Micro Crumbled Rubber Powder as an Additive to Improve Geotechnical Properties and Slope Stability

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Abstract. Disposal of waste tires is an environmental burden, difficult as it is man- ufactured from synthetic rubber which is hard to get decomposed and may cause an environmental burden, especially in a developing country like India. So, suitability of this waste tire in powder as an additive to improve geotechnical properties was inves- tigated. Rubber powder of size less than 425 micron is added in varying proportions, 8%, 10%, 12%, 14%, 16% and 18%. Optimum content of rubber giving maximum shear values and density was found to be at 12%. The application of this mix in slope stability improvement was evaluated using GeoStudio SLOPE/W software by constructing an embankment for different slope angles 27°, 30°, 33° and slope heights 6m, 8m, and 10m. Factor of safety was found to be increased which proved the applicability of rubber powder.

Keywords: *tire powder, shear strength, slope stability*

1 Introduction

Waste products such as rubbers, plastic materials waste tires which are normally generated in our society create a lot of environmental issues. Due to the increase in these issues engineers are focusing on reusing of recycled product. One of such prod- ucts is waste tire which has become major environmental problem for countries across the world. Due to increase in the vehicle production, there is a large number of dis- carded rubber products which are either disposed of or burnt of them has been found difficult [21]. So, reuse of such products is more practicable. There are several investigations on the improvement of physical and mechanical properties, making use of recycled rubber particles from disused tires, with the aim of having a soil suitable for building embankments, roads, etc. In Turkey, the influence of the addition of recycled tire rubberfibers and silica fume to clayey soils was investigated, with the aim of improving shearstrength. The results showed that cohesion and friction angle increased 1.1 and 1.7 times respectively more than the clayey soil sample [8]. The modification of clayey soilswas investigated by adding tires and synthetic fibers with the aim of finding reinforcedsamples subjected to a shear strength. The results showed that the parameters of the shear strength increased 1.2 times to the samples of the non-reinforced soil [2].

In this paper rubber which is a waste material is collected in the powdered form and is added to the soft soil sample collected from the site and are checked for its properties so that its disposal into landfills can be reduced. Also its application in embankment construction is analyzed so that it can be further used for future development economically.

1.1 Materials

Soil

The soil used in this study was collected from Kumbalam, Ernakulam district, Kerala. The soil properties were tested according to IS 2720 and was classified as clayey sand (SC). The properties of the soil are as shown in Table 1. From the results obtained soil showed very low shear strength value. Therefore, tests were performed by using rubber powder as an additive to improve its properties.

Table 1: Properties of soil sample collected

PROPERTIES OF SOIL	VALUE
Field density (g/cc)	1.44
Percentage of silt and clay	28 %
Percentage of sand	72 %
Uniformity coefficient, C_U	3.8
Coefficient of curvature, C_C	0.83
Specific gravity	2.4
Liquid limit (%)	54.3
Plastic limit (%)	22
MDD (g/cc)	1.89
OMC (%)	12.6
Soil type	SC (Clayey sand)

Rubber powder

The rubber powder used in this experiment was purchased from Rubbers India Polymer Products Pvt Limited, Airapuram, Kerala. Size of therubber powder used here in this experiment in size less than 425 microns and its specific gravity was found to be 1.1. The properties of rubber powder collected is as shown in table 2.

Table 2: Properties of rubber powder collected from rubbers India Pvt Ltd

Specifications	30 mesh crumbs
Acetone extract (%)	10.4
Ash content (%)	6.8
Carbon black (%)	24.2
Volatile matter (%)	0.88
RHC (%)	57.72
Specific gravity (%)	1.1

1.2 Preparation of the mixture

The sample used was air dried for 2 to 3 days and then carefully sieved in 425-micron sieve. Rubber powder is added to air dry soil samples at 8%, 10%, 12%, 14%, 16% and 18% by weight.

2 Laboratory investigations

Various tests are conducted to evaluate the compaction and shear strength characteristics of soil at different percentages of micro crumbled rubber.

2.1 Compaction test

Light compaction test was conducted as per IS 2720-part VII 1980. The results obtained from the tests conducted are plotted and are as in the figure 1. It can be observed that MDD value decreased from 17.3kN/m^3 to 15.4kN/m^3 on addition of rubber powder from 8% to 18%.

As per IRC 36-2010, the MDD required for the safe construction of embankment is that it should not be less than 16kN/m^3 for embankment of height greater than 3m. But, at 12% of micro crumbled rubber powder, the obtained dry density is 1.61g/cc and it found to be satisfying the IRC criteria for embankment construction.

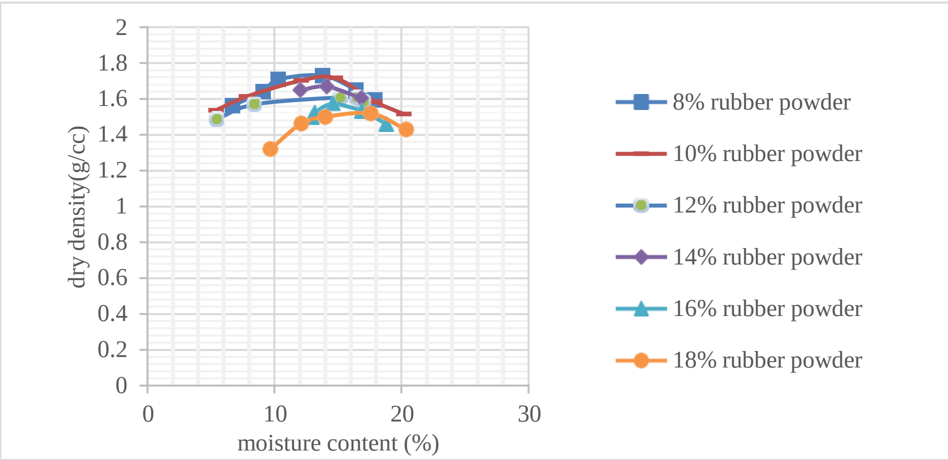

Figure 1: Compaction curves

2.2 Direct shear test

Direct shear was conducted according to IS 2720 (part 13) 1986 on different proportions of rubber powder soil mixes. The rubber powder soil mixes were prepared and tested at their respective light compaction test results of MDD and OMC in order to obtain the shear strength parameters (cohesion and angle of internal friction).

Direct shear test results shown in table 3 indicates that the angle of internal friction decreases whereas cohesion value increases. The increase in cohesion is found upto 12% and thereafter decreases. So, it can be concluded that the optimum percentage of rubber powder which gave the maximum shear strength is obtained as 12%. The graphical representation of shear stress versus normal stress is in figure 2.

Table 3: Shear strength parameters

Micro crumbled rubber powder (%)	Angle of internal friction (Φ)	Cohesion (c)
0	36	0
8	32.26	6.2
10	30.35	15.25
12	30.96	19.55
14	31.34	10.44
16	31.24	8.46
18	31.14	3

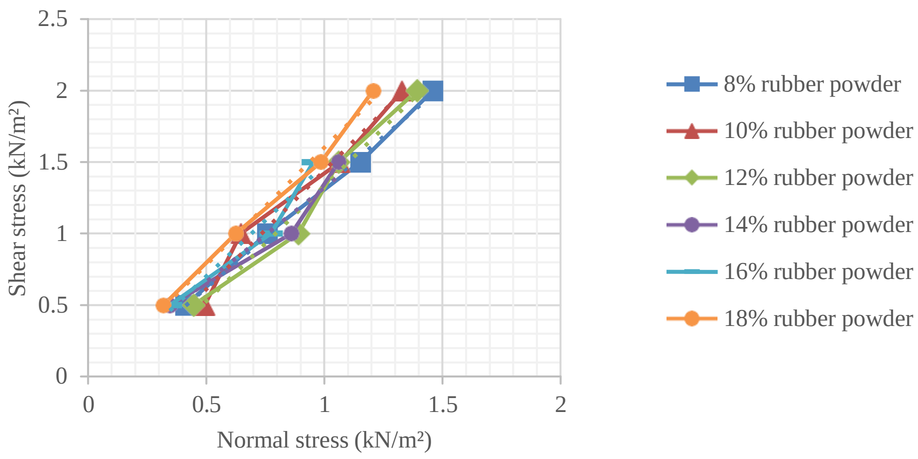

Figure 2: Shear stress versus normal stress

The application of these rubber and clayey sand mixes is presented in the form of numerical analysis for slope stability of the embankment for the highway. The following section presents numerical modeling of an embankment with the optimum value of rubber powder obtained from the experiments at different slope angle and slope height.

3 Numerical modeling

The slope stability analysis was performed using GeoStudio SLOPE/W software. Geo Studio is an integrated software which has been found suitable for modeling slope stability, ground deformation, and heat and mass transfer in soil and rock. SLOPE/W was available since 1977 and with the development in the electronic computers made it easier to handle modern limit equilibrium software such as SLOPE/W by making it easier to solve complexity in analysis.

The embankment model is as shown in the figure 3. The embankment model in the figure is of height 8m with road width of 6m and slope angle varied from 1.5:1 to 2:1. Roadway width was taken as 12 m as per the code which states width of NH roads as 12 m for plain terrain. The geometry here is fixed in such a way to avoid the influence of side boundary effects. The soil domain here was defined by Mohr Coulomb failure criteria.

The embankment here is modelled using rubber powder-modified soil as well as using sample soil collected from the field. Where the entire model is replaced by modified soil and are compared. Limit equilibrium method of analysis is used here to run the stability analysis. Here entry and exit method of slip surface analysis is used to define the failure planes. The failure planes provided is as shown in the figure 4 that is point 7-5.

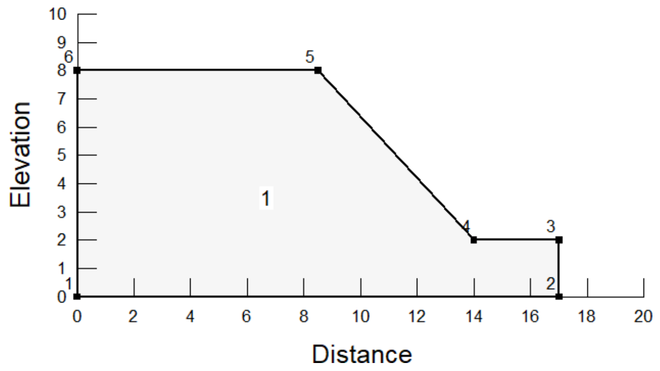

Figure 3: Embankment model constructed using GeoStudio

In the present study, the slope stability analysis was performed for the embankment for heights varying 6m, 8m,10m, and slope angles varying from 29°, 31° and 33°. The FOS was also checked for different methods of analysis such as Morgensten price, Jambu, Bishop and Spencer. The final results are as in figure 5, figure 6 and figure7 based on Morgenstern price method.

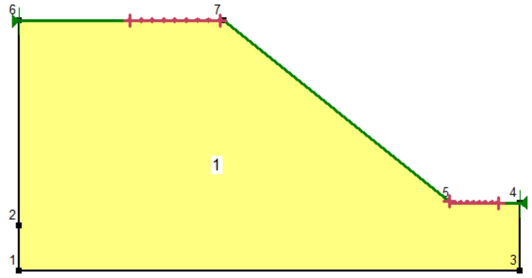

Figure 4: Schematic of the entry and exit slip surface

The values used in the analysis are obtained from the laboratory results conducted as per IS specifications. The results showed that the cohesion values of the rubber modified soil was increased to the maximum value also field density obtained for the micro crumbled rubber modified soil was within the limits as per IRC for construction of high embankments.

Table 4: FOS based on Morgenstern price and Jambu

		Bishop		Spencer	
Height (m)	Slope angle (˚)	Field soil	Micro-crumbled rubber modified soil	Field soil	Micro-crumbled rubber modified soil
6	27	0.982	2.112	0.842	2.015
	30	0.970	2.065	0.814	2.015
	33	0.973	2.056	0.816	2.012
8	27	0.670	1.793	0.669	1.727
	30	0.655	1.806	0.654	1.740
	33	0.998	1.800	0.856	1.734
10	27	1.039	1.594	0.888	1.534
	30	0.650	1.621	0.649	1.555
	33	0.630	1.611	0.629	1.549

Table 5: FOS based on Morgenstern price and Jambu

		Bishop		Spencer	
Height (m)	Slope angle (˚)	Field soil	Micro-crumbled rubber modified soil	Field soil	Micro-crumbled rubber modified soil
6	27	0.98	2.116	0.976	2.116
	30	0.951	2.067	0.956	2.068
	33	0.96	2.078	0.965	2.083
8	27	0.67	1.797	0.67	1.796
	30	0.655	1.806	0.655	1.802
	33	0.997	1.801	0.991	1.809
10	27	1.041	1.599	1.032	1.596
	30	0.65	1.622	0.65	1.625
	33	0.63	1.612	0.63	1.617

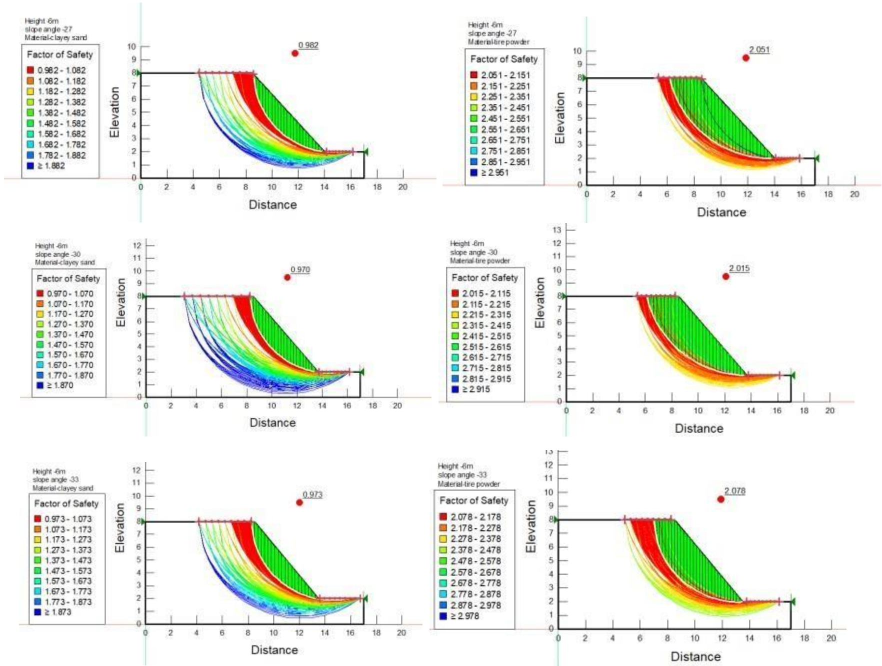

Figure 5: Variation of FOS on entreated as well as treated (12%) sample at 6m height and different angles based on the Morgenstern price methods

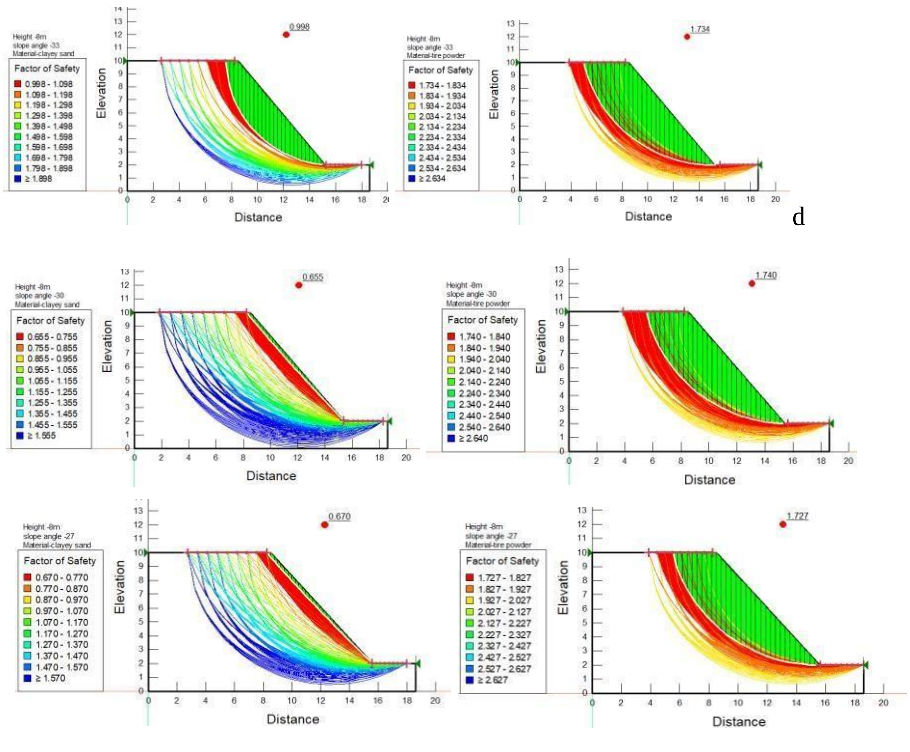

Figure 6: Variation of FOS on entreated as well as treated (12%) sample at 8m height and different angles based on the Morgenstern price method

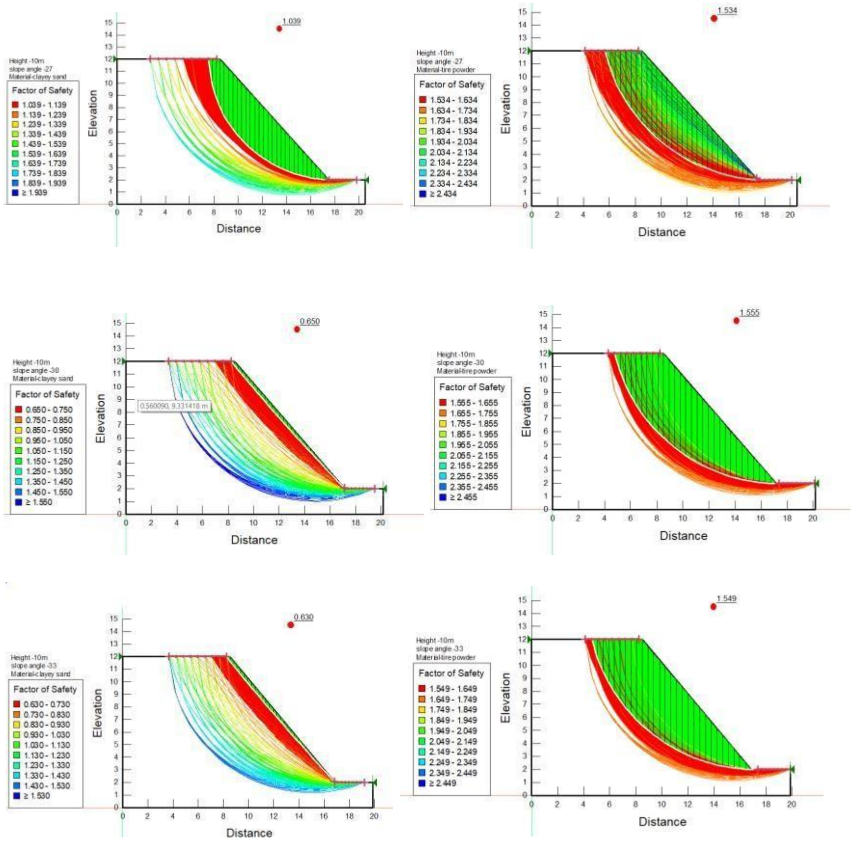

Figure 7: Variation of FOS on entreated as well as treated (12%) sample at 10m height and different angles based on the Morgenstern price method

From the above results obtained from Geo studio software as in table 4 and 5 it was concluded that FOS value showed an increase in the values when the same was modelled by using rubber powder mixed clayey sand obtained from the field. For a slope height of 6m the FOS value on clayey sand varied from 0.9-0.6. Whereas on addition of rubber powder FOS value ranged from 1.5 to 2**.** This proves more stable slope than constructing slope with clayey sand. This improvement in factor of safety may be due to high degree of compactness induced by filling pores of soft soil with rubber powder.

4 Conclusion

The present investigation mainly aimed at effective use of rubber powder in an economical way without harming the environment and using it effectively for human development. The values obtained from the experiments concluded that significant improvement in soil properties on the addition of micro-crumbled rubber powder. The optimum moisture content was found increasing whereas maximum dry density was found decreasing, this may be due to the light weight of the rubber powder. From the shear tests conducted it was concluded that shear parameters increased upto 12% of micro-crumbled rubber powder and was found decreasing thereafter. So, it can be inferred that optimum rubber powder content for soil stabilization is 12%.

Further its stabilization application was proven by constructing a model embankment using micro- crumbled rubber modified soil in Geo Studio SLOPE/W software. Embankment constructed was found to be stable after the addition of micro crumbled rubber for different heights varying 6m, 8m, and 10m and for varying slope angle. The FOS values were found to be increased about 1.5 times the original value when the same embankment was constructed using the field soil. Thus, micro crumbled power is proven to be a low cost soil stabilization technique. The stabilized soil can befurther used for application in embankment construction. Also, it offers a solution to reduce the burden due to waste rubber disposal and burning.

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