Visakhapatnam Chapter

Proceedings of Indian Geotechnical Conference 2020
December 17-19, 2020, Andhra University, Visakhapatnam

Strength and Deformation Characteristics of Subgrade Soil Stabilized with Plastic Covers

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Abstract. The plastic waste is one of the burning issues in the present scenario due to the harmful effects produced by it. The recycling of plastic releases toxic gases during the melting of plastic and the major portion of plastic waste ends up in landfill which results in the leaching of toxic substances to the soil. Soil stabilization is one of the effective ways for plastic waste management. This new technique can be productively used to meet the problems raised by plastic waste and also it is a good solution for the scarcity of good quality subgrade soil. This study investigated the possibility of utilizing plastic cover strips for the reinforcement of soils. The effect of variation in aspect ratio and thickness on strength characteristics is studied in this paper. The various thickness ranges used are 15 micron, 30 micron and 45 micron and the aspect ratio used are 1 and 2. Unconfined compressive strength (UCC) tests are carried out with plastic contents of 0.1% to 0.7% and the optimum amount required is found out. Laboratory results obtained favorably suggest that shear strength increases up to an optimum value, with the increase in plastic content and the longer and wider strips leads to strength reduction. Thus the use of plastic waste in subgrade soil improves its strength as well reduces the thickness of pavement layer.

Keywords: plastic waste; stabilization; shear strength; aspect ratio; thickness

1 Introduction

The fast growth of population and the resulting increase in construction activities leads to the scarcity of land with desirable soil conditions. Nowadays, Engineers were forced to the use problematic soils for construction purposes through various stabilization methods. Soil stabilization can be explained as the technique of improving the performance of soil by chemical, physical or biological means and thereby making it suitable for construction activities. This process can be achieved by mixing soil with several admixtures like lime, cement, calcium chloride, fly ash and bituminous materials but they are highly expensive. The stabilization using lime and cement results in various environmental issues and are not adopted nowadays. Due to the increasing cost and the harmful effects produced by the additives, alternative methods for soil stabilization are to be found.

Plastic becomes an integral part of our lives. It is produced on a gigantic scale all over the world and its global production exceeds 150 million tons per year [1]. The plastic waste being non biodegradable, they are mainly disposed by burning that releases toxic gases harmful to the health. Therefore, the plastic products should be disposed properly for the better future. Recycling of plastics is a promising alternative for plastic waste management, but it can be done up to 3 to 4 times. The impact of using plastic waste in civil engineering constructions were analyzed by various researchers. Plastic waste was mixed with cement [2] 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. Reclaimed High-Density Polyethylene (HDPE) which resists tensile force was used to reinforce locally available sandy soil to enhance its engineering properties [3]. Research studies were conducted to check the alternative of stabilizing soils using waste plastics in the form of bottles and bags. In order to find out the consolidation characteristics, experiments were performed on clayey soil and found that the plastic waste stabilized specimen obtains a lower initial void ratio [4]. Higher values of CBR were achieved upon adding plastic strips of particular size and amount to locally available sand at 4% plastic content [5].

Due to the harmful effects caused by the industrial waste, many developing countries were forced to use them in the road construction and it is based on technical, economical, and ecological considerations. The characteristics of clayey soil were enhanced by the introduction of industrial wastes combined with lime and cement. The decrement of the friction angle were attained on the inclusion of Polypropylene in the form of fibers to silty soil treated with lime and rice husk ash [6] while cohesive nature of the mixture boosted initially and then dropped with further addition of fiber, and the optimum value was obtained at 0.4% fiber content. The utilization of waste polyethylene material for soil stabilization can be considered as an eco-friendly solution for plastic waste management [7]. The effectiveness of HDPE plastic strips were studied by conducting experiments on both solid and perforated strip reinforced sandy soils and the results indicates that the greater improvement in the friction angle happens at 0.1 % strip content, length of 15 mm and with perforations of 2 mm diameter [8]. It was also seen that the strength reduces considerably beyond the optimum length of plastic strips. The incorporation of plastic bottle strips reduces the compressibility of soil along with higher compressive strength [9]. The use of shredded plastic covers in weak soil has greater influence on strength compared to that of plastic in strip form. The inclusion of finely shredded plastic waste shows greater improvement in strength compared to that of coarsely shredded plastic waste [10].

In this study, potential of plastic covers on the strength and deformation characteristics of sub grade soil is investigated. If unconventional materials are used to replace subgrade, it becomes difficult to predict the pavement performance [11]. Therefore; in the present study the utilization of plastic cover in soil reinforcement were analyzed by performing Unconfined Compressive strength (UCC) tests by the uniform mixing of plastic strips with the soil at different percentages. The UCC tests were also conducted by changing the thickness and aspect ratio (AR) of the plastic strips added.

2 Experimental Studies

2.1 Materials used

Waste plastic covers used for the investigation were locally collected within the thickness ranges of 15µm, 30µm and 45µm. Wide width tensile strength test [12] as per ASTM D 4595 were carried out to find the tensile strength of plastic covers and results obtained are presented in Table 1. The soil was also collected locally which was found to be clayey in nature upon visual inspection. The geotechnical characteristics of soil are summarized in Table 2. The soil was classified as MH [13].

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

2.2 Methodology

The plastic covers were cut into strips of size 10 mm x 10 mm, aspect ratio (AR) = 1 and 20 mm x 10 mm (AR = 2) using scissors and measuring ruler shown in Fig. 1 and Fig. 2. At the initial stage, UCC tests were performed by adding plastic strips (AR = 1) at different amounts ranging from 0.1% to 0.7%. The tests were done for plastic strips of thickness 15 µm, 30 µm and 45 µm. In order to find the effect of aspect ratio tests were also done by changing the size of strips for all the thickness ranges.

Fig. 1. Plastic strips with AR = 1

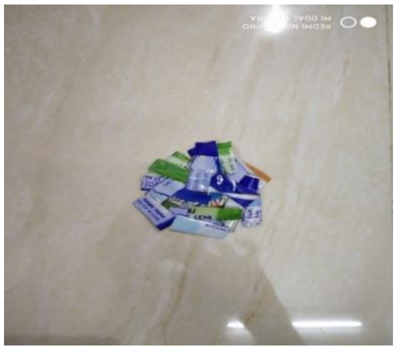

Fig. 2. Plastic strips with AR = 2

3 Results and Discussion

3.1 Effect of thickness and aspect ratio of plastic strips on strength characteristics

The stress-strain relationship of soil obtained by the inclusion of plastic strips of varying thicknesses 15 µm, 30 µm and 45 µm are presented in Figs. 3, 4 and 5 respectively. From the graphs it is clear that introduction of plastic strips in soil increased the peak stress. The UCS of natural soil increases from 49 kPa to 152 kPa for 0.5% plastic mixed soil. The UCS value is found to be decreasing as the percentage of plastic increased beyond 0.5%. Similarly the maximum value of UCS obtained for plastic strips with thickness 30 µm and 45 µm are 78 kPa and 92 kPa respectively at 0.5% plastic content. The strength increases up to an optimum percentage for all the thickness ranges and then decreases. It can be also observed from these figures that strain to reach peak stresses increases with plastic content.

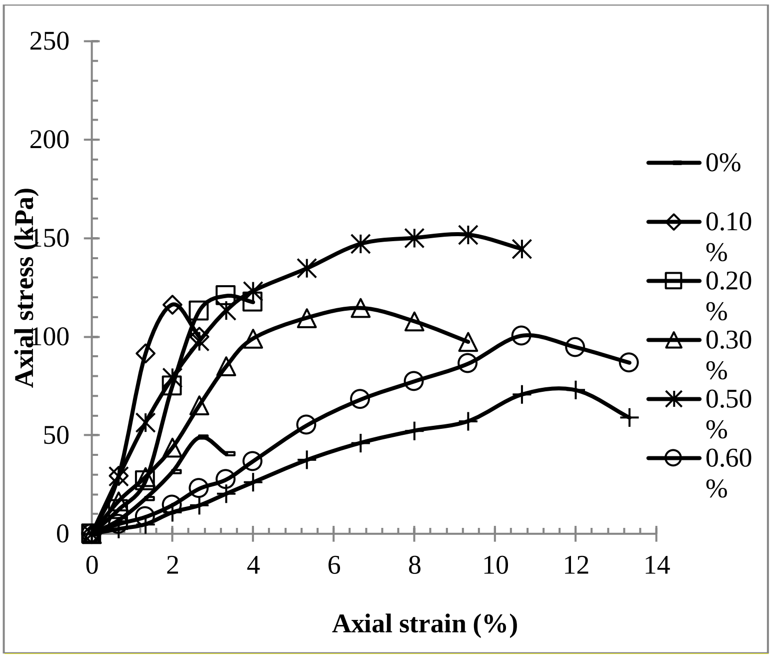

Fig. 3. UCC results of soil treated with plastic strips of thickness 15 µm (AR = 1)

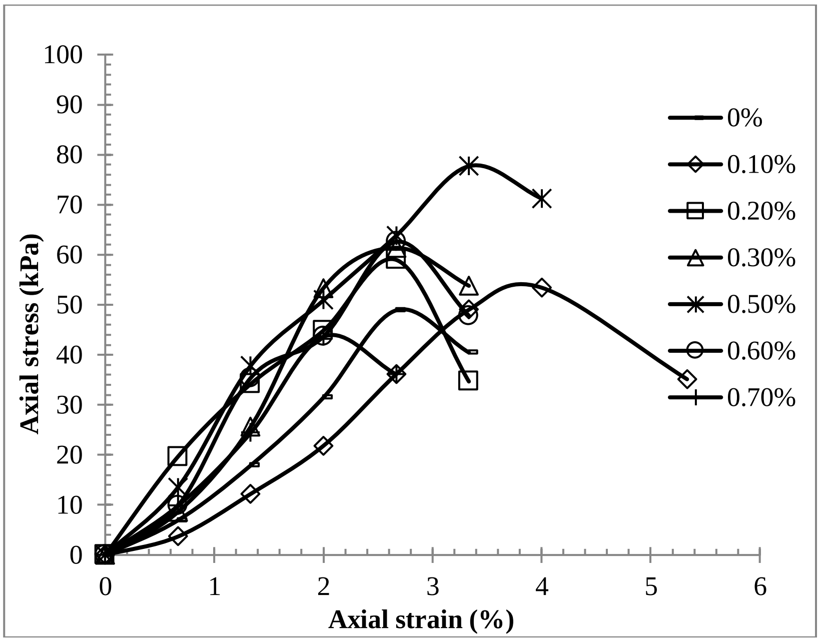

Fig. 4. UCC results of soil treated with plastic strips of thickness 30 µm (AR = 1)

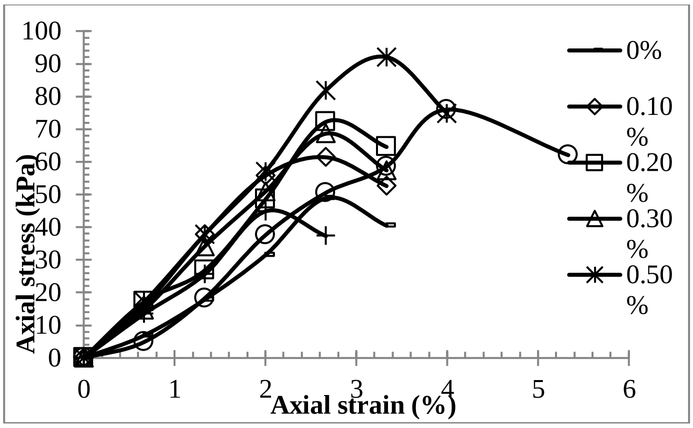

Fig. 5. UCC results of soil treated with plastic strips of thickness 45 µm (AR = 1)

It has already been examined that the plastic strips having a thickness of 15 µm (AR = 1) is having the peak value of compressive strength. This is 3 times more than that of an unreinforced soil. Further tests were also conducted by changing the size of strips to 20 mm x 10 mm (AR = 2) for all the thickness ranges. The results obtained with the change in aspect ratio of plastic strips are shown in Fig.6 & Fig. 7. From the graphs shown it can be inferred that the optimum improvement in UCS is obtained at 0.5% for both the thickness ranges.

The increase in compressive strength may be as a result of increase in total contact area between soil and plastic strips. The addition of plastic strips consequently enhanced the friction between the soil and plastic which leads to tensile stresses in the plastic material which absorbs the more load above the normal soil's capacity.

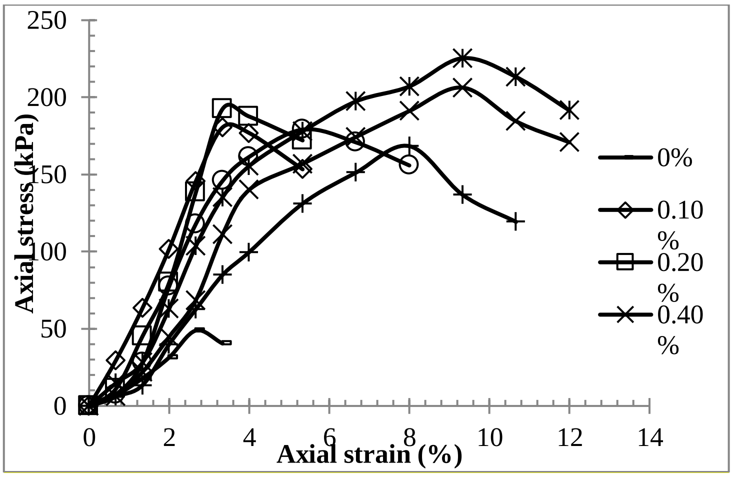

Fig. 6. UCC results of soil treated with plastic strips of thickness 15 µm (AR = 2)

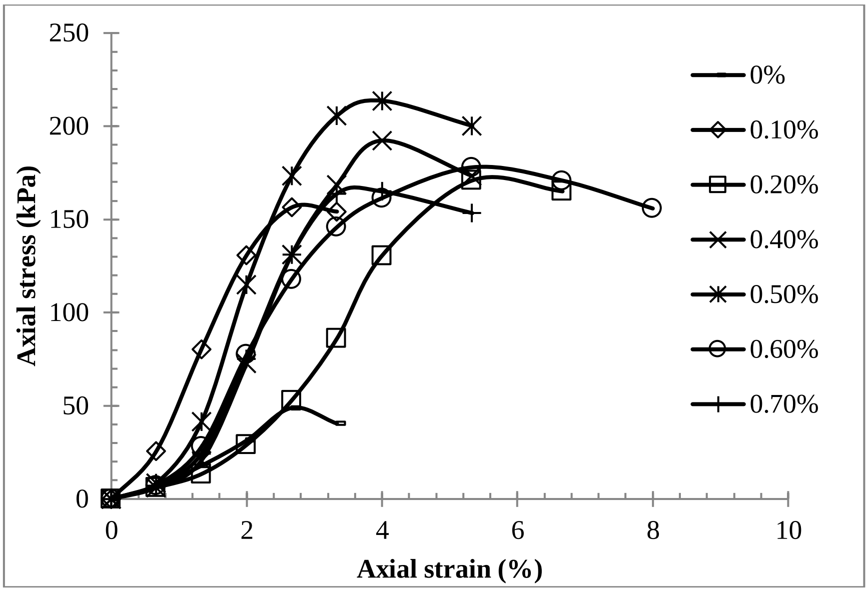

Fig. 7. UCC results of soil treated with plastic strips of thickness 30 µm (AR = 2)

3.2. Comparison of results

The variation in UCS with the change in plastic content was presented in Fig.8. The maximum improvement in UCS can be seen by addition of plastic strips of thickness 15 µm for both the aspect ratios. The increase in thickness of plastic strips results in decrease in compressive strength. This may be as a because of decrease in friction between the soil and plastic due to the decrease in contact between particles. When the aspect ratio of plastic strips goes on increasing, notable improvement in UCS can be seen i.e. as the strip length increases keeping the width constant, higher strength were achieved. However beyond the optimum length, there will be reduction in the compressive strength. This may be due to the increased contact between the plastic strips which leads to the decrease in soil-plastic interaction.

The variation in UCS with the change in thickness of plastic was shown in Fig. 9. The optimum percentage of plastic strips for soil is 0.5% for all the thickness ranges. Further increase in plastic content causes strength reduction. As the plastic content increase beyond 0.5%, UCS decreased due to the increased interaction between the plastic strips due to more overlapping of plastic and it results in reduced soil plastic interaction.

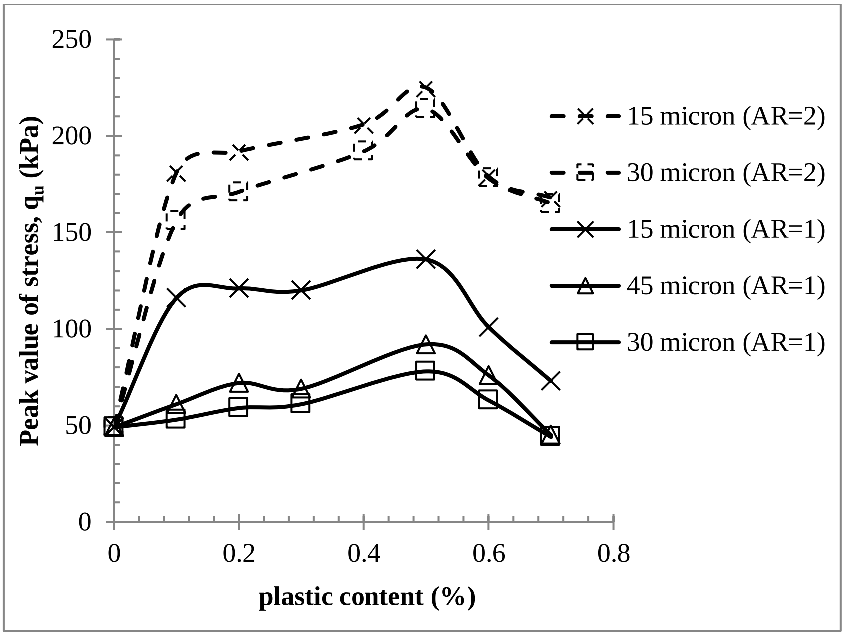

Fig. 8. Variation of q_u with different percentage of plastic

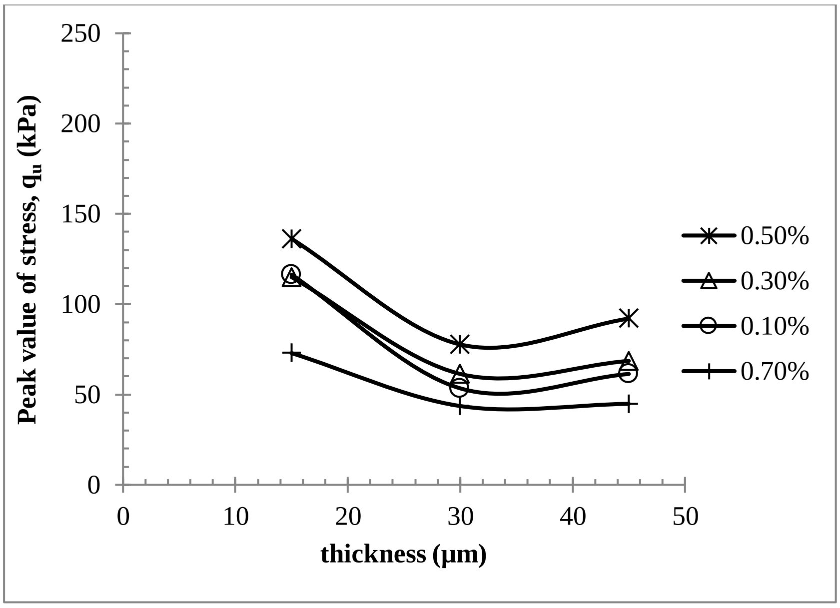

Fig. 9. Variation of q_u with thickness (AR = 1)

4 Conclusions

1. The maximum value of UCS is obtained by adding 0.5% plastic with aspect ratio 2 and thickness 15 µm.
2. The UCS value increases with the increase in aspect ratio of plastic strips.
3. The strain to reach peak stresses increases with plastic content.
4. The nature of soil changes from brittle to ductile during the inclusion of plastic strips.

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