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Evaluation of Fibers Effect on the Shear Strength of Municipal Solid Waste

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ABSTRACT: In order to evaluate the effect of fiber part in the municipal solid waste on its shear strength, a study was conducted on the Kahrizak waste disposal landfill in Tehran. Shear strength of the waste samples was evaluated through the large-scale tri-axial consolidated and undrained (CU) tests on reconstructed fresh and 9 years old waste specimens. Evaluation and comparison between the results is done on the reconstructed waste samples with a density of 11 kN/m^3 in the non-fibrous state and containing the 12%- weighing plastic fibers. To study the fibers effect, three different types of the plastic bags with three ranges of the tensile strength including 7, 16 and 21 Mpa was used that their dimensions is 2.5*8 cm. In the next step these sheets and the waste samples were mixed. The results show that the fiber part of waste material samples is one of the main factors in providing the shear strength of the waste material. As the tensile strength of the fibers increases, the shear strength of the waste masses increases too. As an initial result an increase about 200% in the tensile strength of the fiber, causes an additional tension increase more than 100% in the waste sample. The plastic fibers in the samples caused a reduction in cohesion (C), and increase the internal friction angle (Φ) of the samples that could be seen in the old waste samples more than fresh ones. In addition to the tensile strength, the elasticity and the amount of deformation before the fracture of the fiber part can influence the behavior of the waste mass.

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1- Introduction

The non-homogenous nature of the urban solid waste (MSW) materials, as composition of various components, can cause the complexity of its behavior. Due to decomposition, the behavioral changes of the masses can increase this complexity over time. Many failures of the landfill slopes caused environmental damages over the last two decades [1-2]. It shows that further researches and studies for the time-dependent behaviors of the waste masses is needed.

Machado (Machado et al) [3] introduced a behavioral model for the municipal solid wastes and then they studied many of the waste parameters. Machado et al [4] examined the effect of the fibers on the shear strength of the waste. They showed a good agreement between results of MSW shear strength increase with increasing amount of the fiber contents. Due to the Terzaghi relationship and the Scampton (relation 1), they presented the (relationship 2) between the tension components and the pore water pressure to determine effective tension.

$$\sigma' = \sigma - (1 - Cs/C) * u_w \qquad \text{Scampton(1996)} \qquad (1)$$

$$\sigma' = \sigma - A * u_w \qquad \text{Machado et al(2010)} \qquad (2)$$

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According to their findings, if effective tension in the materials like MSW is needed to be calculated, which have the contact levels instead of the contact points, it will be needed to consider the degree of the participation of the pore water pressure. The suggested relationship, which is provided by Machado (Machado et al [4]), shows a reductive factor of the pore water pressure level participation is effective at the level of tension. Moreover, C and Cs are the total compressibility of the sample and the compressibility of the sample particles respectively, and the parameters σ, σ 'and uw are the total tension, the effective tension and the pore water pressure caused by the shear process respectively. Conducting the research on the new waste of 5, 14 and 21-year old by using the large-scale tri-axial experiment, Shariatmadari et al [5] figured out, the sample fibers is between 17% and 32%, and the 5-year old samples have the highest shear strength and the new samples have the lowest one. The shear strength of the 5-year samples is higher than the 21-year old samples due to their higher percentage of the fibers and their tensile strength. In this study the effect of the tensile strength of the fibers on the shear strength of the MSW mass is studied to. Adding fibers along with the different tensile strength of the fresh and the old-waste samples in the initial states through the laboratory experiments is evaluated.

2- Landfill Description and Sampling

About 7,500 tons of the municipal solid waste is produced in Tehran each day, and the waste disposal landfill in Kahrizak has been the main one since the early 1970s. The Kahrizak landfill is 25 km away from the south of this metropolis. [6] In order to study and aply this experiment accurately, new samples of the incoming waste in the landfill and the 9-year old samples through digging the landfill is taken. Experiments on the new and old waste from each group is carried out in the Geotechnical Engineering Research Center (GERC) in Iran University of Science and Technology (IUST). 15 samples with a weight of approximately 30 to 40 kg is taken. The components of the new and old waste samples were examined in this center and evaluation of the changing components process of MSW material is noted in Shariatmadari et al. studies [7].

3- The Research Method

The initial studies and the fiber-tensile tests have been done by using a fiber tensile strength test device in the Institute of Polymer and Petrochemicals of Iran. Municipal waste samples were mixed with different percentages of the different tensile strength fibers in this experiment. The large scale tri-axial experiments were conducted on samples. All laboratory experiments were done based on their instructions from the of ASTM standards.

In this research typical plastic fibers which uses in all kinds of the plastic bags is used. Total examined fibers are three groups with 7 Mpa, 16 Mpa and 21 Mpa tensile strength. The modulus of the elasticity of these three groups is 10.35, 8.83 and 28.3 MPa, respectively. The average of the length increase before the sample failure is equal to 279%, 193%, and 42% respectively. According to the results by Machado et al, and Asadi [4, 8], the weight percent of the fibers in the samples was determined to be 12%, and the fibers were made in particles with dimensions of 2.5*8 cm. Tri-axial tests (diameter 150 mm and height 300 mm) for the reconstructed samples with a density of 11 kN /m3 in CU conditions on the saturated samples are carried out. Loading progress is carried out by using displacement control method with a displacement rate of 0.6 mm per minute. The fiber traction machine and the large-scale tri-axial equipment are shown in figure 1.

4- The Results and Discussion

The results of the tri-axial experiments for new samples in the confining pressure of 50, 150 and 300 kPa are presented in figure 2. Considering the abbreviations to show the results and the charts, the samples of the new waste without adding the fibers in this figure is considered. Despite the fibers with the tensile strengths of 7, 16 and 21 MPa, the marks with F3, F2, F1, F0 respectively is considered, and the old samples with similar conditions are shown by the marks T0, T1, T2, and T3. The results shows the level of the deviator stress increases during loading in MSW samples such as soil, as confining pressure increases. As strains increase, the excessive pressure increases steady, no maximum point in their curve will be see. In this way, the properties of the shear strength of the waste can be considered as a function of the strain level. The general evaluation of the stress-strain behavior of the samples show, use of fibers with different tensile strengths can enhance the sample resistance and it increases excessive tensions.

The comparison of the stress-strain chart shows that the chart curves of the samples, which have been used with 21 Mpa tensile strength in all parts, is in the higher amount among the others. The chart curves of the samples which are mixed with tensile strength fibers with 16 Mpa and 7 Mpa, is in the second place. Finally, the curve of the non-fibrous samples is at the lowest point. Shariatmadari et al [5] noted that the fiber part is the waste reinforcement element, and the major part of it, composed of a variety of plastics. Moreover, less than a third of it, is composed of the variety of the textiles and leathers. Due to the charts, it can be concluded that the tensile strength of the fibers impacts on the shear resistance of the MSW masses. The chart in figure 3 shows the excessive tension against the tensile strength of the fibers with four levels of the strain 20%, 10%, 5% and 30%. These charts refer to the experiments in terms of the 300kPa confining tension condition. As it can be figured out, the additional tension levels in the samples increase by adding the fibers. This process in chart has a rising and falling slope at the beginning and the end of curve because of mechanical difference in behavior of the fibers. Therefore, the rise of the shear strength of the MSW mass, which is caused by the presence of the fibers, depends on many factors. In addition to the tensile strength of the fibers, some other factors such as materials, reinforcing, and particles interlock, and surface friction with other parts of the waste mass is considered.

Figure 1. to the right: Fiber traction device, left and center: The three-axis device components used in this research

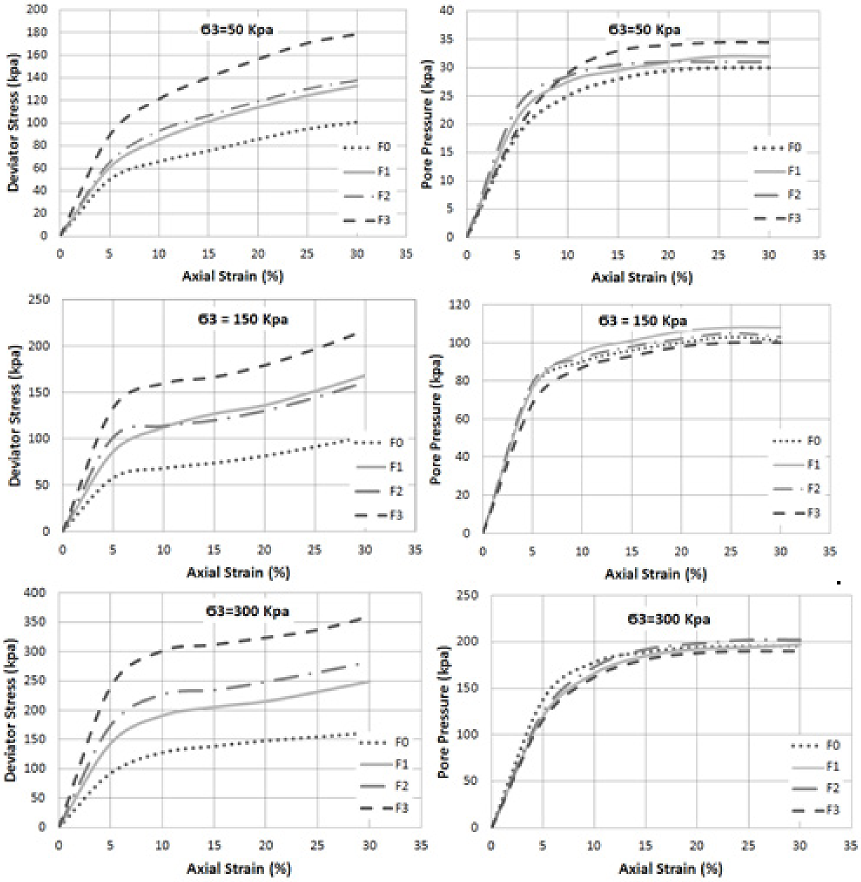

Figure 2 Stress-strain diagrams and pore pressure changes of fresh waste samples

As it shows in the charts, the amounts of the additional tension for all three types rise by increasing the strain and this issue shows that the effect of the fibers in the larger strains is bigger. The difference of the sample behaviors get bigger in confining pressures, and it rises by increasing the strain level. The larger shear strength at higher levels of strain can be seen. It could be due to the impact of the fiber section. The shear strength of the waste mass is provided, the shear strength gets bigger. Subsequently, the fibers can be effective by increasing the confining pressure and the strain levels.

Due to the results of the tri-axial tests, shear strength parameters of the samples is presented for new and old samples in accordance with Mohr-Coulomb failure envelope in Table 1. Measuring the pore water pressure during the experiment, Terzaghi method is used to determine the parameters for the total and effective tension in different modes. Furthermore, Machado's method (Machado et al) is used for the comparison. [4]

The degree of the internal friction angle and the cohesion of each sample is presented. Despite the different tensile strength of fibers, the effective internal friction angle increases. However, the amount of this increase in old samples is higher than the new ones. The granularity and homogenization, increase in amount of particle inter locks, and the friction of the materials in the process of aging and reducing the organic materials can increase the friction of the MSW materials. The fibers have an inverse impact on the effectiveness of the cohesion parameters, and the level of this parameter gradually decreases. In addition, one of the reasons is the lack of the cohesion and the fiber conflict with other parts of the sample. The elastic property (deformation before disruption) of this fiber decreases by increasing the tensile strength. By this results, the values of the total and effective parameters of the new samples and the old samples are different.

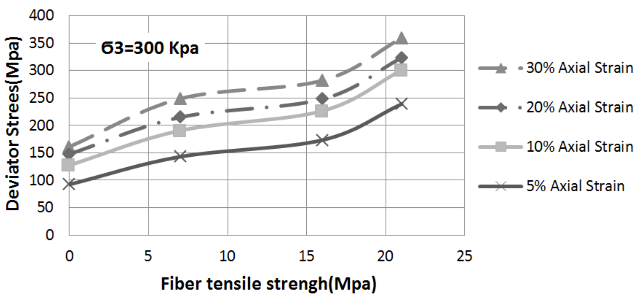

Figure 3 pattern of Deviator stress against the fiber tensile strength Related to fresh samples

Table 1 Shear Resistance Parameters of fresh and aged waste samples (9 years old)

Sample type	Test number	Tensile strength of the fibers (Mpa)	Cohesion (Kpa)			Internal friction angle (degrees)		
			Total	Effective (Terzaghi)	Effective (Macha-do)	Total	Effective (Terzaghi)	Effective (Machado)
Aged	T0	-	21.6	10.7	27.9	11.9	31.4	17.8
	T1	7	18.9	6	23.3	16	44.2	14.8
	T2	16	12	4	22.8	16.6	45.5	24.9
	T3	21	9.3	2.6	14.6	21.2	46.1	29.5
fresh	F0	-	30.6	18	39.1	10.2	15.1	13.6
	F1	7	27.5	16.2	32.5	11.9	20.8	15.4
	F2	16	24.2	13.5	31.2	16.2	24.8	20.1
	F3	21	19.7	11.1	27.3	19.2	27.2	23.6

It occurs because of the water pressure increase at the shear stage. This difference is bigger in the internal friction angle parameter, and the difference in the friction angle results is more effective for the old samples than the new one. Moreover, the difference in the results of the cohesion parameters along with the internal friction angle of the total tension with the effective tension by Machado method is less than the one by Terzaghi method. It seems that the method suggested by Machado et al [4] to determine the effective parameters of MSW has better agreement with the results. The contact of particles in some material is made on the surface not in one point and therefore we had better consider the pore water pressure reducing parameters in order to calculate the effective tension.

5- Conclusion

The hardening strain behavior by examining the tension-strain behaviors of the samples in a tri-axial experiment is found out.This issue occurs as the result of the fiber involvement and the mobilization of their resistance by increasing the strains. The amount of the excess pressure increases by tension increase because of the greater involvement of particles in higher tensions. In addition, it has a double effect on fibers. It occurs due to the inter locking of the components, involvement of the fibers with the mass of the waste and the overall behaviors of the mass. For the bigger strains, the effect of the fiber section increases as an arranged element. Due to the involvement of the fibers in the waste mass, the bearing capacity increases. The tensile strength of the fibers can have effect on the shear resistance of the MSW mass. In addition to this, the elasticity and the state of the surfaces can affect the shear strength of the waste mass. The comparison of the results of the resistance parameters show that the fibers in the waste mass reduces total cohesion and increases the internal friction angle. The effects of increasing tensile strength of the fibers in the waste appear in the form of an increase in the internal friction angle of the materials. The internal angle of the friction increases by adding fibers, and the increase in the old samples is higher than new ones. This issue can be due to the granularity and homogenization of grains, a rise of the amount of particle interlocking, the friction of the materials in the process of aging and reducing the organic materials.

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