Studies on the effects of addition of shredded plastic waste as reinforcement on engineering properties of black-cotton soil

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Abstract. Plastic waste is non-biodegradable and its disposal problem has become very critical issue nowadays. Black-Cotton soil has been proved one the problematic soil which requires improvement for its swelling and other characteristics. Therefore, this plastic waste has been attempted to be reused for improving the performance of this soil's engineering properties. For this, plastic waste was collected and shredded into strips of different aspect ratio of (5mm x 10mm, 5mm x 20mm, 3mm x 10mm, 3mm x 20mm). To decide the optimum aspect ratio several tests were carried out by pilot study than for optimum aspect ratio, optimum amount of dosage was found out after adding 0.05 to 0.3 % in the increment of 0.05% of the weight of soil sample. The results of the tests performed on black cotton soil revealed that the optimum aspect ratio and economical dose for unconfined compression strength test was 5mm x 20mm and 0.1 % of the weight of the soil sample. For California bearing ratio test optimum dose of the fiber was found to be 5mm x 20mm and 0.1 % of weight of soil sample collected, However, for free-swelling test the results was varying and it was due to orientation of the flacks and was difficult to generalize the dose and percentage swelling control.

Keywords: Plastic Waste; Reinforcement; Black-Cotton Soil ;Sustainable Development.

1 Introduction

In today's era the dumping of the solid waste has been proved a great problem further, the amount of plastic particularly the empty snacks and beverages pouches which has metalized coating is great problem. Plastic itself is non-biodegradable and all over the world the use of the plastic is now being restricted however in developing country like India still the awareness is less. Plastic bags, plastic pouches, PET bottles etc are few to list which are most common. This plastic's disposal is great challenge and due to unsystematic disposal it is creating lot of trouble even to cattle. In Rajkot city of Gujarat only the amount of the waste plastic produced is about 15-20 tons/day. Therefore, the sustainable disposing of plastic is the need of the day. On the other hand use of Geosynthetics for soil improvement has been proved versatile in terms of the reinforcement. Therefore in this paper an attempt is made to use the shredded plastic

(waste) and added to soil for its improvement in the engineering properties and check the feasibility of the amount waste being utilized.

1.1 Plastic waste sample collection

The plastic bags are collected from the Nakrawadi dumping yard station of Rajkot city as shown in Fig-1. Then it was washed and dried after that it was shredded in to various sizes of flakes to act as reinforcing element. More details are given in [1 & 3]. The shredded plastic were produced in the varying sizes of flakes viz; 5mm x 10mm, 5mm x 20mm, 3mm x 10mm, 3mm x 20mm few of them are as shown in Fig-2.

Fig-1: Rajkot city's waste dumping yard at Nakrawadi

1.2 Black-Cotton soil:

Since centuries this soil has remained problematic due to its montomorillionite mineral which has tendency to swell more than 100% of its original volume when subjected to moisture or saturation and equally shrinks and come back to original volume upon drying. This has many disadvantages which results in cracking of the super structure be it road, or bridge or any other structure. Hence, many attempts are made like mechanical stabilization as well as chemical stabilization and use of Geosynthetics to certain extent. However very few attempt is made to utilize the plastic waste to control such behavior as well as study the changes in the other engineering properties of such soil. The Black-Cotton soil used in this study was collected from village Bedi near Rajkot city which has index properties as listed in Table-2.

Table-1. Index properties of the Black-Cotton soil used in this study

Sr. no	Index Property	Value
1	Free Swell Index	53.9 %
2	Liquid limit w_L	81.5 %
3	Plastic limit w_p	33.2 %
4	Plasticity index I_p	48.3 %
5	IS soil classification	CH

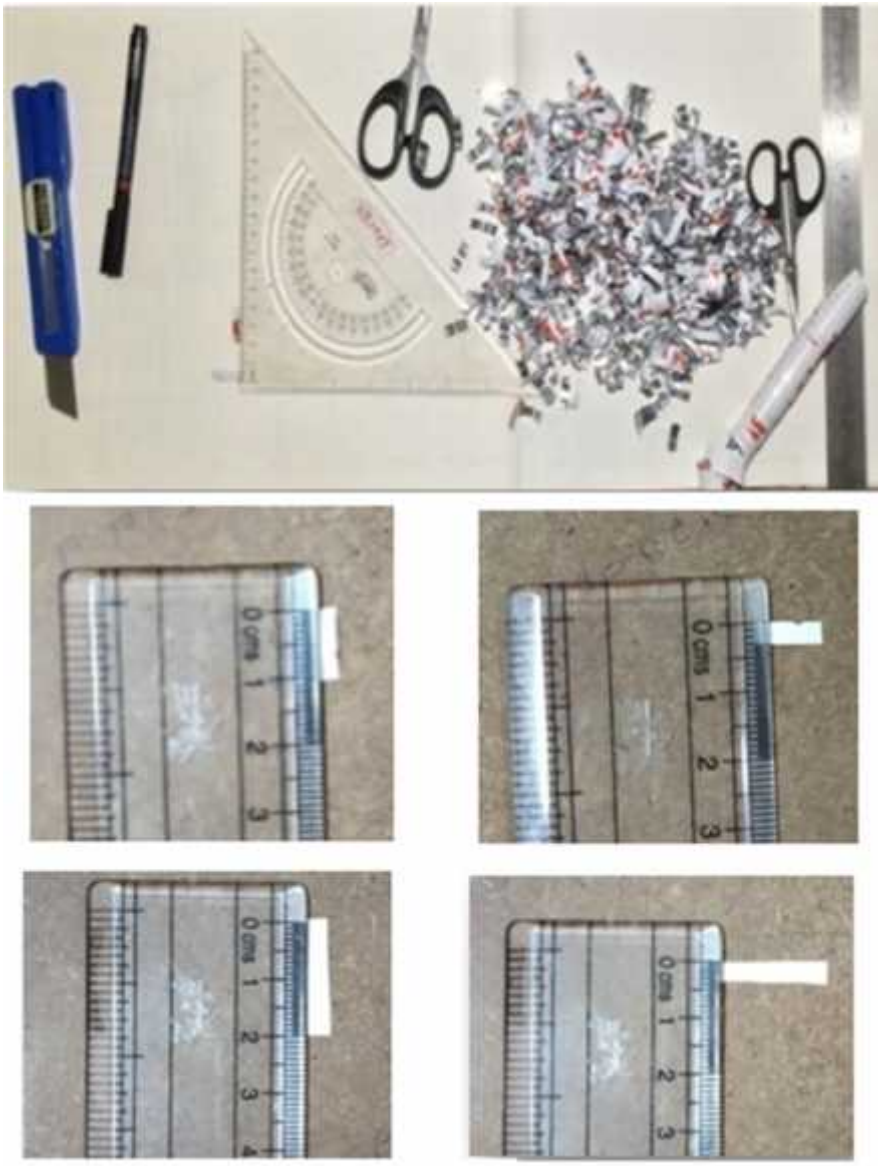

Fig-2. Shredding the plastic waste sheet in different aspect ratios (typically shown for 3x20 mm & 3x10 mm)

2.0 Methodology

To utilize the waste plastic in expansive soil, the shredded waste plastic in different aspect ratios (5mm x 10mm, 5mm x 20mm, 3mm x 10mm, 3mm x 20mm)were tried one by one and added to the dry soil by the percentage weight of the soil ranging from adding 0.05 to 0.3 % in the increment of 0.05%. The Black-Cotton soil was also

tested in its virgin conditions and kept as the reference soil and the above mentioned dosages were added and the engineering properties like California Bearing ratio test (CBR) and Unconfined Compression test (UCS) were carried out to observe the effects of this shredded plastic on these properties. The total sets of the testing done is presented in Table while Figure 3 narrates the step by step procedure of preparation of the sample for these tests.

Fig 3. Step by step mixing and testing

Table 3. Scope of the work

Sr No	Fibre Aspect Ratio	Dose (%)	Tests carried out
1	No plastic/original		UCS, CBR & Free-swell test
2		0.05	
3	5mm x 20 mm	0.10	UCS
4		0.15	CBR
5		0.20	Free-swell
6		0.25	
7		0.30	
8		0.05	
9	5mm x 10 mm	0.10	UCS
10		0.15	CBR
11		0.20	Free-swell
12		0.25	
13		0.30	
14		0.05	
15	3mm x 20 mm	0.10	UCS
16		0.15	CBR
17		0.20	Free-swell
18		0.25	
19		0.30	
20		0.05	
21	3mm x 10 mm	0.10	UCS
22		0.15	CBR
23		0.20	Free-swell
24		0.25	
		0.30	

The Unconfined compressive strength and CBR tests were carried out as per the relevant Indian standard codes.

3.0 Results and Discussion

As mentioned earlier, the different aspect ratio of shredded plastic was mixed with the black cotton soil and were tested for the different engineering properties.

The unconfined compressive strength UCS of raw soil was 200 kPa. Later the different aspect ratio were tried in to the soil and it is mixed in the soil. Various aspect ratio and their different percentage were tried and optimum dose is find for each of the aspect ratio. The optimum dose is decided on the basis of maximum improvement in the UCS value. The best results obtained in UCS value corresponding to the different aspect ratio are tabulated below in table 4. The aspect ratio 5 x 20 mm (dose of 0.1%) gives the improvement of 5% as the value of UCS increased to 210 kPa. The dosage and orientation of the fibers is crucial in the strength achievement, it was observed that if the dosage of the plastic waste is increased, than the too much plastic by volume is accommodated in the sample and the strength reduces which may be due to slip among the fibers itself. Further, the orientation of the fiber across the failure plane may have imparted some higher strength due to the high tensile strength of fiber however the fibers were not failed, indicating the slip of the fiber and thus not much of the improvement in shear strength is observed, however this dosage by weight has

much volume and this is a positive sign for its usage in soil without adversely affecting strength.

Table 4- Maximum Improvement in UCS corresponds to different aspect ratio

Sr No	Aspect Ratio	Dose (%)	UCS (kPa)	Improvement
1	5mm x 20 mm	0.10	210	5%
2	5mm x 10 mm	0.15	208	4%
3	3mm x 20 mm	0.20	205	2.5%
4	3mm x 10 mm	0.30	207	3.5%

Other geotechnical properties known as CBR value is also a important factor particularly in the deciding the thickness of the pavement. The effect of this plastic waste is also seen on CBR value. The Value recorded for raw soil was 8. The aspect ratio used for UCS, were kept the same in the CBR testing with same percentage of the dose. In the similar manner the results obtained are tabulated in table 5

Table 5. Maximum Improvement in CBR corresponds to different aspect ratio

Sr No	Aspect Ratio	Dose (%)	CBR	Improvement
1	5mm x 20 mm	0.10	12	50%
2	5mm x 10 mm	0.25	10	25%
3	3mm x 20 mm	0.20	10	25%
4	3mm x 10 mm	0.30	10	25%

Table 6. Results of free swell tests for different aspect ratios

Sr No	Aspect Ratio	Dose (%)	Swelling	Improvement
1	5mm x 20 mm	0.10	52	1.0 %
2	5mm x 10 mm	0.25	53	0.5 %
3	3mm x 20 mm	0.20	51	1.5 %
4	3mm x 10 mm	0.30	53	0.5 %

It can be observed from the table-5 that for the aspect ratio 5mmx 20mm with 0.1 % by the weight of the soil yields the maximum improvement in the CBR value of the soil. This might be possible due to 5mmx20mm has large surface area to stick with soil and have given better grip and therefore the while deformation, the fibres placed across the plane would have shown resistance by mobilizing the tensile strength of fibers. However, in case of other aspect ratios the orientation and the grip length would have not been sufficient.

Further, the dosage and size of the fibers have negligible effects on swelling. The minor improvement is noticed. The reason for that may be because plastic waste is not contributing any chemical bonds to hold the molecules against swelling, neither the fibers are held by soil particles to mobilize its tensile strength, hence no improvement is found in swelling control.

4.0 Analysis for the utilization of plastic shredded waste

The analysis was done for the utilization of the plastic shredded waste in the construction of the pavement. In 1 km of road length, per lane width of 3.5 m and assuming the 30 cm of the average pavement thickness for the base and sub-base layer then it will comprises of the 1050 m^3 of soil per lane per unit kilometer. Considering average unit weight of soil as 18 kN/m^3 then total 18,90,000 kg of soil would be utilized. Now from this study optimum dose of plastic waste is 0.1% by weight of soil, hence approximately 2000 kg of plastic waste would be utilized. 2000 kg of plastic waste has significant volume and therefore lot of space can be saved in dumping yard.

5.0 Conclusion

In this study the metalized plastic waste was utilized in black-cotton soil and its engineering properties in terms of UCS and CBR were studied. After the careful analysis the following broad conclusion can be drawn:

- After adding the fiber of an aspect ratio of 5mmx20mm, 5mm X 10 mm, 3 mm X 20 mm, 3 mm X 10 mm. We came to know that orientation of a fiber reinforcement is very important because fiber directly transfer the load and elongate up to the plastic capacity when their orientation is parallel to the load acting on the soil.
- After adding the fiber of different aspect ratio the optimum dose we got for Unconfined Compression Strength Test is 5 mm X 20 mm @ 0.1 % of its weight.
- After adding the fiber of different aspect ratio the optimum dose we got from pilot test for California Bearing Ratio Test is 5 mm X 20 mm @ 0.1 % of its weight.
- Effect plastic fiber on controlling the swelling is not observed
- Although the improvement in the geotechnical properties is not huge but plastic can be used at construction site so that the dump ward land can be saved.

6.0 Limitation of the study

These are the findings of the few laboratory test, however on the site the performance very much depends upon the cleaning and orientation of the fibers, accuracy of the adding fibers in proportion to soil as well as balling effects are the challenges for site conditions. But it is validated that if the plastic is added within this limit, it is not affecting the strength.

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