USING SHREDDED PLASTIC SHOPPING BAGS WASTES IN SOIL IMPROVEMENT

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Abstract

Colossal tonnages of waste are produced each year worldwide, with a considerable amount being in the form of plastic (polyethylene) grocery bags. Most of this is non-degradable and destined for landfill. This study investigated the potential of utilising this type of waste to reinforce soils paving way for its use in civil engineering projects such as in road bases, embankments and structure foundations. A comprehensive test programme was undertaken including direct shear tests on two selected sandy soils. Plastic strips were used as reinforcement inclusions at concentrations of up to 0.3% by weight. The effect of the dimensions of the strip was investigated by varying the length of the strips from 15 to 45 mm and the width from 6 to 18 mm. Shear strength parameters were obtained for each composite material from which analyses were done to identify the extent of the soil improvement. The laboratory experiments favourably suggest that inclusion of these strips in sandy soils would be an effective soil reinforcement method.

Keywords

Environment, Engineering, Geotechnical, Plastic, Soil Reinforcement, Waste.

1. Introduction

Plastic (polyethylene) shopping bags have been used extensively since their first introduction over fifty years ago. These bags are reliable and easily adaptable, very light in weight but strong, highly convenient, inexpensive and readily available everywhere. For these reasons, consumers and businesses alike are depending on them to deliver goods between places. However, their major weakness is that they severely pollute the environment: littering parks and roadsides, clogging sewers and filling landfills (Kalumba and Petersen, 2010). With landfills rapidly filling up, finding a solution to this non-degradable polyethylene waste is key to a sustainable environment. This research, therefore, was undertaken to investigate the potential increase in soil shearing strength when it is reinforced with plastic strips. It was anticipated that positive laboratory results could trigger field applications, success of which would permit reduction of the plastic grocery bag wastes destined to landfills bringing along environmental and economic benefits.

2. Material and Methods

2.1 Plastic Shopping Bag

The materials used in the study were plastic grocery shopping bags sourced from the local Woolworths Supermarket (Woolworths House, 93 Longmarket Street, Cape Town, South Africa). The bags were medium sized and manufactured, from high-density polyethylene by Transpaco, Sixth Street, Wynberg, Johannesburg, South Africa. The material density was measured to average 798 kg/m^3, with the tensile strength ranging between 14 and 20 MPa.

2.2 Soil Material

The two soils used were Cape Flats and Klipheuwel sands which were obtained locally. Both are clean, consistent and easily controllable, making it possible to form identical samples if prepared the same way. Cape Flats sand is uniformly graded medium dense, light grey, clean quartz sand, whereas Klipheuwel sand is uniformly graded medium dense, reddish brown sand. Figure 1 shows the soils grading while Table 1 summarises their physical properties determined according to BS 1377: 1990.

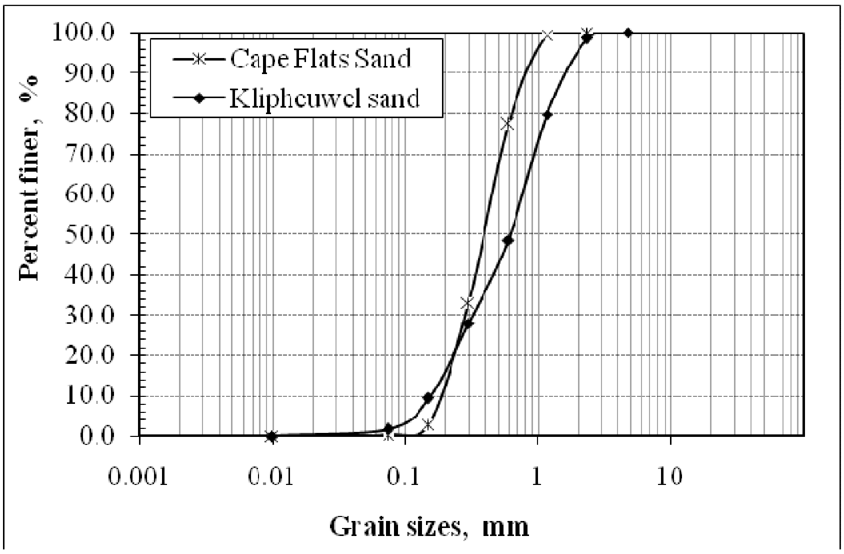

Figure 1. *Soils Grading Graph*

Table 1. *Soils physical properties*

Characteristics	Cape Flats Sand	Klipheuwel sands
Specific gravity	2.66	2.63
Optimum moisture content (%)	15	6.5
Maximum dry density (Mg/m^3)	1.710	1.985
Average densest dry density (Mg/m^3)	1.720	1.824
Average loose dry density (Mg/m^3)	1.538	1.587
Angle of internal friction (°)	33. 9	39.0
Residual shear strength (°)	28.0	35.9
Apparent cohesion (kN/m^2)	9.4	8.2

3. Procedure

The plastic bag material were cut into strips of 5 distinct rectangular dimensions using a guillotine allow for an investigation of the effect of reinforcement length, width and concentration to the soil strength characteristics of the composite material. The 5 reinforcement strips dimensions used were; 6 x 15 mm, 6 x 30 mm, 6 x 45 mm, 12 x 15 mm and 18 x 15 mm. The elements dimensions chosen were in the range of 0.06 – 0.45 of the shear box dimensions so as to control entanglement between the reinforcing strips. Strips entanglement would limit soil particles forming surface attachments with the reinforcement resulting into lower shearing strengths of the composite material (Kalumba and Petersen, 2010). For each testing regime, a predetermined weight of plastic strips of known dimensions was added and mixed randomly with a known mass of dry soil to form a composite material with the required reinforcement concentration. Dry soil was used in all experiments order to eliminate any effect of moisture fluctuations. Three reinforcement concentrations of 0.1, 0.2 and 0.3% by mass were adopted. The low concentration values were based on the fact that although the strips were light in weight, they occupied large volumes. Besides, at those respective concentrations, it was easier to ensure consistency and even distribution of reinforcing elements within the soil sample without entanglement between strips.

With the test samples thoroughly mixed, the composite specimens were poured into the 100mm square direct shear box in three layers compacting each to the required density. Three normal stresses of 25, 50 and 100 kPa and a shear speed of 1.2 mm/min until a residual state were applied. The peak shear stress from each composite sample was then recorded for the respective applied normal stresses. These values were plotted against normal stress to determine the friction angles for particular composite material tested.

4. Test Results and Discussion

In Figures 2 to 4, the relationship between the friction angle and the studied reinforcement parameters are plotted. It is clear from Figure 2 that addition of high-density polyethylene strips of any length enhances the peak friction angle for both Cape Flats and Klipheuwel sands. Studying the effect of lengthening the reinforcement shows a non-linear relationship with each sandy soil exhibiting a unique characteristic response (Figure 2a). In the Cape Flats, the soil shear strength improved with increased strip length over specified lengths of 15 and 45 mm, dropping when strips 30 mm long were used. It is likely that this point could have been an anomaly in that test. The results also displayed that when the fibre length was increased in the Klipheuwel sand, the soil friction angle also became better peaking with the 15 mm long strip elements (shortest strips tested). Therefore, it is likely that there are limiting plastic strip lengths in the soil composites where the reinforcements intersect potential failure surfaces most effectively in the soil mass. Beyond this limit any reinforcement lengthening results in decreases in the shear strength.

In Figure 2b, the effect of reinforcement width on composite peak friction angle is shown. It is demonstrated that the inclusion of plastic strips significantly raises the peak shear strength. Further testing revealed that beyond a specific reinforcement width of 6 mm (narrowest strip tested), the strength decreased. It is possible that more testing could have revealed that the greatest strength gain occurs for strips narrower than 6mm. These results suggest that the gains in strength decrease as the reinforcement strips widen. The plastic material used in this study being smooth, it is likely that when longer and wider strips are used, they overlap each other more during shearing thereby reducing the soil/reinforcement interaction. As expected, there would be less friction generated between strips than between soil and embedded strips. It was again observed that Klipheuwel composites generally had higher peak friction angles.

The results of effect of the quantity of strips in the soil/reinforcement system are shown in Figure 3. It is observed that there was an increment from the initial friction angle of 33.9° in the Cape Flats sand, to 41.7° for the 0.1% concentration composite, after which there was an almost linear increase in the friction angle with concentration. The pattern in Klipheuwel composites was however different. In Klipheuwel, the reinforcement concentration considerably increased the peak friction angle initially. However; further testing revealed that beyond the reinforcement concentration of 0.15 the strength decreased. It can be concluded that for various soils, with different grading, independent tests would need to be conducted to determine the individual soil strength enhancement performances. The laboratory experiments also favourably suggest that inclusion of polyethylene strips in sandy soils would be an effective soil reinforcement method.

Analysis of the results, in Figure 4 shows that there is a general increase in friction angle at lower aspect ratios in both types of sands. However, the friction angles peak at the aspect ratio of 0.4, beyond which the gains in shear strength (tan phi) start to reduce.

Assessment of the laboratory test results shows that inclusion of polyethylene strips in both sands, results in a definite increase in shear strength (tan phi). Strains in the soil mass generated strains in the strips, which in turn, generated tensile loads in the strips. These tensile loads acted to restrict soil movements and thus impart additional shear strength. This resulted in the composite soil/strip system having significantly greater strength than the soil mass alone. Polyethylene as a material has low frictional properties and therefore interacts with the soil particles in a unique way. Instead of particles adhering to the polyethylene surface, the particles ‘punched’ and moulded around the ‘soft’ strips. As the vertical load was applied and increased this ‘punching’ became amplified, and due to the fact that this material has good elongation characteristics it could withstand the high strains.

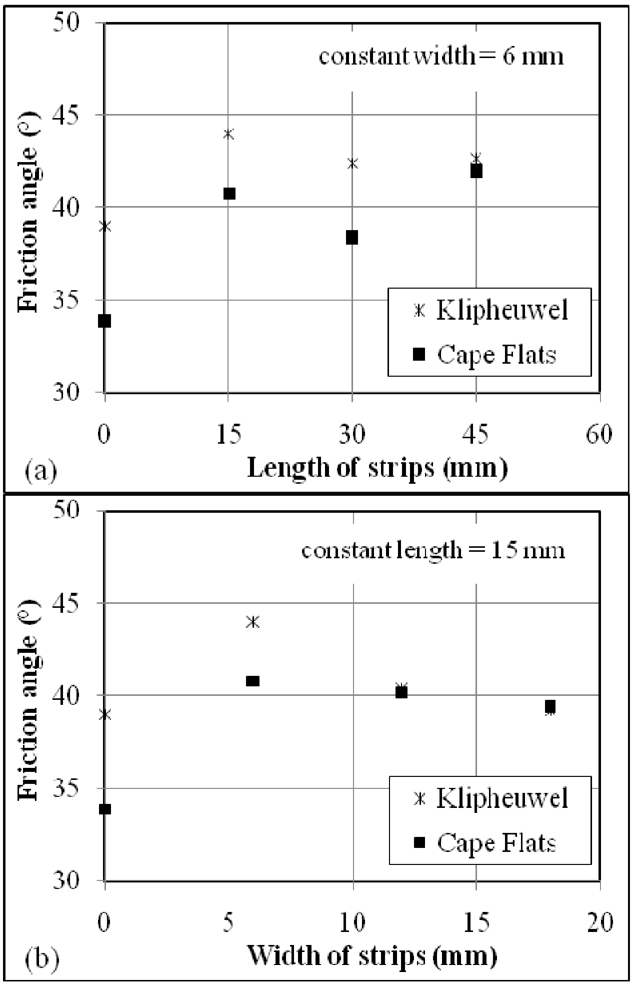

Figure 2. *The friction angle versus reinforcement (a) width, and (b) width*

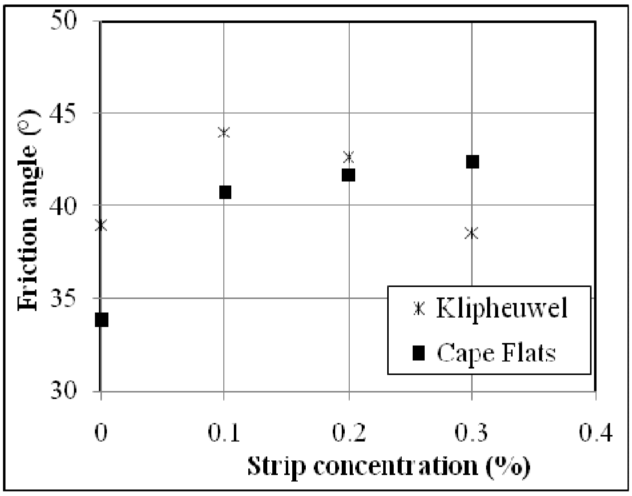

Figure 3. *The friction angle versus reinforcement concentration*

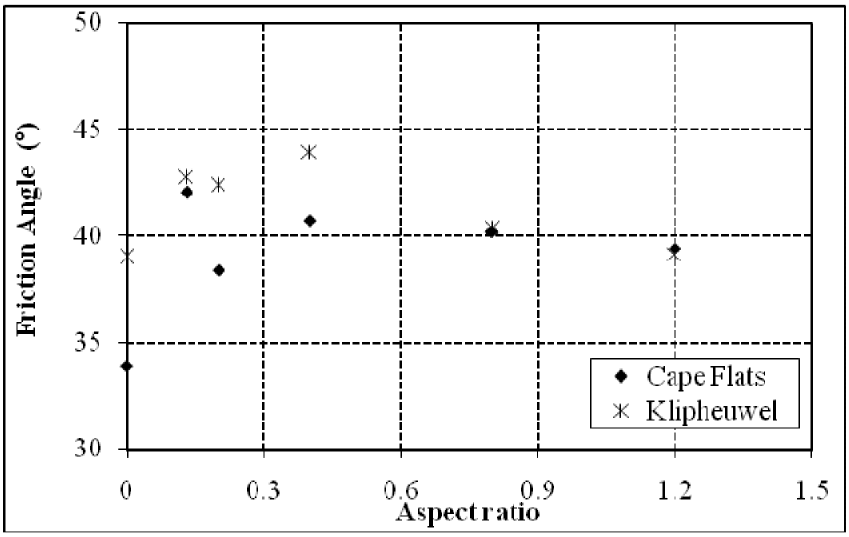

Figure 4. *The friction angle versus aspect ratio (after Petersen, 2009)*

5. Conclusions

It can be concluded from this work that:
Inclusion of plastics sourced from shopping grocery bags can result to an increase of more than 20% in angle of internal friction. Consequently, this can result in significant enhancement in shear strength and soil bearing capacity.
The addition of the strips improved the angle of internal friction but lengthening and widening the strips reduced the improvement. The optimum reinforcement aspect ratio was 0.4.
The results are, however, specific to the particular type of plastic shopping bag used and the soil with which the reinforcement was mixed. In order to properly document behaviour, testing in a range of soil types with inclusion of plastics from different sources, thickness and roughness is recommended.

References

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