Mechanical properties of a blend of waste and clayey sand

M.Zerarka[1], S.Nouri[1], A.Kadri[1]

[1]*Laboratory of Structures, Geotechnical and Risks, Hassiba Benbouali University of Chlef, Algeria*

ABSTRACT

With rapid advancements in technology, the use of plastic waste as polyethylene bags, bottles etc, is also increasing. The disposal of thrown away wastes poses a serious challenge since most of the plastic wastes are non-biodegradable and unfit for incineration as they emit harmful gases. This paper presents a study on the mechanical behaviour of soil mixture reinforced with plastic wastes. This study involves the investigation of the effect of plastic bottles strips on sand-clay mixture for which a series of compaction and direct shear tests have been performed with varying the percentage of plastic strips. The results reflect that there is a significant enhancement in compaction properties , shear strength parameters with plastic reinforcement in soil. The quantum of improvement in the soil properties depends on plastic content. It observed from the study that, improvement in engineering properties of sand-clay mixture is achieved between 0.4% and 0.6% of plastic content.

Key words : Plastic strips, Sand-Clay mixture, Compaction properties, Shear strength parameters.

1 *Introduction*

Algeria, like many other countries, is facing a significant challenge in managing plastic waste. According to the United Nations Development Programme (UNDP), in the recent years, the country generates over 6 million tons of solid waste per year, with plastic waste accounting for a large portion of this. However, the country's infrastructure for waste management and recycling is limited, leading to significant amounts of plastic waste being dumped in landfills or ending up in the environment. Using plastic waste as reinforced soil materials can offer several benefits, including: Recycling plastic waste reduces the amount of plastic waste that ends up in the environment, which can have a positive impact on the ecosystem. Using plastic waste as a reinforcing material can be less expensive than traditional materials such as steel, or concrete. Compared to traditional materials, plastic waste is lightweight, making it easier to handle, transport and set up.

Many researchers are interested in studying the effect of waste plastic in soil reinforcement, and this due to the good properties of this material.

(Hamid, 2000) conducted several tests on clay soil reinforced with plastic strips. Hamid's research concluded that using plastic material could help in ground stabilisation by enhancing the shear strength and ductility of soil, improving compressive strength and decreasing compaction.

(Peddaiah et al., 2018) found also that the use of plastic strips increase the maximum dry density, cohesion and internal friction angle with up to 0.4% of plastic content per mass of natural soil.

A study conducted by (Kassa et al., 2020) aimed to investigate the effect of plastic bottles strips on the geotechnical properties of expansive clay soil. The results showed that the addition of plastic strips caused a reduction in optimum water content and increasing maximum dry density. Internal friction angle and cohesion increased significantly as reinforcement percentages and sizes increased in the direct shear test.

(Tanegonbadi et al., 2021) conducted a series of triaxial compression test to evaluate the behaviour of sand reinforced with two type of plastic waste(polyethylene terephtalate PET and polypropylene PP). The results indicated that inclusion of PET and PP waste increase the shear strength of sand , the maximum shear strength of PP fiber-reinforced sand was higher than that of PET fiber-reinforced sand due to the greater tensile strength of PP fiber.

All of these studies mentioned dealt with the effect of plastic waste in reinforcing one type of soil, whether sand or clay, and did not address other types of soil, and for this reason, our aim in this research is to study the mixture of sand and clay reinforced by adding plastic waste.

2 *Materials and Methodologie*

2.1 *Soil*

The soil used in this work was prepared in the laboratory by mixing 65% sand and 35% kaolin. The sand obtained from Oued chlef in Algeria which which is characterized by its good geotechnical propereties, The kaolinite used in this study was sourced from Guelma. The prepared soil mixture is classified as clayey sand SC according to the unified soil classification system USCS. Table 1 illustrate the physical caracteristics of the tested materials used in this work and Figure 1 presents the grain size distribution curves of the tested materials.

Table 1 Physical caracteristics of the tested materials

	G_s	D_{10}	D_{30}	D_{50}	D_{60}	C_u	C_c	LL	PL	PI
Pure sand	2.66	0.15	0.27	0.4	0.47	3.13	1.03	/	/	/
(65%sand+ 35%kaolin)	2.656	0.018	0.17	0.32	0.38	21.11	4.22	20	12	8

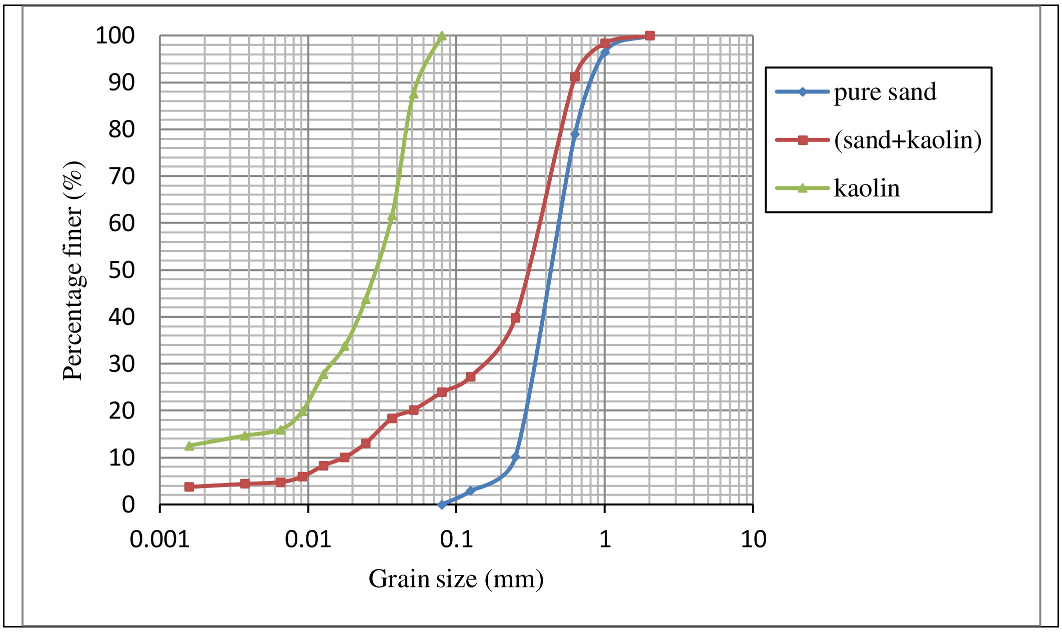

Figure 1 Grain size distribution curves of the tested materials

2.2 *Plastic material*

The empty plastic water bottles were collected from various cafeterias in the province of chlef in Algeria. The plastic bottle waste used in this study was polyethylene terephthalate (PET). After collecting the plastic bottles, they were first cut into small sizes and then into strips. By using a scisor, these strips were then cut into small chips (10mm×10mm).

2.3 *Methodologie*

The stabilization of the sand-clay mixture has been done in this study by using waste plastic bottles at varying percentages by weight of soil. In the present work, the plastic strips mixed in different proportion of (0%, 0.2%, 0.4%, 0.6%, 0.8% and 1%), in order to evaluate the compaction properties and the shear strength parameters.

To investigate the effect of inclusion of waste plastic bottles on compaction properties and the shear strength parameters, standard proctor and direct shear tests were caried out on sand-clay mixture reinforced with plastic strips(PET) at different percentages(0%, 0.2%, 0.4%, 0.6%, 0.8% and 1%).

3 *Results and Discussions*

3.1 *Standard Proctor test*

The Standar Proctor test have been conducted on sand-clay mixture reinforced with waste plastic to determine the optimum moisture content(OMC) and the maximum dry density(MDD).

The results of all the compaction tests carried out in this research are grouped in Figure 2.

From this figure, we notice the impact of the addition of kaolin to the sand which made it possible to densify the material by increasing its maximum dry density from 1.827 to 1.958 and the optimum moisture content from 9.2% to 13.4%. The results also show that the incorporation of polyethylene waste with a small percentage of 0.2% extend the mixture (sand + kaolin) by decreasing its maximum dry density, then when the percentage of polyethylene waste is increased, the material begins to densify to its densest state by adding 0.6%

polyethylene waste. Beyond this percentage, the addition of polyethylene waste becomes unnecessary since it will decrease the dry density of the material. This behaviour is compatible with (Hamid,2017) but the pourcentage of polyethylene waste needed to reache the bigest maximum dry density in his study was found 0.5%.

On the other hand, the inclusion of polyethylene waste decreases the optimum moisture content gradually.

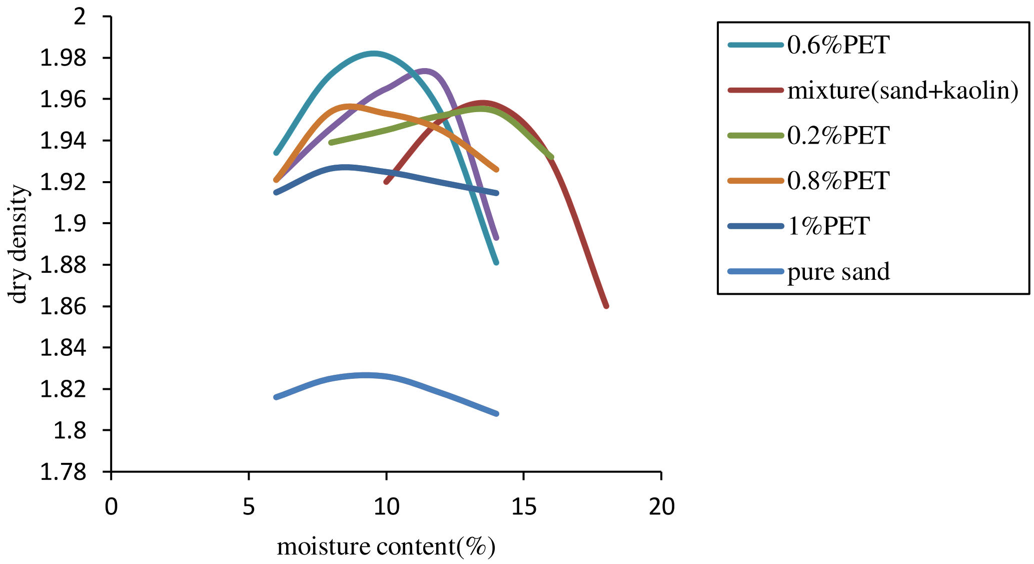

Figure 2: variation in moisture content as a function of dry density for all tested samples.

3.2 *Direct shear test*

3.2.1 *Effect of PET plastic Content on Shear Strength of Sand*

Figures 3 represents shear strength of of the tested materials as a function of horizontal displacement. These direct shear tests were performed under an applied normal stresses of 100,200,300 kPa. The addition of kaolinite to the sand increase the shear strenght from 88 to 91 kPa under a normal stress of 100 kPa, us result that the kaolinite particles fill the voids between the sand grains. For higher normal stresses (200,300 kPa) the inclusion of kaolinite to the sand leads to a decrease in shear strenght. It is also found that the presence of PET plastic content significantly affects the shear stress where a maximum shear stress is observed for the mixture. The mixtures exhibit a typical behavior of a medium dense soil (*Dr* = 50%), with no drop-in strength after the maximum value. It clearly shows that the presence of additional PET plastic in the mixture lead to an improvement in the strength of the soil. Therefore, it can be concluded that the addition of PET plastic aggregate can significantly improve the shear strength of the mixtures. Addition of 0.4% of PET plastic content increases the shear strength of the mixture from 91 kPa to 97 kPa under a normal stress of 100 kPa, but it decreases to 87 kPa for 1% of PET plastic content. This is because in the shear zone the PET plastic surround the mixture grains and tends to roll and slide over them to create more voids. The maximum values of shear strength was found at 0.6% of PET plastic content, 169kpa, 238kpa under normal stresses of 200 and 300kpa, respectively.

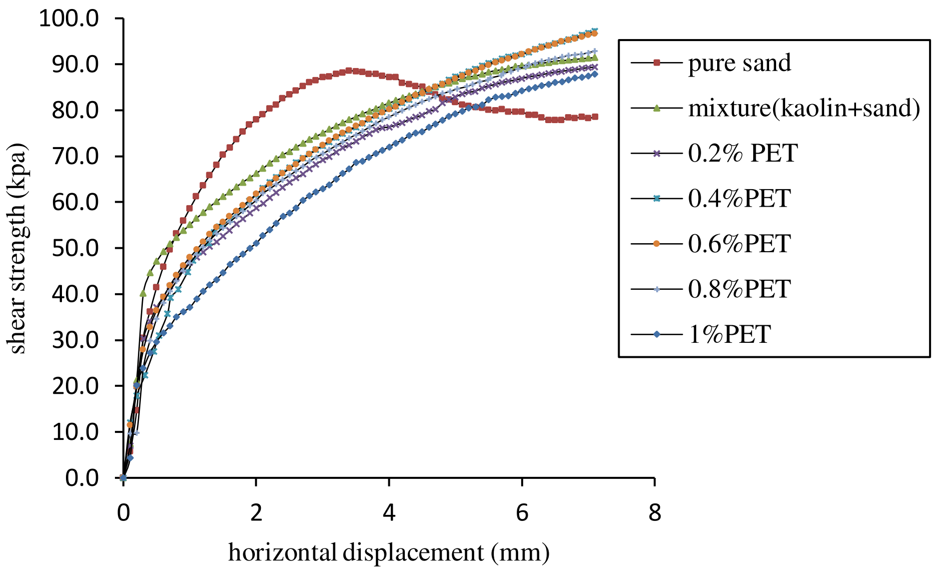

Figure 3 Horizontal displacement versus shear strength under a normal stress of 100kPa

3.2.2 *Effect of Normal Stress on Shear Strength of soil*

The contraction of the mixtures increases with increasing PET content. All the mixtures show contracting behaviour under the effect of shear stress. It is noted that the shear strength of the pure sand , the unreinforced mixture (65% sand+35% kaolin) and reinforced mixture (65% sand+35% kaolin) with PET increases considerably with the increase of the normal stress and this shear strength of the soil becomes greater under higher normal stress which generates an improvement in the contacts between the particles, namely the friction angle.

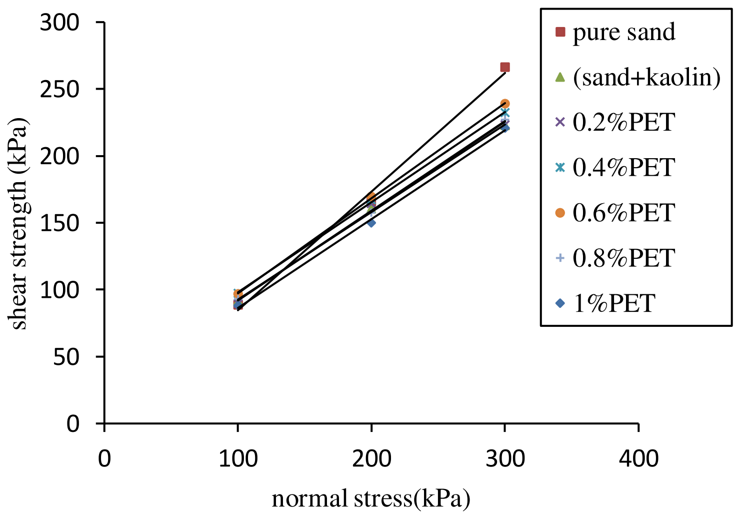

Figure 4 Coulomb failure line

3.2.3 *Effect of PET plastic on the cohesion and friction angle*

The values of cohesion and friction angle for different specimen in the direct shear tests were obtained from the stress-strain graphs by plotting the Mohr-Coloumb failure envelopes.The inclusion of PET plastic to the mixture at different plastic content enhaced both the cohesion and friction angle.

As shown in figure 5, addition of 0.4% of PET plastic to the mixture increase the cohesion from 27.13 kPa to a maximum value of 30.65 kPa.

Inclusion of 0.6% of PET plastic to the mixture increase the friction angle from 33.18° to a maximum value of 35.41°(figure 6).

Enhacement of both cohesion and friction angle is result of contact between plastic particles and soil particles.

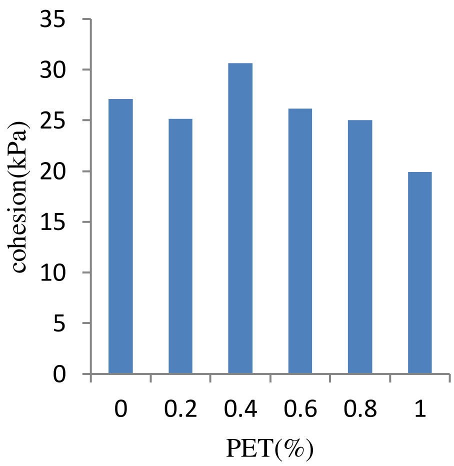

Figure 5 PET percentage versus cohesion

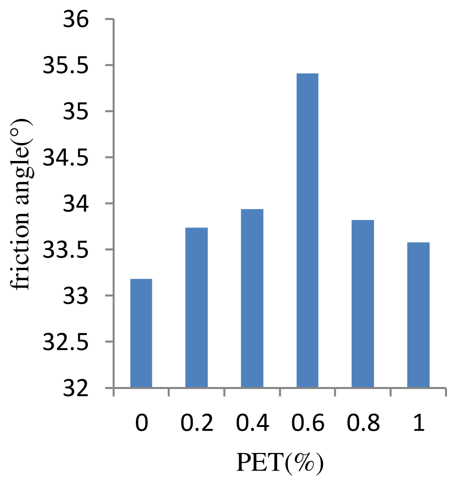

Figure 6 PET percentage versus friction angle

4 *Conclusion*

The current study represents a systematic engineering study on enhacing the geotechnical properties of the mixture(sand+kolin) using polyethylene waste plastic(PET).

The locally availaible water bottles plastic waste was cut into sheets , then mixed with mixture (sand +kaolin) at 0%, 0.2%, 0.4%, 0.6%, 0.8%, 1% (by dry weight of soil).

The effect of PET plastic on the geotechnical properties of the mixture(sand+kaolin) was investigated through a series of proctor and direct shear tests. The following conclusions have emerged from this study :

The incorporation of PET plastic into the mixture significantly altered its engineering properties. It effectively filled the pore spaces, leading to a notable increase in maximum dry density and a reduction in optimum moisture content. Specifically, the addition of 0.6% PET plastic resulted in the highest dry density recorded at 1.958 g/cm³.

Furthermore, integrating 0.4% PET plastic content enhanced the mixture's shear strength from 91 kPa to 97 kPa under a normal stress of 100 kPa. It also elevated the cohesion from 27.13 kPa to a peak value of 30.65 kPa.

The highest shear strength values were observed at 0.6% PET plastic content, measuring 169 kPa and 238 kPa under normal stresses of 200 kPa and 300 kPa, respectively. Additionally, the friction angle increased to 35.41° at this percentage of PET plastic content.

5 *References*

Peddaiah, S., Burman, A., & Sreedeep, S. (2018). Experimental study on effect of waste plastic bottle strips in soil improvement. *Geotechnical and Geological Engineering*, *36*(5), 2907-2920.

Tanegonbadi, B., Noorzad, R., & Shakery, P. (2021). Engineering properties of sand reinforced with plastic waste. *Scientia Iranica*, *28*(3), 1212-1222.

Kassa, R. B., Workie, T., Abdela, A., Fekade, M., Saleh, M., & Dejene, Y. (2020). Soil stabilization using waste plastic materials. *Open Journal of Civil Engineering*, *10*(1), 55-68.

Hamid, A. (2000). Use of Waste Plastics for the Enhancement of Soil Properties: A Recent Advancement in Geotechnical Engineering.

Hamid, A. (2017). Use of waste plastics for the enhancement of soil properties: a recent advancement in geotechnical engineering. *International Journal of Engineering Research & Technology*, *6*(7), 102-111.

Pal, S., Maity, J., & Chattopadhyay, B. C. (2018). APPLICATION OF WASTE PLASTIC BOTTLE FOR THE IMPROVEMENT OF ALLUVIAL SOIL. *International Research Journal of Engineering and Technology*, *5*, 2158-2161.