Polyethylene Terephthalate Strips as a Soil reinforcement

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Summary

This paper summarizes several valuable results derived from the complex experimental program conducted at our university on soil improvement. Here we present the most important observations pertinent to applications of waste material as potential soil reinforcement. In particular, an applicability of polyethylene terephthalate strips cut from soft drink bottles is discussed. Experimental results obtained from both laboratory and in situ measurements show a positive contribution of such a type of reinforcement to the stability of soil structures. However, results derived from the standard isotropic consolidation test suggest that caution should be taken when applying the polyethylene strips to saturated soils.

Introduction

The idea of improving the shearing response of soils has been around for more than a decade or two. Owing to their recent growth in engineering applications, geosynthetic reinforcements such as geotextiles have attracted a large community of researchers. Most of the experimental research, however, has been confined to assessing the pullout resistance of geogrid and geotextile reinforcements under dry condition (unsaturated soils) to make clear the pullout mechanisms of the reinforced soils. Most of the design calculations that employ experimentally derived pullout resistance values were based on limit equilibrium analyses ([1], [2] to cite a few).

Now a new solution is introduced for reuse and recycling ecologically safe waste materials. In a view of our later approach we attempt here to propose a new potential application of the use of polyethylene terephthalate bottle strips as soil reinforcement. The problem with liquidation of the polyethylene bottles is not satisfactory resolved and this way seems to be a good idea of their recycling. For instance, in the Czech Republic the production by the largest company is more then 250 000 000 - water bottles a year.

Direct Shear Test Classical Scale

To assess an applicability of scrap bottles as potential soil reinforcement we started from a standard direct shear test. A sample of clean quartz sand from Provodin (locality in Czech Republic) with grain size ranging from 0,1 – 2 mm was selected for the test. Both reinforced and virgin sands were tested. Reinforced sand was prepared by

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mixing the sand with polyethylene strips having the width equal to 1,5 mm and the length approximately of 20 mm. The degree of reinforcement was maximally 4% of the sand weight. Fig. 1 illustrates the shape of strips and the test setup.

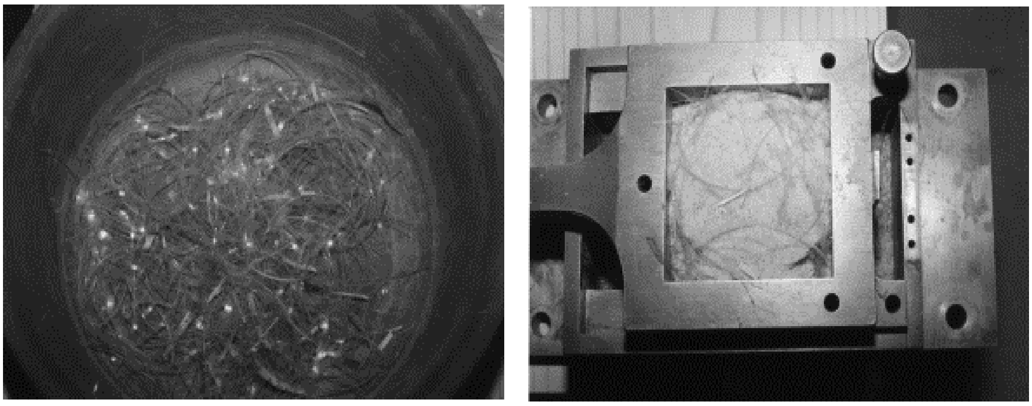


Figure 1: Polyethylene terephthalate strips and test specimen

The positive influence of the reinforcement (Fig. 2 solid line) is manifested by increased stability of the material. Other advantageous are the higher strength, resistance against lateral sliding and limited post peak reduction (the latter effect was observed in the case of lower degree of reinforcement). A slower rise of shear stress of reinforced soil at initial stage can be attributed to insufficient compacting resulting in higher porosity of a sample. From a different point of view, it suggests lower initial wedging of soil grains.

The tensile strength of polyethylene terephthalate strips is fairly incredible (approximately the one half of the steel fiber tensile strength). Stress-strain diagram is presented in Fig. 3. It is worth to note a significantly higher strength of the material when cutting the bottle perpendicularly to its axis as oppose to cuts taken in the axial direction. One of the drawbacks is linked to high compliance of this type of material. The reinforcement thus becomes active not until larger deformations.

To highlight the introduced influence of PET bottles scraps as soil reinforcement, in a small scale, we continued this research on specially prepared large-scale direct shear test apparatus.

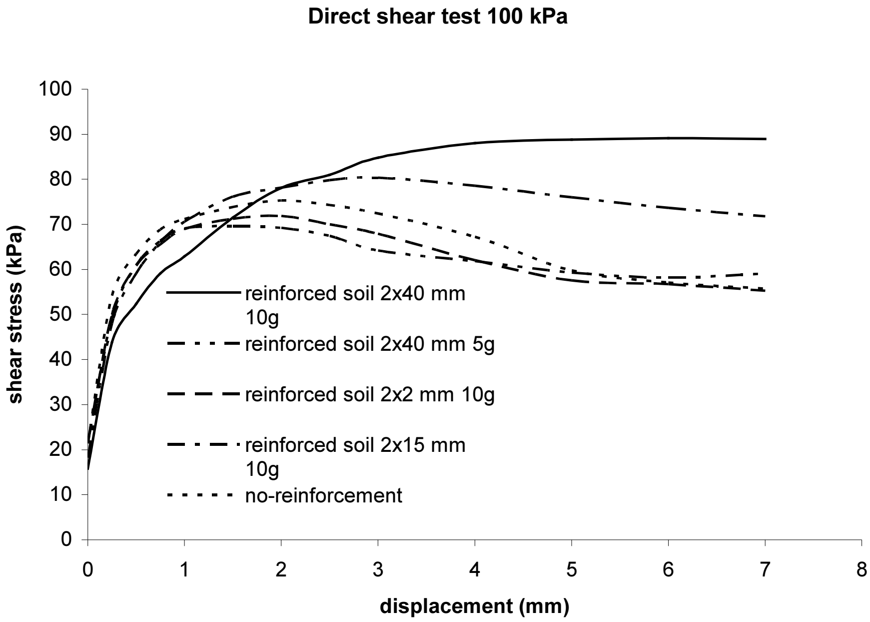
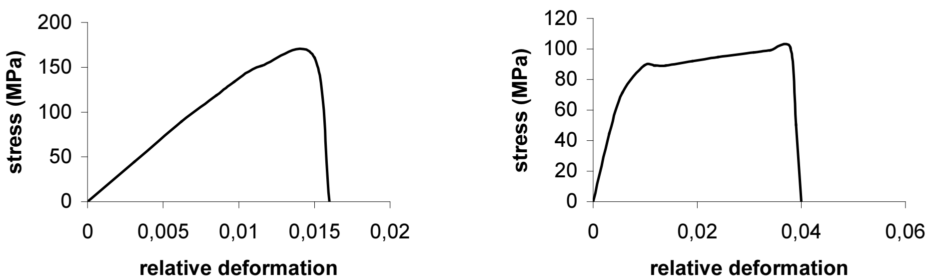


Figure 2: Direct shear stress test working diagram for the normal pressure 100 kPa



(a) (b)

Figure 3: Stress-strain diagrams of polyethylene terephthalate: a) cut in transverse direction, b) cut in axial direction

Direct Shear Test Large Scale

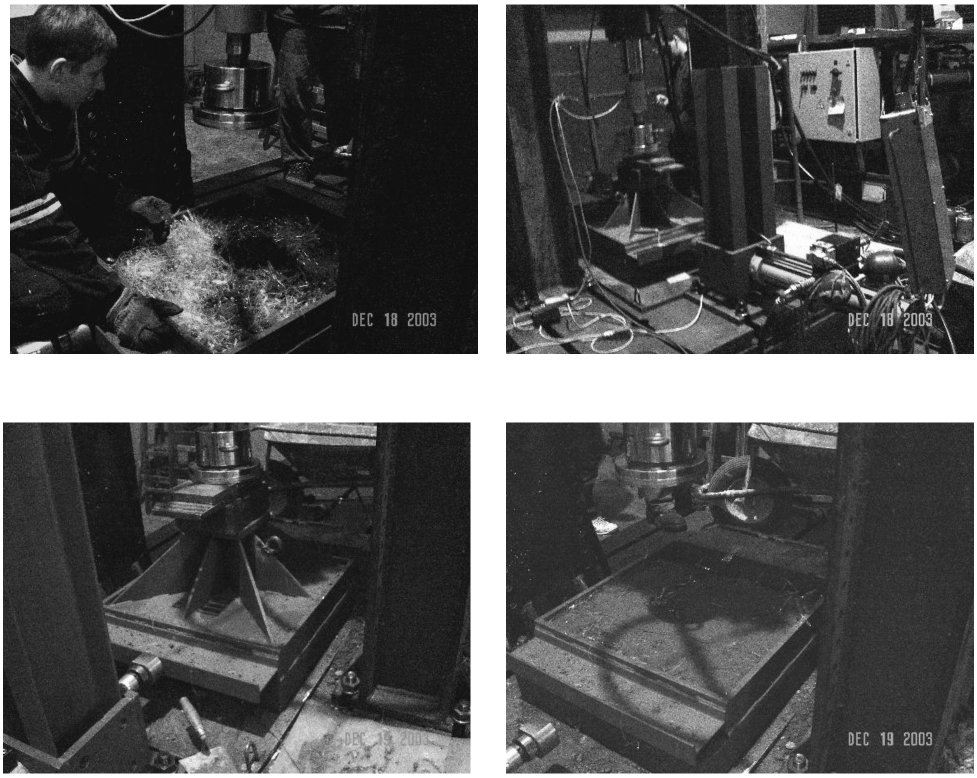


Figure 4: Direct shear test apparatus and sample preparation

The experimental setup appears in Fig. 4. The dimensions of the apparatus box are 600x600x100 mm. The reinforced sample was prepared in several layers mixing the soil with strips of 300 mm in length and 5-7 mm width. Soil with loamy sand grains of size 0,063 - 16 mm was used. The sample was continuously compacted. The results appear in Fig. 5.

Analysis

Experimental measurements alone, however, do not suffice and the back analysis is usually called to substantiate the assumptions used in the design. The tensile strength test of the reinforcement together with its volume fraction and spatial distribution within a soil sample should reveal an actual contribution of the reinforcement to the stability of a soil structure. Nevertheless, it still important to assess the limiting value of the effective stress state, which does not promote a pullout or fracture of the reinforcements. In this regard, the actual volume fraction of reinforcements (degree of reinforcement) plays a significant role.

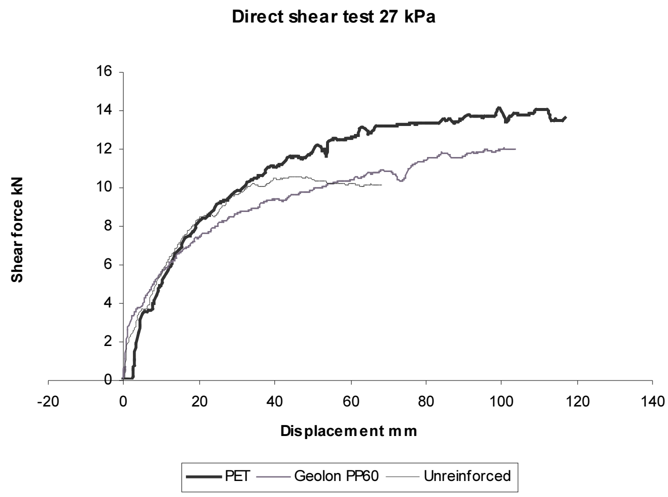


Figure 5: Direct shear stress test working diagram for the normal pressure 27 kPa

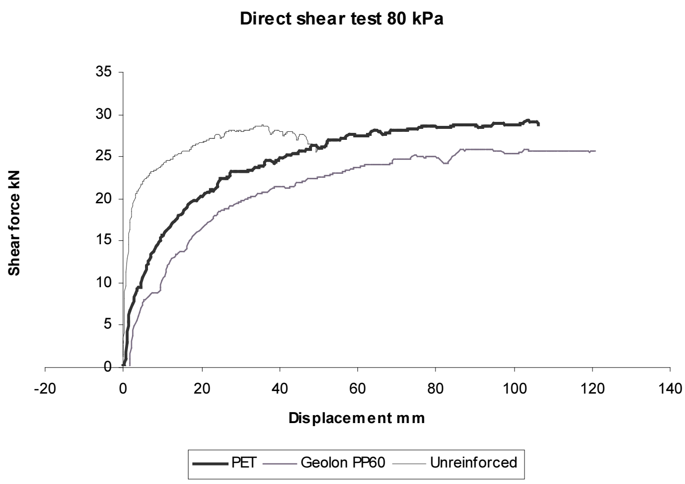


Figure 6: Direct shear stress test working diagram for the normal pressure 80 kPa

A simple limit analysis based method was applied to roughly estimate the effect of reinforcement. Both location and orientation of strips within a sample were assumed to comply with statistically uniform distribution. Providing the failure zone is known (e.g. the predefined slip surface for the direct shear test) it is possible to estimate a number of strips bridging the slip surface. In addition, information about the pull out force and the force required to break a strip are needed. Those are sufficient information to estimate an increase in the shear resistance due to presence of reinforcement. Such a theoretical result can be easily verified using experimental measurements displayed in Fig. 2 (compare the solid and dotted lines). The calculation takes into account both the shape and length of strips. Influence of parameters is clearly demonstrated in Fig. 2. Since in this case the pull out mechanism is decisive, it becomes evident that short strips (2x2 mm) experienced no anchorage length. Similarly, comparing 40 mm and 15 mm long strips reveals an advantage of longer anchorage length for 40 mm long strips. The same result was obtained from the large-scale direct shear test.

Much better theoretical estimation is expected when accounting for the actual microstructure of reinforced soil sample. To that end, images taken from real material samples can be used to assess a spatial distribution of reinforcements and to verify the degree of anchoring of strips inside the soil body.

Conclusion

Both laboratory and in situ measurements proved the applicability of polyethylene therephtalate strips as soil stabilizer. The post peak reduction of the shear bearing capacity was not in general observed. On the other hand the drawback associated with lower initial resistance of reinforced soils (recall lower rate of consolidation in case of reinforced soils) should not be neglected. Much work has yet to be done in assessing optimal shape and amount of reinforcement to exploit its full potential. This problem is still under current investigation.

Acknowledgement

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Reference

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