Strength Characteristics of Subgrade Soil Stabilized with Plastic Bag Strips

Vismaya A.,Monica Simon, P. K.Jayasree and Leema Peter

[1] College of Engineering Trivandrum, 695016, Kerala, India, vismaya.av@gmail.com
[2] College of Engineering Trivandrum, 695016, Kerala, India, monicasimon100@gmail.com
[3] College of Engineering Trivandrum, 695016, Kerala, India, jayasreepk@cet.ac.in
[4] College of Engineering Trivandrum, 695016, Kerala, India, leema.cet@gmail.com

Abstract. Plastic is perhaps the most dangerous scrap and pollution it causes has become a villain to the society. For the betterment of our planet we must use and recycle the plastic in a fruitful way. During recycling process due to melting of plastic, toxic gases are released. One of the effective ways to manage plastic waste is using it for soil stabilization. This study investigated the possibility of utilizing plastic bag waste for the reinforcement of soils. The effects of variation in thickness and aspect ratio on strength characteristics were studied in this work. The various thickness ranges used were 15μm, 30μm, and 45μmand waste plastic carry bag strips were added at 0.1%, 0.2% and 0.3% concentration. The unconfined compressive strength test wasconducted, and the results obtained favorably suggest that up to an optimum value, shear strength increases with increase in plastic content.An improved UCS value was achieved at 0.2% plastic content having an aspect ratio of 2.5.Results of experimental studies on soil reinforced with plastic waste showed that, plastic can be effectively used as stabilizing material so as to solve environmental issues.

Keywords: plastic waste, stabilization, shear strength, thickness

1 Introduction

The rapid development of urban areas and the increase in construction activities have resulted in a scarcity of land with favorable soil conditions, necessitating the use of locally available weak soils for construction activities through stabilization techniques. Soil stabilization can be explained as the improvement in soil properties by chemical, physical or biological means in order to enhance the engineering quality of the natural soil. This process is accomplished using a wide variety of additives, including lime, cement, ground granulated blast furnace slag (GGBS), fly ash (FA), and bottom ash (BA) and they are highly expensive. However, using lime and cement raise environmental concerns and are not preferred nowadays. Due to the increasing cost and the harmful effects produced by the additives, alternative methods for soil stabilization are to be found.

Plastic waste is a major issue in urban and rural areas in India. Littering of plastic waste and its by-products may lead to major health concerns for all living beings. These days, plastic becomes essential part of our lives; however, the data on plastic pollution is shocking. It is produced on a massive scale worldwide and its production crosses 150 million tons per year globally. For the environmentally conscious citizens and organizations, disposing off the non-biodegradable used plastic bottles has become a major concern. Approximately 600 billion bottles are discarded every year all around the world and only 47% are collected[1].

Therefore, the garbage products should be disposed properly for the better future.The efficient method to handle such wastes is to utilize them for engineering applications. Nowadays, recycled HDPE are used for fence line posts of guard rail posts for highways and light weight reinforcing inclusions in concrete. The plastic waste can be used as areinforcing material in weak soils. This improves its strengthcharacteristics and it is a way of recycling these materials in anefficient, environment friendly and cost-effective manner[2].In this study, effect of plastic waste covers on the strength characteristics of subgrade soil is investigated. Prediction of pavement performance becomes difficult if unconventional materials are used as a part of pavement structure[3].Therefore, in the present study the strength characteristics of subgrade soil stabilized with plastic bag strips was studied. The unconfined compressive strength (UCS)tests were carried out by varying the percentage and thickness of the plastic strips added. The results obtained clearly show that plastic cover strips can be used as an effective reinforcing material.

2 Investigations on Soil Stabilized with Plastic Waste

Recycling of plastics is a promising alternative for plastic waste management. Recently many research studies have been made on the effective reuse of plastic waste in civil engineering constructions. Plastic waste was mixed with cement [4] to produce sturdy and flexible concrete slabs.In India, now it has become a rule for all road manufacturers to use plastic waste, along with bituminous mixes, for road construction. A new tensile force resisting material calledreclaimed High-Density Polyethylene(HDPE)was introduced and reinforced to locally available sandy soil toenhance the engineering property of sub-grade soil [5].

Research studies were conducted to check the alternative of stabilizing soils using waste plastics in the form of bottles and bags. Experiments were conducted on clayey soil to find out the consolidation characteristics of soil stabilized with plastic waste and found that the plastic waste stabilized specimen exhibited a lower initial void ratio [6].Waste plastic stripsof appropriate size and proportionswere added to locally available sand which results in increase in both the CBR and secant modulus.It may be due to the increased friction between reinforcing material and soil [7].

Recently, industrialized and developing countries are greatly fascinated to use industrial waste in road construction and it is based on technical, economical, and ecological considerations.Absence of prevalent materials and improvement of the environment makes it compulsory to search for replacement, comprising that of industrial

wastes. Industrial wastes (e.g., fly ash, slag, and mine tailing) have combined with lime and cement to enhance the geotechnical properties of subgrade soil. Polypropylene was added in the form of fibers to siltysoil stabilized with lime and rice husk ash [8]. The addition of fibers resulted in a decrement of the friction angle while the cohesion of the mixture boosted initially and then dropped with addition of fiber content, and the largest value was obtained at 0.4% fiber content.

The use of waste poly-ethylene material for soil stabilization can be considered as an eco-friendly method for soil stabilization [9]. To understand moreabout the behavior of HDPE plastic strips,perforated HDPE strips were used to reinforce sandy soils and it was found that the reinforced soil exhibits the maximum angle of internal friction at 0.1% strip content only with width of 6 mm and perforation diameter of 2 mm [10]. It was also seen that the longer and wider strips resulted in strength deduction.

Production of poly-ethylene grains as a stabilizing soil material has a lower carbon footprint than cement or other hydraulic binders. As a sustainable solution to shallowslope failures,fiber reinforced recycled plastic pins (RPP) were exerted into the slope face, which gavemore resistance along the slip surface, adding the factor of safety against shallow slopefailure [11].

3 Experimental Studies

3.1Materials Used

Waste plastic covers used in the study were collected from the institution premises. The thickness ranges used were 15µm, 30µm and 45µm. Theproperties of plastic [12] are shown in Table 1.The soil for stabilization was collected from a road construction site atMangalapuram, Trivandrum which was found to be clayey in nature upon visual inspection. The soil was classified as MH [13]. The soil properties are tabulated in Table 2.

Table 1.Properties of plastic waste

Thickness (µm)	Tensile stiffness (kN/m)
15	0.5
30	0.9
45	1.2

Table 2: Properties of soil

Property	Value
Specific gravity	2.56
Gravel (%)	1
Sand (%)	40
Silt (%)	32
Clay (%)	27
Liquid limit (%)	53
Plastic limit (%)	37
Plasticity index (%)	16
Shrinkage limit (%)	22
MDD (g/cc)	1.6
OMC (%)	20.5
UCS(kN/m^2)	49
CBR (%)	3

3.2 Methodology

The plastic covers were cut into strips of size 12 mm x 30 mm (Fig. 1,having an aspect ratio of 2.5) using scissors and measuring ruler. UCS testswere conducted on plain soil and on soil reinforced with plastic strips with varying percentages of 0.1, 0.2 and 0.3. The effects of thickness of plastic strips on the strength characteristics of reinforced soil were also studied.

Fig.1. Plastic strips

4 Results and Discussion

4.1 Effect of Thickness of Plastic Strips on UCS of soil

The stress-strain relationships fromUCS tests for soilreinforced with plastic strips of varying thicknesses 15 µm, 30 µm and 45 µm are presented in Figs. 2, 3 and 4 respectively.The results of unreinforced and reinforced specimens are included for the purpose of comparison. The unreinforced specimens exhibited brittle failurewhereas the reinforced specimensexhibited ductile behavior. Generally, increased strain to failure of the fiber-reinforced specimens resulted in improved toughness of the specimens. Toughness is a measure of a specimen's ability to absorb energy during fracture.

For 0.2% addition of plastic strips with thickness 15 µm, 30 µm and 45 µmmaximum value of UCS obtained was 92 kN/m^2, 106 kN/m^2 and 174 kN/m^2 respectively (Figs. 2, 3 and 4). The UCS value increases with the thickness of plastic strips. This is because the tensile stiffness of plastic increases with its thickness which ultimately affects the strength of soil.

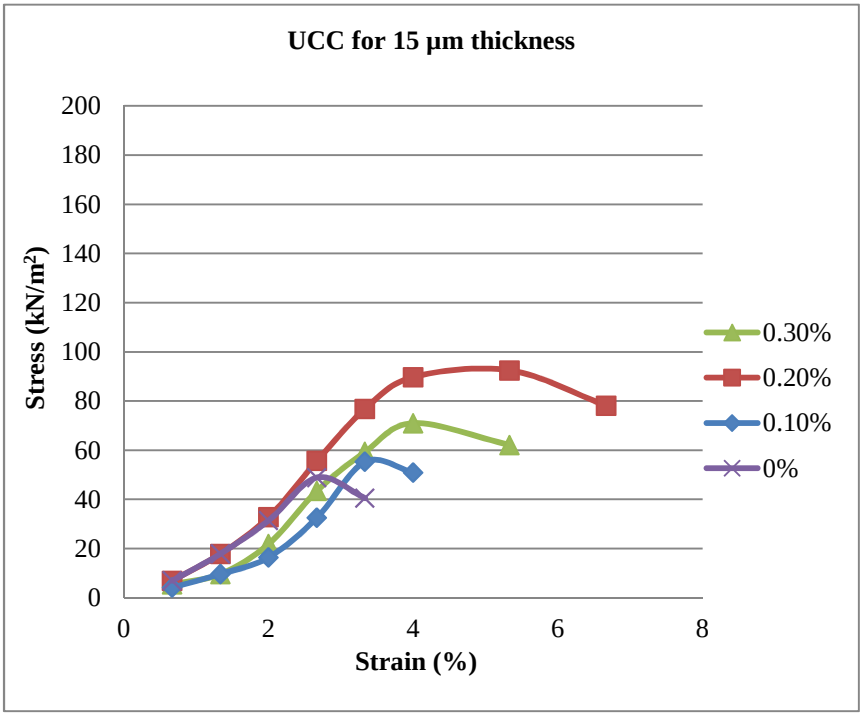

Fig. 2.UCS results for soil reinforced with plastic strips of thickness 15µm

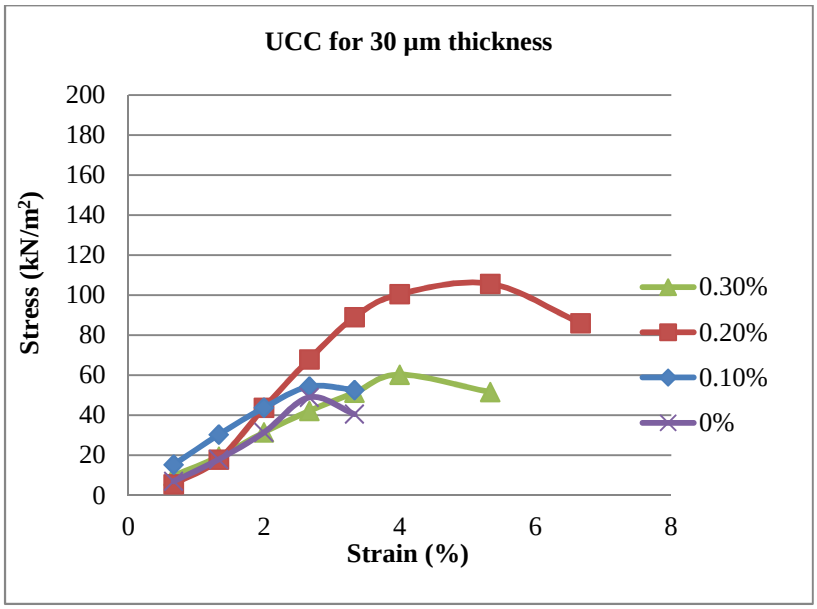

Fig. 3.UCS results for soil reinforced with plastic strips of thickness 30µm

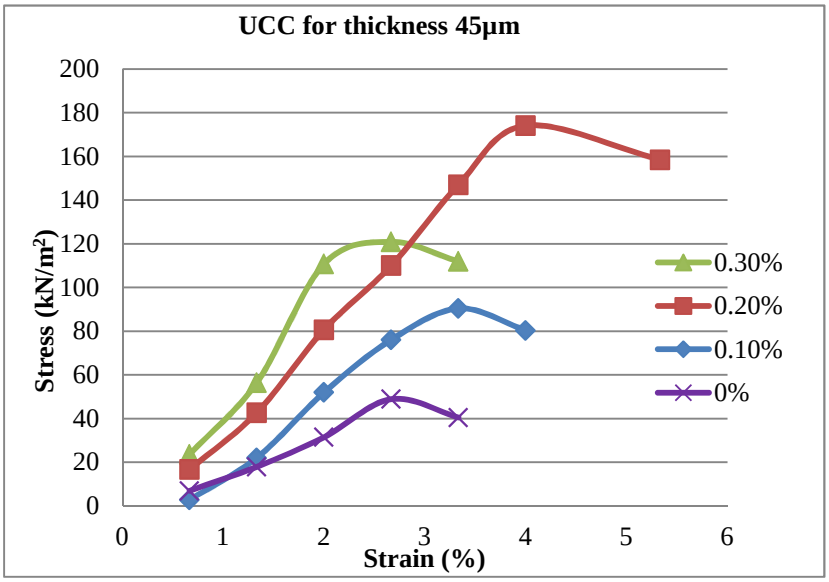

Fig. 4.UCS results for soil reinforced with plastic strips of thickness 45µm

4.2 Effect of Plastic content on strength of soil

The variation of UCS with the plastic content is shown in Fig. 5. The strength increases up to 0.2 % of plastic content for all the thickness ranges and then decreases.This may be due to due to increase in total contact area between plastic strips and soil particles. The increase in plastic content consequently increased the friction between the soil particles which contributes to increasing resistance to the forces applied.Beyond 0.2% addition of plastic, UCS value decreased due to increased interaction between the plastic strips due to more overlapping of plastic and it results in reduced soil plastic interaction.

The maximum compressive strength was obtained for soil reinforced with plastic strips having a thickness of 45 µm. Hence there is an improvement in strength with the addition of plastic strips when compared to that of unreinforced soil. Similarly the variation of strain at failure with the plastic content was shown in Fig. 6. The maximum value of strain was obtained at 0.2% plastic content which is higher than that of the unreinforced soil. Thus the inclusion of plastic strips reduces the brittleness behavior of soil.

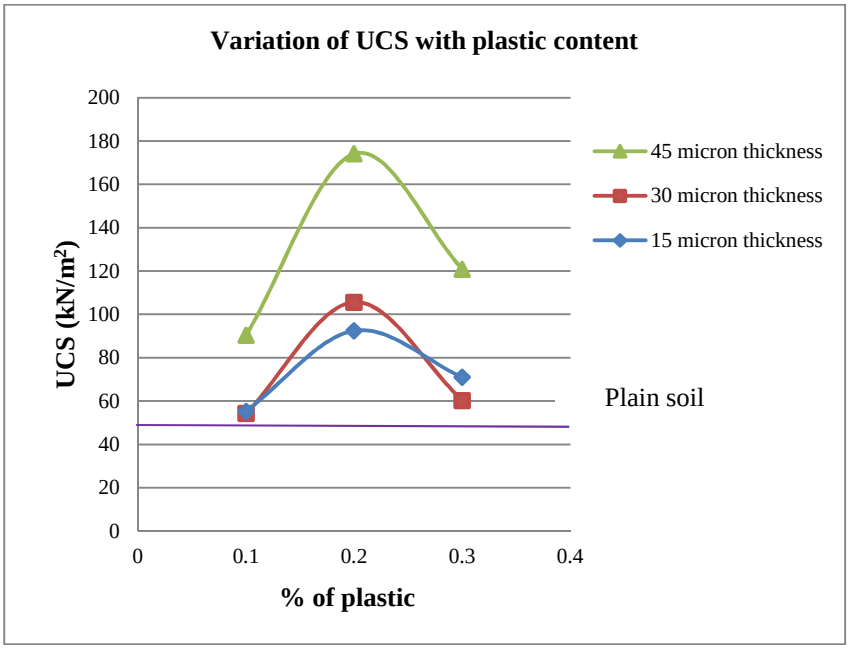

Fig. 5. Variation of UCS with plastic content

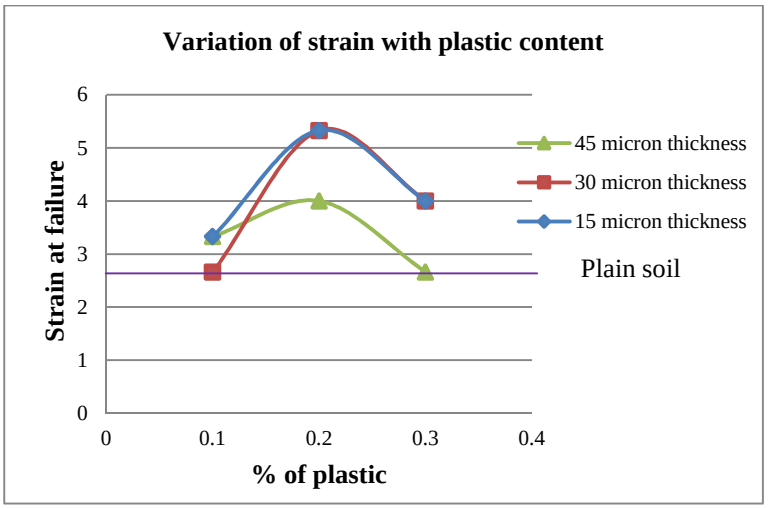

Fig. 6. Variation of strain at failure with plastic content

5 Conclusions

- The effect of plastic waste in improving soil properties mainly depends on strip size, plastic content and the type. The plastic added in the form of strips is more beneficial in improving the strength characteristics.
- The behavior of soil when reinforced with different concentrations of plastic showed almost same trend. There is a significant improvement in strength characteristics at an optimum percentage depending upon the type of soil.
- The maximum value of UCS is obtained for soil reinforced with 0.2 % plastic content having an aspect ratio of 2.5. Soil stabilized with plastic strips of thickness 45µm is having maximum compressive strength.

The tests are done with only one aspect ratio. Further tests are needed to find the variation in aspect ratio on the strength characteristics. When the types of plastic strips are varied i.e. PET, HDPE or combinations of them are used then the quantum of improvement of different soil parameters would be different. Further tests are needed to exactly quantify their effects on soil improvement.

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