strength in low to moderate proportions, especially in clayey and sandy soils. However, further research is still required to assess the long-term effects and economic viability of this technique. Together, these authors have contributed to understanding the mechanical properties of soils improved with PET fibers.

Despite the benefits that have been observed in the use of synthetic fibers for soil improvement, the dynamic behavior of soils with fibers has not been widely studied. Also, most of the investigations have been carried out for sandy soils, while for fine soils there have been relatively few. Heineck, M. et al (2005) observed in sandy soils that the inclusion of 24 mm long polypropylene fibers does not modify the initial stiffness modulus at small shear strains (10-5 mm/mm). Diambra A., et al (2009) observed in sandy soils that the stiffness modulus at medium strains (10-3 mm/mm) is not modified by the incorporation of polypropylene fibers.

Sadeghi and Beigi (2014) Performed undrained consolidated cyclic triaxial tests in clayey sand with confining pressures of 50 and 100 kPa and two deviator stress ratios of 0.3 and 0.6 up to 150 load cycles, demonstrating that the stiffness modulus increases with increasing content of 12-mm polypropylene fibers. Clariá Juan José and Vettorelo Paula (2015) Determined the stiffness modulus of loose and dense sand reinforced with polypropylene fibers for confining pressures of 28 to 440 kPa and observed that the inclusion of polypropylene fibers tends to reduce the initial stiffness modulus of the soil to small deformations. Li Haiwen and Senetakis Kostas (2017) performed resonant column and shear wave propagation tests in sandy soil supplemented with polypropylene fibers, and they concluded that the maximum stiffness modulus (Gmax) decreased with increasing fiber content and that the damping increased slightly with increasing fiber content.

As we have seen previously, the conclusions about the behavior of soils reinforced with synthetic fibers are still not clear, which is why one of the objectives of this research focuses on knowing the dynamic parameters of a plastic clayey soil in Mexico City. fiber reinforced. of PET. This is important because Mexico is in a zone of high seismicity and the ground is prone to site effects due to earthquakes. Another of the problems associated with plastic clay soils is cracking due to the tendency to expansion and contraction of the soil, for which it has been decided to study the tensile strength of the reinforced soil.

2 MATERIALS

2.1 Soil

The sample recovered for this investigation was extracted from the ancient Lake Texcoco in the Valley of Mexico. This comprises an area of 4,431 hectares of highly deformable clay-loam soils with very low shear strength. In addition, the soil use in this investigation has a moisture content of 400 to 600%, a salinity three times higher than that of seawater and a very high compressibility. High resolution levels in the area of the former Lake Texcoco have shown that during the last decades the northern portion of the site is settling at around 6 to 8 cm/year while settlement rates in its southwestern sector reach 22 at 27 cm/year, the average subsidence rate has been estimated at 13.2 cm/year (Ovando et al. 2020), registering maximum subsidence of 40 cm/year in some places where the subsoil has thicker clay (Marsal and Masari, 1969).

In addition to the above, the Valley of Mexico is located in a region of intense seismicity. In the period between 1990 and 2016, the National Seismological Service (SSN) reported an annual average of 28 earthquakes of magnitude between 5 and 5.9; 35 of magnitude between 6 and 6.9, and one of magnitude between 7 and 7.9 every two years, approximately. In that same interval, an earthquake of magnitude between 8 and 8.9 was reported (Pérez-Gavilán et al. 2018). In addition, it is necessary to consider that there are significant effects of amplification of seismic waves and lengthening of the duration of ground movements in a good part of the Valley of Mexico, due to the significant thickness of soft materials that underlie it (Ovando et al. 2007), which significantly increases the risk and potential damage to infrastructure.

The characterization tests carried out include the determination of the specific gravity of the solids – Gs (ASTM D854-14 Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer); the estimation of the plastic limit (ω_P) and the plasticity index (IP), following the ASTM D 4318 standard (Liquid Limit, Plastic Limit, and Plasticy Index of Soils). The determination of the liquid limit (ω_L) was carried out by means of the alternative procedure of penetration cone, due to the difficulties of sample preparation. The results are shown in Table 1.

Table 1 *Results of characterization test*

ω_L (%)	ω_P (%)	IP (%)	Gs	SUCS
123.7	53.4	70.3	2.74	MH

According to the results of the characterization tests, the water content necessary for the soil to go from a plastic to a liquid state increases linearly from 123.7 to 135.8% as the fiber content increases, this could be due to the fact that the fibers they form a network between them and cause the slip of the cone to be damped, so a greater amount of water is required to reach the liquid limit. In the same way, the density of solids grows from 2.73 to 2.9 with respect to the increase in fiber content.

Finally, based on the results obtained from the compaction tests shown in Table 2, these conditions were used to perform the mechanical tests. Where γ_m is soil density, ω is optimal water content, Gw is saturation degree and e is void ratio. In these results, a densification of the soil is observed because the fiber generates links between the soil particles, causing a rearrangement in the soil structure.

Table 2 *Results of the compaction tests*

% fiber	γ_m g/cm^3	Gs	ω %	Gw %	e
0.00	1.25	2.73	43.10	69.00	1.71
0.10	1.20	2.77	43.10	68.17	1.75
0.30	1.22	2.82	43.10	67.43	1.80
0.50	1.35	2.83	43.10	67.30	1.81
0.70	1.25	2.90	43.10	66.70	1.87

2.2 PET fiber

The elaboration of PET fibers consists first of obtaining PET bottles or products; these are classified by color, then caps and labels are removed to finally be ground and obtain transparent PET flakes (Figure 1). To obtain the fiber, a viscous solution is prepared. Afterwards, the extrusion of this solution is done through a nozzle to form the fiber. Finally, the solidification of the fiber is obtained by coagulation, evaporation or cooling (Mansilla and Ruiz, 2009).

Recycled PET fibers can be found in the market with different length and diameter. For this research project, polyethylene terephthalate fibers were used as a reinforcement element, provided by the company Tecnología de Reciclaje S.A. of C.V. These fibers have an average length of 50 mm and a diameter of 15 μm.

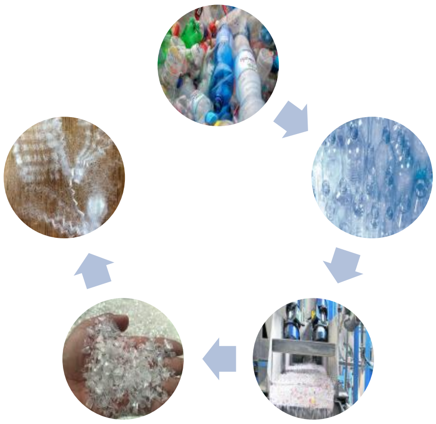

Figure 1 *Fiber PET obtention*

3 METHODS

3.1 Static Triaxial test UU

To determine the resistance parameters and compare the stress-strain behavior of the soil with different fiber contents, UU-type triaxial tests (unconsolidated and undrained) were carried out under static load for samples of the same soil with fiber contents of 0. 0.1, 0.3, 0.5, 0.6 and 0.7%. These tests were carried out with controlled deformation, varying the confining pressure at 50, 100 and 150 kPa, in total 18 tests were carried out.

The soil used was dried in the air, broken up with the help of a porcelain capsule and sieved through a No. 40 mesh to control the water content of the sample and later compact it with the optimum water content, in these tests. the optimum water content was used for all trials; The water was added and mixed with the help of spatulas, then the PET fibers were incorporated into the soil sample and the whole was mixed again.

The compressive strength measurement was performed in accordance with ASTM D2850 - 03a (2007) Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils, the equipment used was a triaxial chamber developed at the Engineering Institute of the UNAM. The camera has an LVDT displacement transducer with a 25 mm stroke, a submersible load cell capable of detecting up to 150 kg, and a pressure sensor capable of 100 psi.

The sensors described above are connected to a signal conditioner that can be analyzed and observed from a computer. The program used to visualize and digitize the signals received from the triaxial camera was LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench). The type of tests carried out were at a controlled deformation of 0.1667 mm/min, which is equivalent to 10 mm per hour.

3.2 Dynamic Triaxial test UU

Cyclic triaxial tests were performed by applying a signal with a sinusoidal dynamic pattern to the specimen, generating angular deformations of 0.3 to 10% at controlled displacement and maintaining a constant frequency of 1 Hz, which is usually equivalent to seismic actions. (Akhila M. et al. 2018). The equipment used in these test is shown in Figure 2.

With the experimental results corresponding to the load vectors (P), the displacement (δ) and the volumetric data of the specimen, the shear strength (τ) and the angular deformation (γ) have been calculated using a Poisson ratio corresponding to silt of 0.35 (Bowles, 1996).

Figure 2 *Static and dynamic test equipment*

3.3 Bending beam test

To determine the maximum tensile strength of the soil, simply supported PET-soil samples subjected to static load were tested, the test layout was carried out in accordance with the technical standards ASTM D1632 and D1635, these standards are specified for soil specimens -cement; the load was distributed at two points at each 1/3 of the length of the beam (Figure 3).

Figure 3 *Bending beam test equipment*

For these tests, three determinations of flexural strength were made for each fiber content of 0, 0.1, 0.3, 0.5 and 0.7%, a total of 15 tests were carried out. The dimensions of the mold used for the conformation of the beams, the internal dimensions of the mold are 70 x 70 x 28 mm. The tests were carried out at controlled deformation with a deformation speed of 0.667 mm/min, in accordance with the D1632 standard; since in the controlled load tests the behavior after the maximum load cannot be evaluated because the breakage occurs suddenly and totally, because the accumulated work given by the product of the force by the displacement is always incremental.

4 RESULTS

4.1 Static behaviour

To evaluate the effect of the fibers on the shear stress resistance of the soil under study, UU triaxial tests were carried out, according to the methodology proposed in the previous chapter. With these tests, the stress-strain relationships were determined, in which it is observed that the compressive strength increases with respect to the fiber content for all confining pressures (Figure 4) and for unit strains greater than 15%. On the other hand, for deformations less than 15%, the fibers are not acting, so the resistance is taken only by the soil.

On the other hand, for higher fiber contents (0.5 to 0.7%) there is greater interference between the fibers and the soil particles, so the initial resistance provided by the soil is affected by the interaction of the fibers with the soil. As the deformation increases, the fibers begin to act and take load. It is also observed that the most favorable fiber content depends on the maximum strain analyzed and the confinement stress. For example, for a unit strain of failure of 10% and with a confining pressure of 50 kPa, the compressive strength of the soil with 0.1% fiber increases 90% with respect to the resistance of the soil without fiber, the samples with 0.3 and 0.5 % fiber increase 119 % and the soil with 0.7 % fiber increases 163 %.

In this same sense, for a confinement stress of 100 kPa, the maximum resistance for a unit strain of 10% corresponds to a soil with a fiber content of 0.5%. When increasing the confinement pressure from 100 to 150 kPa, a decrease in the resistance of the soil with 0.7 % fiber can be noticed, in relation to the other samples. The maximum resistance observed for a confining pressure of 150 kPa corresponds to a soil with a fiber content of 0.5 %.

We can also observe that the maximum increase in resistance occurs in the fiber contents of 0.3 and 0.5% for a deformation of 10 and 5%, for these levels of deformation there is a greater performance of the fibers in the resistance of the soil. With respect to minor deformations, the fibers increase the resistance up to 50%. Regarding the mechanical behavior observed for the failure deformation of 1 %, there is an increase in the resistance of all the samples tested with fiber, this increase is less than that observed for higher failure deformations, the maximum increase in resistance is reaches with a content of 0.3 % fiber, after this content, the resistance does not change.

From the above results, we can state that, although fiber inclusions increase resistance to large deformations, they do not necessarily increase resistance to low deformations because the resistance provided by fibers to the soil acts at higher deformation levels. than 3% and it increases as the deformation increases.

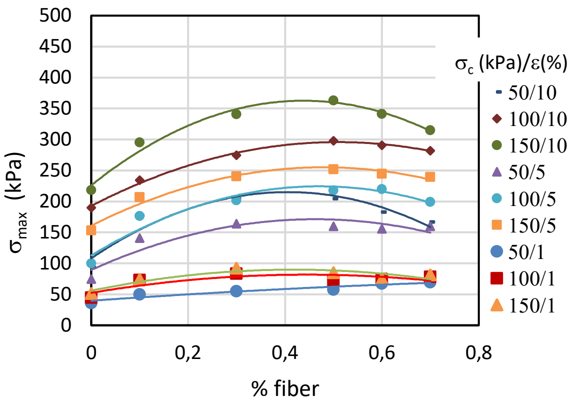

Figure 4 *Maximum deviating stress (σ_{max}) vs % fiber*

To evaluate the cohesion and the apparent internal friction angle, three different unitary strains of 1, 5 and 10% were considered as failure strain and the strength parameters were calculated using Mohr's circles. The results obtained from the triaxial tests are presented in Figure 5. In these figure It is noted that the fiber acts favorably for a unitary deformation of 5% for all fiber contents, finding a maximum cohesion increase of 67% for a fiber content of 0.3%. For the other strains, the optimal fiber content is the same. however, at 1% deformation, the fibers present a less important contribution, because they have not elongated enough to have a more significant contribution. In addition, a considerable decrease in cohesion is noted when the optimum fiber content is exceeded, due to the fact that the contacts between particles decrease significantly due to the interference that the fiber induces.

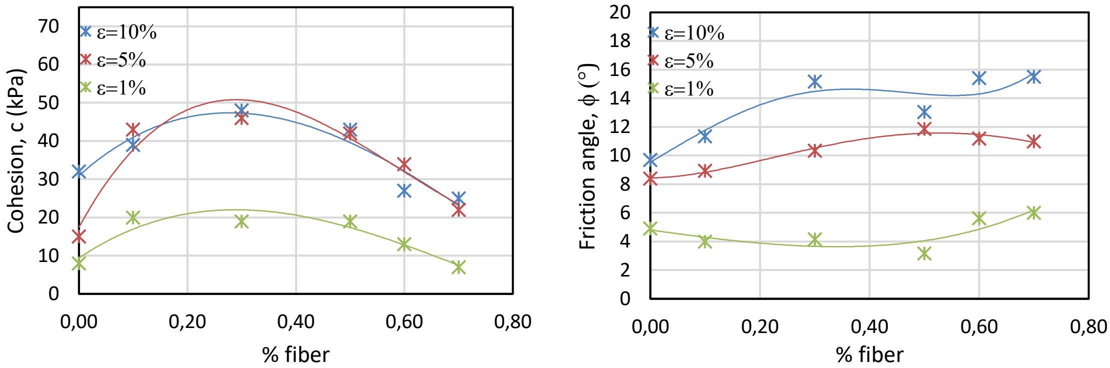

Figure 5 *Variation of cohesion (c) with the percentage of fiber (left) Variation of friction angle (ϕ) with the percentage of fiber (right)*

Finally, the tangent and secant moduli of elasticity are calculated. Figure 6 shows the initial Young's moduli calculated from the nonlinear elastic model of Duncan and Chan (1970). An increase in the modulus of elasticity of around 50 % is observed for all the test pieces tested with fiber compared to the

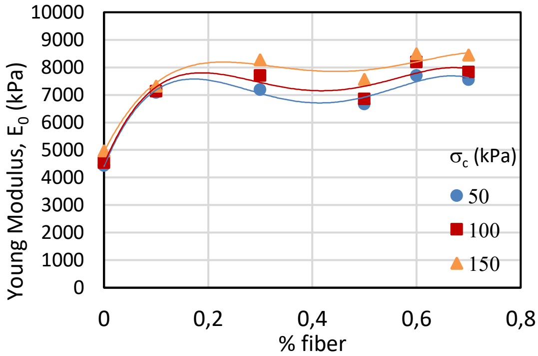

Figure 6 *Young Modulus for different fiber contents*

soil without the addition of fiber. The increase in the modulus of elasticity is significant for the addition of 0.1 % of fiber, from then on there is a lower trend in the increase, because the fibers are the ones that are supporting a greater load and absorbing a greater deformation.

4.2 Dynamic behaviour

The results show that the rigidity modulus for high deformations calculated from the cyclic triaxial tests (angular deformations from 0.4 to 10%) increases with respect to the fiber content up to 20% for 0.7% of fiber content for all confining pressures (Figures 7 to 8). This increase could be due to the fact that in the specimens with high fiber content the fibers begin to act at higher deformations, forcing the soil-fiber contact. In addition, the behavior of the soil-fiber mixture begins to be similar to that of a polymer, in which it reaches its maximum resistance after to be subjected to high deformations. The increase in the stiffness modulus seems to be more noticeable for low strains than for high strains, according to the results observed by Hernandez et al. (2022b).

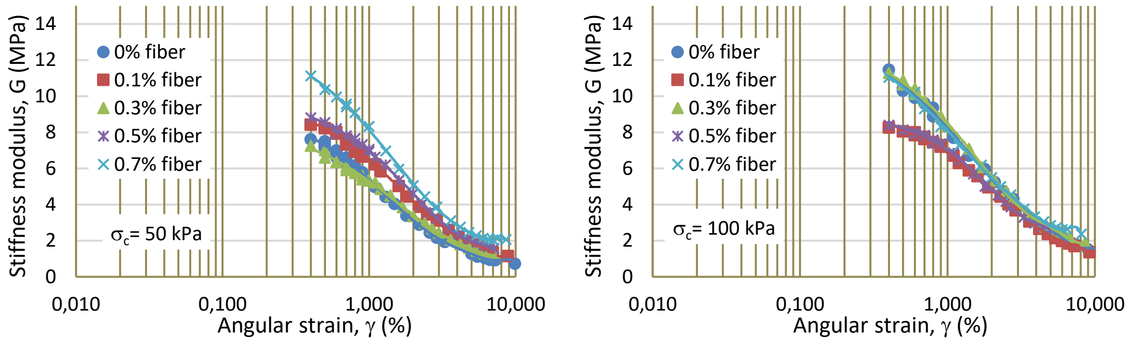

Figure 7 *Variation of stiffness modulus (G) vs angular strain (γ) for a confining pressure of 50 kPa (left) Variation of stiffness modulus (G) vs angular strain (γ) for a confining pressure of 100 kPa (right)*

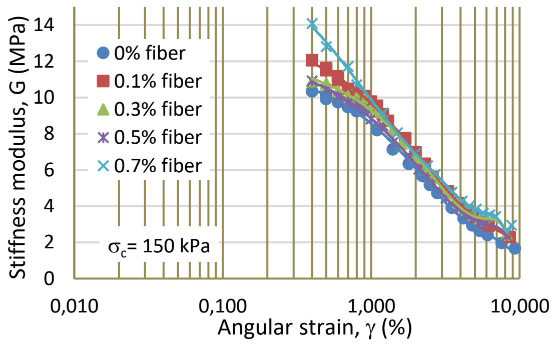

Figure 8 *Variation of stiffness modulus (G) vs angular strain (γ) for a confining pressure of 150 kPa*

The previous analysis indicates that the maximum stiffness modulus occurred for the soil with 0.7% fiber. In addition, all the fiber contents respond positively at an angular strain greater than 0.3%, since from that angular strain the stiffness modulus increases approximately 10% in relation to increasing fiber content in the soil. This increase may be because in the samples with higher fiber contents, the fibers begin to intervene as the strain increases, acting as a reinforcement between the soil particles and increasing the stiffness modulus, although for small strains, the stiffness modulus for the fiber-reinforced samples is smaller than that of the natural soil. When the effective strain is sufficient to mobilize the tensile strength of the fibers, the applied cyclic load is partially absorbed by the fibers, mitigating the collapse of the stabilized soil matrix.

Therefore, it is necessary to determine the specific amount of added fiber that does not interfere with the interparticle contacts of the soil and that in turn does not induce zones of cracking or failures. For angular strains greater than 1%, the stiffness modulus tends to be practically the same for the cases studied because at these levels of deformation, the fibers have been subjected to maximum elongation, and their contribution is insignificant. In addition, these are smooth fibers whose ability to adhere to soil particles has been exceeded.

The variation in the damping ratio for the reconstituted specimens was also calculated and is shown in Figures 9 and 10. The effect of the fiber content on the damping ratio is most distinct at the confinement pressure of 50 KPa. However, the damping ratio only varied by 5% between the lowest (0%) and highest (0.3%) fiber contents.

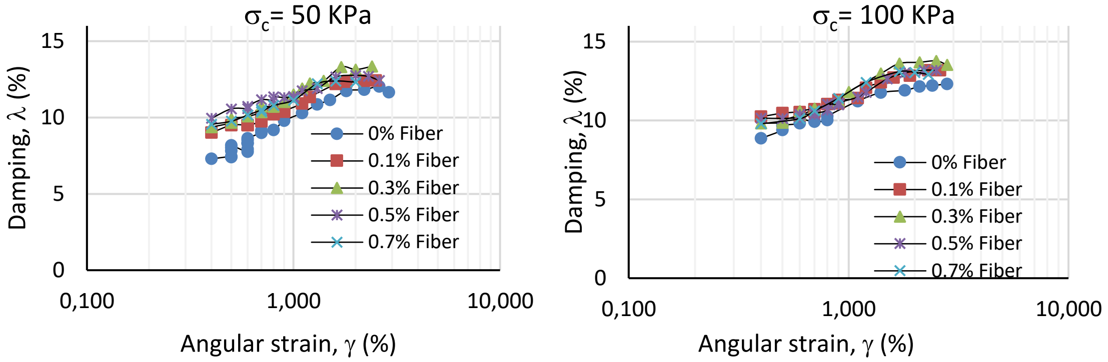

Figure 9 *Damping ratio vs shear strain for confinement pressures of 50 KPa (left) and 100 KPa (right)*

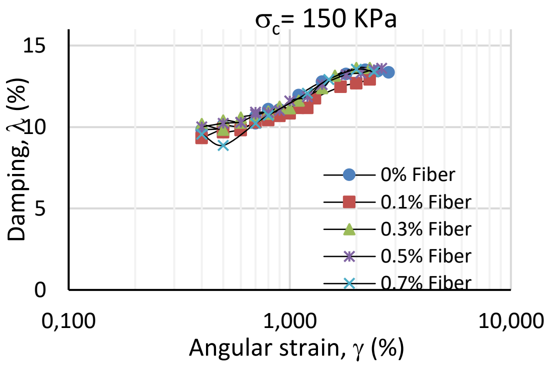

Figure 10 *Damping ratio vs shear strain for a confinement pressure of 150 KPa*

Despite the fact that there is an increase in the stiffness of the soil with the increase in the fiber content in the cyclical triaxial tests, it is necessary to evaluate the dynamic behavior at low deformations (γ = 0.001 - 0.03%).

4.3 Tensile strength

the stress-strain curves are presented in Figure 11 for fiber contents from 0 to 0.7%. The stress-strain curves present a high dispersion in their points after the fracture started in the fiber tests, this due to the loss of contact between the piston and the soil beam due to the type of failure tested. However, the data define trends that can be fitted to other types of curves.

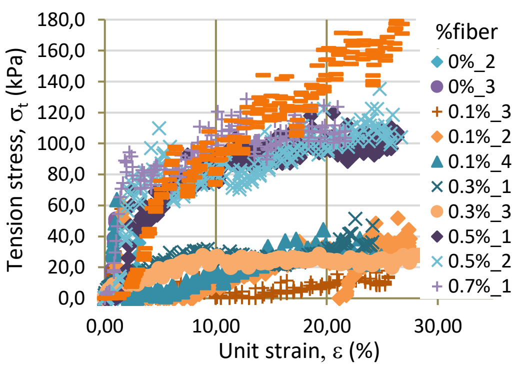

Figure 11 *Tensile stress (σ_T) vs unit strain (ε)*

The bending failures in the beams without fiber appeared suddenly and at low unitary deformations, around 2%, there is no ductile behavior after the maximum tensile stress is reached. On the other hand, unlike the behavior observed for the samples without fiber, all the beams that were mixed with PET fiber presented a ductile behavior after the cracking of the soil began.

It is also observed that for the soil with a fiber content of 0.1%, the tensile strength at the beginning of cracking increases approximately 30% with respect to the soil strength without fiber, from 40.4 kPa to 58.85 kPa on average, both maximum values. they are presented at a unitary deformation of approximately 2%. However, unlike the beam without fiber, the sample with 0.1% fiber does not fail suddenly, but rather presents some tensile strength after cracking has started.

On the other hand, the tensile stress at the beginning of cracking decreases 39% on average when the fiber content is increased by 0.3% with respect to that of the soil without fiber. However, the post peak tensile strength increases. This could be due to the fact that, for higher fiber contents, the tensile strength of the fibers begins to act at higher strains.

When the fiber content increases by 0.5 and 0.7%, the tensile strength at the beginning of the cracking and after it increases by around 50% with respect to the soil without fiber, this increase being greater in the beams with 0.7% fiber. However, at higher fiber content, crack planes increase at the expense of increased tensile strength as can be seen in the Figure 12.

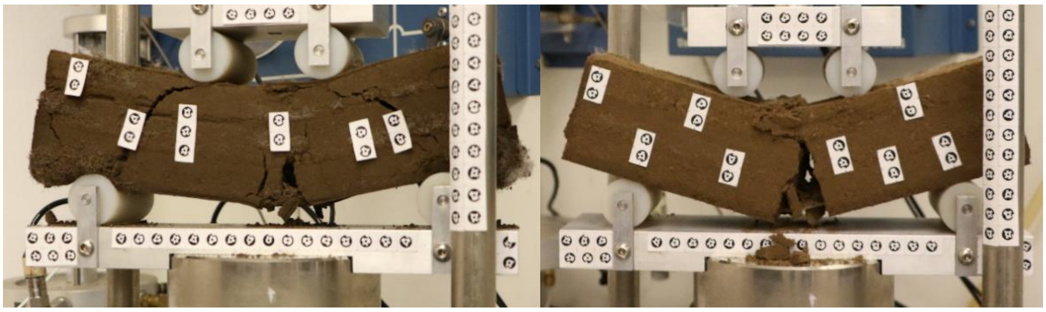

Figure 12 *Soil beam with 0.7% fiber at the end of the test (left) Soil beam with 0.1% fiber at the end of the test (right)*

5 CONCLUSIONS

A laboratory program was carried out to determine the deformational and resistance characteristics of a fine soil, classified as a highly plastic silt recovered at a depth of 0.5 m, mixed with different PET fiber contents from 0 to 0.7 % by weight dry soil and in optimum compaction conditions. According to the stress-strain graphs obtained in the UU triaxial tests, it was observed that the compressive strength increases with respect to the fiber content at all confining pressures for unitary deformations greater than 15%. On the other hand, for unitary strains less than 15%, the optimal fiber content varies depending on the selected strain, since the fibers of the specimens with lower fiber contents (0.1 and 0.3% fiber) begin to act at lower strains in comparison with those with higher content (0.5 and 0.7% fiber).

The rigidity modulus for high deformations calculated from the cyclic triaxial tests increases with respect to the fiber content up to 20% for 0.7% of fiber content. For the case studied of the clays of the Valley of Mexico, the increase in the modulus of rigidity for high deformations allows to reduce the damage in structures built on them by seismic action. However, within this investigation only the dynamic behavior for low deformations is studied, a more complete study is necessary to determine the maximum stiffness at low deformations of the soil, since the behavior could vary with the unitary deformation applied.
Regarding the resistance to the tension induced by the fibers in the soil, it is observed that for the soil with a fiber content of 0.1%, the resistance to the tension at the beginning of the cracking increases approximately 30% with respect to the resistance of the soil without fiber. When the fiber content increases by 0.5 and 0.7%, the tensile strength at the beginning of the cracking and after it increases by around 50% with respect to the soil without fiber, this increase being greater in the beams with 0.7% fiber. At higher fiber content, crack planes increase at the expense of increased tensile strength. In

addition, the fiber samples do not fail suddenly, but show some tensile strength after cracking has started.

The results of this research show beneficial results so that the PET fiber can be used as a reinforcement element in geotechnical works subject to large deformations, tensile stresses and cracking in soft soils. Despite the increase in tensile strength in the soil reinforced with PET fiber present in this research, it is necessary to evaluate other parameters for the study of soil cracking, such as resistance to crack propagation, this can be approached from a point of view of Fracture Mechanics. Likewise, for a better understanding of the mechanical behavior of this type of reinforcement, it is necessary to evaluate parameters such as permeability and deformability under different soil saturation conditions.

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