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Experimental Investigation of Expansive Soil Mixed With Shredded Rubber Tyre

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Abstract. Black cotton soil, which is expansive in nature covers about 20% of land area in India. Black cotton soil possesses a high potential for shrinkage and swelling, and has the low bearing capacity and shear strength hence it is unstable under heavy loads. The typical behavior of black cotton soil makes it difficult and dangerous to be used as a foundation material. This study characterizes the Geotechnical properties of black cotton soil partially replaced with shredded tyre rubber (5% to 20%) by weight of the soil. The present study enumerates the effect of rubber tyre on engineering properties as well as index properties of black cotton soil. Atterberg's limit, Standard proctor test, Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) test were conducted on soil sample mixed with 5%, 10%, 15% and 20% tyre rubber by weight. The test has clearly shown a significant improvement in the Geotechnical properties of the soil. This study deals with stabilization of black cotton soil using shredded rubber sample of different proportions. Stabilization is the method employed for modifying the properties of soil to improve its performance as a civil engineering material. The main objective of this study is to increase the strength properties of black cotton soil and reduce the construction cost intofroducing locally available material "Scrap Tyre".

Keywords: Black Cotton Soil, California Bearing Ratio (CBR), Rubber Tyre shred, and Unconfined Compressive Strength (UCS).

1 Introduction

The black cotton soil was found in the central and western part of India. Black cotton soil was collected from Agriculture University, Borkhera locality of Kota city in Rajasthan state of India provision. The black cotton soil is also called as Regur soil, which is generally clayey, deep and impermeable in nature. As the black cotton soil expands it becomes sticky during the rainy season and contract during summer season, causing deep cracks in to the soil. Black cotton soil is formed by lava basaltic rocks. The soil is very dark in colour. They develop cracks during the dry period and swell if moisten, hence they are self-tilling in nature, that's why they are fertile and can hold water for a long time. The whole area cracks up 150mm wide and formed up to a depth of 3.0 to 3.5 meter. But when the soil is moist it expands, becomes very soft and loses bearing capacity. Black cotton soil is an inorganic clay of medium to high compressibility and is characterized by high shrinkage and swelling properties. The expansive soil is rich in mineral montmorillonite and few in the elite. Black cotton soil has been a challenge to the Geotechnical engineers for a long time in designing the foundation of the building. Soil stabilization improves the engineering properties of the soil and making it more stable. Soil stabilization can be categorized into two main categories, such as mechanical and chemical stabilization. The tyre waste is a hazardous material in the sense of disposing. Now a day sustainable use of waste product is necessary. This assignment concentrates on obtaining the optimum amount of crumb rubber tyre for practical work by observations of the effect of crumb rubber tyre on engineering properties of soil. However the crumb rubber tire can only is used as a partial replacement of adhesive/cementious material like cement and lime. It cannot completely take over the cementious material because crumb rubber tyres have the inherent binding property which is required for long lasting material or durability. The experiments were conducted on soil specimen mix with different proportions of shredded tyre are stated in table 2.

2 Literature Review

Srivastava et al. (2014) [1] studied the shredded tyre waste with expensive soil for enhancing the Geotechnical properties. In addition to 30%-50%, shredded tyre waste decreases the shear strength property. It was concluded that shredded tyre waste helps in reducing its shrinkage and swelling properties. The shear strength was improved in 5% shredded tyre waste. Further, the addition of shredded tyre rubber waste increases the compressibility value. Hambirao et al. (2014) [2] investigated the clayey soil stabilization various percentages (0%, to 15%) of rubber tyre chips. The UCS and CBR values increased with increase in rubber tyre content with an optimum moisture content of 10%. It was remarked that the shredded rubber tyre can be used as a virtuous strengthen the material. The investigation shows an increment in CBR values of 2.63% to 13.79%, which reduces pavement thickness by 66.66%. Shubha and Balichakra (2018) [3] inquired information with proportion 0%, 4%, 6%, 8%, 10% and 15% of tyre waste. As the proportion of rubber crumb increase, the Maximum Dry Density tends to starts decreasing. The best enhancement in CBR value was evaluated at 12% of rubber crumb. Kaur and Singh (2019) [4] investigated the black cotton soil with various proportion of rubber powder from 0%, 5%, 10%, and 15%. As the rubber crumb was increased by 10% the value of CBR values also increased. They concluded that the optimum rubber tyre was taken to be 10% for the stabilization of black cotton soil. Saini et al. (2018) [5] concluded an increase of UCS value up to 8.29% with the increment of 2% tyre powder waste with black cotton soil.. Saini et al. (2018) [5] concluded that there is slightly an increase of UCS value up to 8.29% on the addition of 2% shredded tyre waste with black cotton soil. Prasad and G.V. R Prasada (2009) [6] studied the functioning of shredded tyre on the model flexible pavement from the experimental analysis of rock and fly ash material reinforced with different proportion of shredded tyre rubber, the ideal proportion of waste tyre is equivalent to 5% and 6% of dry unit weight of soil. Sathwik et al. (2016) [7] found an increment in CBR values with content up to 8% of shredded rubber. Vinod B R et al. (2020) [8] investigate the optimum proportion for shredded tyre waste is 5% and for sea shell powder is 12% in expansive soil.

3 Material Used

3.1 Black cotton soil

A large part of Central India was covered with black cotton soil. The black cotton soil is residual deposit formed from basalt or trap-rocks and possess high plasticity. Soil sample was collected from 2m below ground level in agriculture university of Kota, Rajasthan state. Untreated soil was oven dried for 24 hours at 105°C to 110°C before performing the experiments. The Latitude and Longitude of the area is 25. 1783° N, 75. 8850° E respectively. Extremely difficult to work with such soils and is quite suitable for growing cotton.

Fig. 1. Black Cotton Soil

3.2 Crumb Rubber Tyre (CRT)

Every year greater number of rubber tyres are manufactured and the same number is permanently removed from the vehicle now a day, these tyres are manufactured fundamentally with natural and synthetic rubber and reinforced with the metal element and chemical additives. After the removal the tread from the tyre, they become useless and the management of this waste becomes crucial. These obsolete tyres are then stockpiled and dumped into landfills has exposed communities to environmental and health risks. The burning of these tyres is also not possible as they produce toxic gases which make the environment surrounded by hazardous gases. After identification of this problem, a study has been carried out by converting the tyre into powder form and then mixing it into the soil to check the bearing capacity of a rubber tyre. The metal elements were removed while preparing the powder of tyre. The waste tyres were bought from a tyre puncture recovery shop located near Kumher Gate in Bharatpur District of Rajasthan state in the Republic of India. The tyre was then shredded, crushed and then converted to powder form until the powdery tyre rubber is completely passed from a sieve of 425 microns. After that, the chemical properties of tyre rubber were analyzed in the laboratory.

Fig. 2. Crumb Tyre Rubber

Table 1. Parameter of Crumb Rubber Tyre

S.NO.	Parameters	Values Found
1	Ph	7.26
2	Elect. Conductivity (at 25^0C)	1.113ms/cm
3	Moisture (at 105^0C)	1.39%w/w
4	Organic Carbon (as OC)	1.42% w/w
5	Sulphur	0.167% w/w
6	Phosphorus	0.23% w/w
7	Potash	1.393% w/w
8	Organic Matter	2.448% w/w

4 Experimental Study

The soil sample collected from Agriculture University, Borkhera was tested as per Indian Standard. Various tests were performed to evaluate the Index and Engineering properties of soil which are listed below in the table

Table 2. List of Tests for determining Index and Engineering Properties

S.NO.	Experiment Performed	Property Evaluation
1.	Sieve analysis	Soil Classification
2.	Pycnometer Test	Specific Gravity
3.	Cone Penetrometer Test	Liquid Limit (LL)
4.	Thread Test	Plastic Limit (PL)
5.	Plasticity Index	PI = LL-PL
6.	Standard Proctor Test	(a.) OMC
		(b.) MDD
7.	Unconfined compressive strength	Cohesion (c')
8.	California Bearing Ratio	(a.) Unsoaked
		(b.) Soaked

5 Results and Discussion

5.1 Sieve analysis

Sieve analysis test was used for soil classification. It was performed as per IS 2720 (Part-4) 1985. It was observed that particles passing through 75 micron sieve were greater than 50%. So the soil was classified as fine soil. Fine soils are classified as per their Atterberg's limits. The results obtained from sieve analysis are shown in Fig. 3.

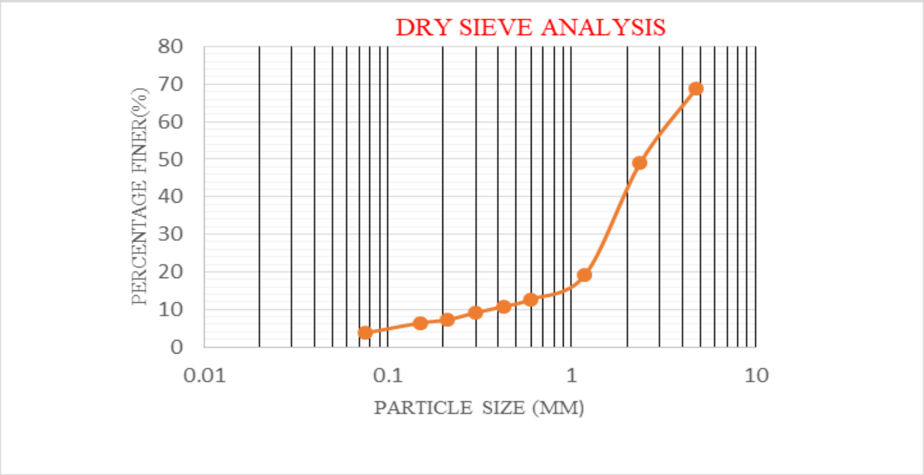

Fig. 3. Grain Size Distribution curve for virgin soil

5.2 Specific gravity

The Specific gravity was governed by pycnometer test apparatus as per IS 2720-3-1 (1980). It was found that the specific gravity of soil sample is 2.70.

5.3 Atterberg's limits

For determination of liquid limit (LL) cone penetrometer test was performed as per IS 2720-5 (1985) and for plastic limit, the test was performed. It was observed that the liquid limit of virgin soil was 43% (Table 3) which is greater than 35% and plasticity index (PI) is 14% so that the soil is classified High plasticity clay (CH) as per IS 1498 (1970).

Table 3. Atterberg's Limits

Sr. No.	Sample	Liquid Limit	Plastic Limit	Plasticity Index
1	BC+0%CRT	43%	29%	14%
2	BC+5% CRT	35%	23%	12%
3	BC+10% CRT	30%	21%	9%
4	BC+15% CRT	32%	22%	10%
5	BC+20% CRT	34%	23%	11%

5.4 Standard proctor test

The Standard proctor test was performed for determination of optimum moisture content (OMC) and maximum dry density (MDD) as per IS 2720-7 (1980). It can be seen from table no. 4 that value of OMC and MDD of soil sample is 18% and 1.60 g/cm^3 respectively. It was observed that by increasing the tyre rubber content MDD is decreasing, which is because of the light weight of the tyre rubber.

Table 4. Standard Proctor Test

Sr. No.	Sample	OMC (in %)	MDD (g/cm^3)
1	BC+0% CRT	18	1.60
2	BC+5% CRT	20	1.55
3	BC+10% CRT	14	1.54
4	BC+15% CRT	17	1.52
5	BC+20% CRT	15	1.51

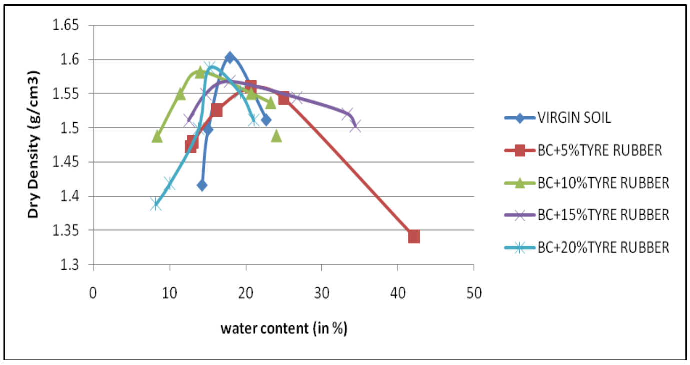

Fig. 4. Standard Proctor Test

5.5 Unconfined compressive strength test

UCS test was conducted as per IS 2720-10 (1991) for determination of shear parameter of soil. The UCS value of untreated soil is 37.51 KN/m^2 (Table 5). UCS value tends to increase with the addition of Tyre rubber, but after an optimum proportion of 10% tyre rubber it starts decreasing.

Table 5. Unconfined Compressive Strength Test

Sr. No.	Sample	UCS value (kN/m^2)	Cohesion (c')(kN/m^2)
1	BC+ 0% CRT	37.51	18.75
2	BC+5% CRT	42.25	21.12
3	BC+10% CRT	56.83	28.41
4	BC+15% CRT	46.54	23.27
5	BC+20% CRT	33.63	16.81

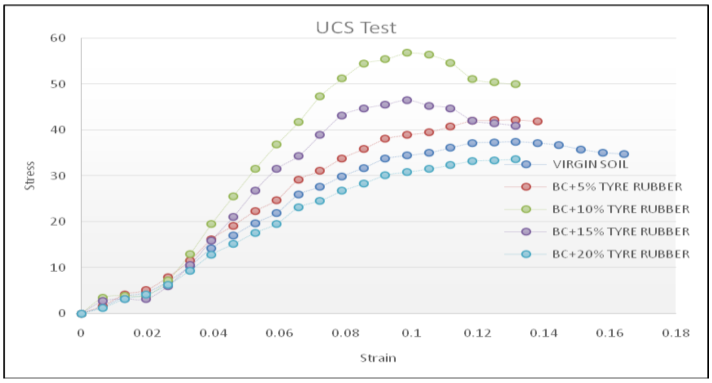

Fig.5. Unconfined Compressive strength test

5.6 California bearing ratio test

CBR test was conducted to evaluate the behavior of soil in normal (unsoaked) and worst (soaked) condition as per IS 2720-16 (1987). It was observed that the CBR value of virgin soil is 7.74% and 2.27% in unsoaked and soaked condition respectively. It can be observed that, CBR is increasing by addition of tyre rubber up to an optimum content of 10%. After that, it starts decreasing.

Table 6. California Bearing Ratio Test

Sr. No.	Sample	Unsoaked CBR (%)	Soaked CBR (%)
1	BC +0% CRT	7.74	2.27
2	BC+5% CRT	7.97	2.58
3	BC+10% CRT	8.50	3.47
4	BC+15% CRT	8.23	3.15
5	BC+20% CRT	7.90	2.48

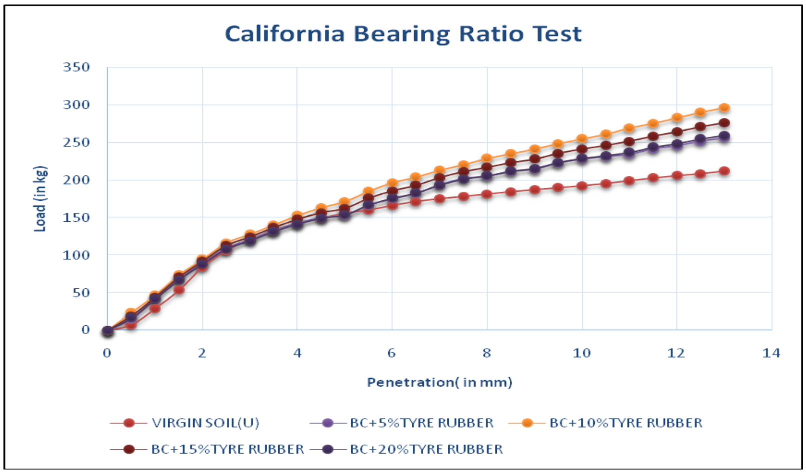

Fig. 6. California Bearing Ratio (Unsoaked) Test

6 Conclusions

1. The optimum percentage of Shredded tyre rubber for stabilization of expensive soil was found to be 10% based on the UCS and CBR test results.
2. MDD value shows decrease with increase in shredded rubber content and OMC values tends to increase.
3. The Percentage improvement in soaked and unsoaked CBR was 34% and 7% respectively. Increase in CBR value of stabilized soil can significantly redoes the overall thickness of pavement.
4. 35% increment in UCS value with 10% shredded tyre was concluded.

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