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Stabilization of black cotton soil by using grounded rubber powder

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Abstract
Solid waste management is one of the major environmental concerns worldwide. In India, the scrap tyres are being generated and accumulated in large volumes causing an increasing threat to the environment. In order to eliminate the negative effect of these depositions and in terms of sustainable development, there is great interest in the recycling of these non-hazardous solid wastes. The potential of using rubber from worn tyres in many civil engineering works has been studied for more than 30 years. Applications where tyres can be used have proven to be effective in protecting the environment and conserving natural resources. In recent times with the increase in the demand for infrastructure and feasible foundation design in not applicable due to poor bearing capacity of ground soil stabilization has started to take a new shape. Stabilization is process of fundamentally changing the chemical properties of soft soils by adding binders or stabilizers, either in wet or dry conditions to increase the strength and stiffness of the originally weak soils. In the present investigation attempt is made to stabilize black cotton soil using grounded rubber tyre powder. Black cotton is mixed with grounded rubber tyre with 5%, 10%, 15% and 20%. The unconfined and CBR tests were carried out in the laboratory for different mix proportions of rubber powder with black cotton soil. Considerable improvement is found in strength of black cotton and shedi soil for the 5% percent mix of rubber.

Keywords: solid waste management, tyre rubber powder, grounded rubber, soil stabilization

1. Introduction
1.1 General
Soil stabilization is a process of improving the load carrying capacity and performance of sub soils, sands. The main objective of soil stabilization is to improve the Bearing capacity of in situ soils. The other objective of soil stabilization is to improve onsite materials to create a solid and strong sub base and base courses. In all developing countries and now more frequently in developed countries, soil stabilization is being used to stabilize the soil and thereby increasing its load carrying capacity.
It is desirable to build a foundation on soils which have ideal and consistent density. Thus, the goal of soil stabilization is to provide a solid, stable foundation. Density is the measure of weight by volume of a material and is one of the relied upon measure of the suitability of a material for a construction purposes. A high density material possesses, the fewer voids. Hence a soil with least void ratio can have high strength. Improving an in situ soil engineering properties is referred to as either soil modification or soil stabilization. The term modification implies a minor change in the properties of soil, while stabilization means that the engineering properties of the soil have been changed enough to allow field construction to take place.

1.2 Why We Should Stabilize the Black Cotton Soil
A small amount of rainfall, such as 6mm can make black cotton soils impassable for all traffic. Due to plastic nature, the black cotton soils stick onto wheels, animals' feet, clog cultivation machines, and are hard to remove. Expansive nature of this soil negatively affects its bearing capacity. When dry, black cotton soil is so hard that the clods cannot be easily pulverized for treatment for its use in road construction. This leads to serious problems related to consequent performance of the road. If black cotton soil stabilization is not applied, the damage will be apparent usually several years after construction.

Replacement of expansive soil with a non-expansive material is a common method of reducing shrink-swell risk. In the case when expansive soil or stratum is thin, then the entire layer can be removed. However, often the soil or stratum extends too deep and in that case this method is not economically efficient.
One of methods of black cotton soil stabilization is wetting in order to saturate soil and thus prevent potential expansion if the high moisture content can be maintained. Soils with low hydraulic conductivity may take years to saturate. On the other hand soils with high hydraulic conductivity may never become sufficiently wet. Therefore, this method is not efficient for many black cotton soils.

1.3 Why we use waste tyre rubber as soil stabilizer

Solid waste management has gained a lot of attention in the research field. Out of the various solid waste, accumulated waste tyres has become a problem of interest because of its non-biodegradable nature. With the increase in the automobile production, huge amounts of waste tyre need to be disposed. Most of the waste tyre rubbers are used as a fuel in many industries such as thermal power plant, cement kilns and brick kilns etc. This kind of usage is not environment friendly and requires high cost. So it's become necessary to think about alternates for waste tyre rubber consumption. Waste tyre rubber is a promising material in the construction industry due to its light weight, elasticity, energy absorption, sound and heat insulating properties. Thus the use of scrap tyre rubber in the soil stabilization has been thought as an alternative disposal of such waste tyres to protect the environment. Waste tyres have characteristics that make them not easy to dispose, and potentially combustible. This technique has been gaining popularity in the field of geotechnical engineering due to its highly versatile and flexible nature.

1.4 Objectives of the Study

- The main objective of this experimental study is to improve the properties of the black cotton soil by adding ground rubber powder as stabilizing agent.
- To achieve the whole project some experimental investigation is needed in laboratory. The experiments which to be conducted are Specific Gravity of the soil sample & rubber powder, Grain size Distribution of soil sample and liquid limit plastic limit test to identify the material and Standard Proctor test to obtain maximum dry density and optimum moisture content of soil sample, permeability test and finally CBR test to measure bearing capacity of soil.
- The principal objective of the study is to investigate the behavior of Black cotton soil by adding waste tyre rubber powder in different volume proportions (5%, 10%,15%,20%).
- To compare the behavior of normal black cotton soil and black cotton soil with rubber powder.

2. Experimental Program

2.1 Materials Used

The different materials used in this investigation are:

- Black cotton soil
- Waste tyre rubber

2.1.2 Black Cotton Soil

Black soils are derivatives of trap lava and are spread. These are mostly clay soil sand form deep cracks during dry season. An accumulation of lime is generally noticed of varying depths. They are popularly known as "Black cotton soils" because of their dark brown colour and suitability for growing cotton.
Black soil is formed by the decomposition of lava rocks. Hence this type of soil is mostly found in the volcanic regions. It is usually found away from the coastal areas and is most suitable for growing cotton. Soil color is influenced by the amount of proteins present in the soil. Yellow or red soil indicates the presence of iron oxides. Dark brown or black color in soil indicates that the soil has a high organic matter content. Wet soil will appear darker than dry soil. Due to plastic nature, the black cotton soils stick onto wheels, animals' feet, clog cultivation machines, and are hard to remove. Expansive nature of this soil negatively affects its bearing capacity. When dry, black cotton soil is so hard that the clods cannot be easily pulverized for treatment for its use in road construction. This leads to serious problems related to consequent performance of the road. If black cotton soil stabilization is not applied, the damage will be apparent usually several years after construction.
The soil samples have been identified for their swell potential and have been broadly grouped into three categories based on their degree of expansiveness and problematic nature as

1. Highly expansive and problematic group
2. Moderately expansive and problematic group and
3. Least expansive and problematic group.

In the present work, the samples collected from four different regions in Gudur Municipal Corporation area, Nellore (Dt), A.P. Each sample came under moderately expansive category. These samples have been considered for the stabilization study.

Fig 1: Black Cotton Soil in Natural Dry State

The location and the category of these samples are indicated below:

Table 1: Location and the category of soil samples

Soil type	Black cotton soil
Location	Gudur
Category	Moderately expansive

About 120 kg. of the above black cotton soil samples were collected by open excavation from a depth of 1 meter from the natural ground level. The soil samples were air dried and pulverized to pass through IS 425 micron sieve before testing. The geotechnical properties of the above soil samples are given in following chapters.

2.1.2 Waste Tyre Rubber
Tyre may be divided in to two types- car and truck tyres. Car tyres are different from truck tyres with regard to constituent materials. Usually three main categories of discarded tyre rubber have been considered such as
1. Chipped rubber
2. Crumb rubber
3. Ground rubber

Chipped rubber is used to replace of gravel (coarse aggregate). This rubber is obtained by cutting 300-430m long and 100-230mm width rubber sheets in the first stage and later on second stage further cutting the sheets to change its dimensions to 20-10mm size.
Crumb rubber is used to replace of sand (fine aggregate). This rubber is obtained by separate mills where big size rubbers are converted into smaller sizes of size about 4.75-0.425mm.
Ground rubber is used to replace the cement. In this type rubber particles of size about 0.075-0.475mm in dimension are used. These are also obtained by grinding in separate mills. It has a granular texture and ranges in size from very fine powder to sand-sized particles. It is made from used tyres, by crushing and grinding under normal temperature. It is widely used on road, tyre making and rubber products. Rubber powder has higher purity and performance.
In the present study ground rubber of size 0.075-0.475mm were used for the soil stabilization.

Table 2: Properties of waste tyre rubber

Type of rubber	Ground type
Size	0.075-0.475mm
Colour	black
Specific gravity	0.8 to 0.9.

Fig 2: Ground rubber powder

2.2 Testing Procedure on Materials Used
The laboratory experiments conducted, to evaluate their properties, are as per the IS code specifications. Various tests were carried out in the laboratory for finding the index and other important properties of the rubber powder used during the study. Compaction, direct shear and CBR tests are conducted by using different percentages of rubber powder mixed with soil. The details of these tests are given in the following sections

2.2.1 Specific Gravity
Specific gravity of a substance is defined as the ratio of its mass in air to the mass of an equal volume of water at 4 ºC. The specific gravity of the soil has been determined using the density bottle method, as per IS: 2720-(part III section I, 1980).

Specific gravity of solids (G) = $\frac{(M2-M1))}{(M2-M1)-(M4-M3)}$

Fig 3: Pycnometer equipment

2.2.2 Grain Size Distribution
The soil is sieved through a set of sieves. The material retained on different sieves is determined. The percentage of material retained on any sieve is given by Sieve analysis has been conducted as per IS: 2720 (Part IV 1965).

Fig 4: IS set of sieves

Fig 5: Sieving of soil sample

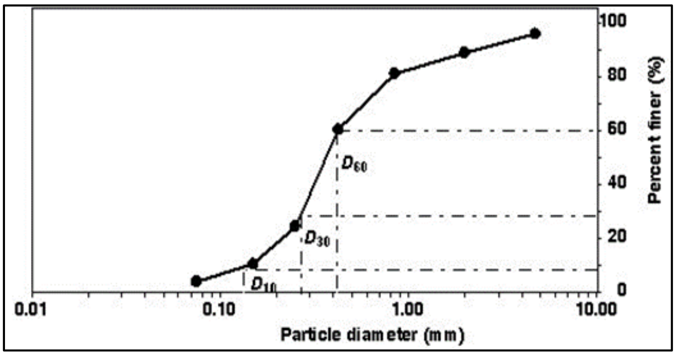

Fig 6: Particle size distribution curve

2.2.3 Liquid Limit
The test has been carried out using the standard Casagrande liquid limit apparatus as per IS: 2720-(PartV-1965).
Different percentages of rubber powder ranging from 0, 5, 10, 15 and 20% by dry weight are mixed with the soil and the liquid limit were determined as per IS: 2720 (part-5)-1985.
Liquid limit is the moisture content at which 25 blows in standard liquid limit apparatus will just close a groove of standard dimensions cut in the sample by the grooving tool by specified amount. The flow curve is plotted in the log-

scale on the x-axis, and the water content in the arithmetic scale on y-axis. The flow curve is straight line drawn on the semi-logarithmic plot, a nearly as possible through three or more plotted points. The moisture content corresponding to 25 blows is read from this curve rounded off to the nearest whole number and is reported as the liquid limit of the soil.

The liquid limit is the water content at which soil changes from liquid state to plastic state.

Fig 7: Cass grand Liquid limit apparatus

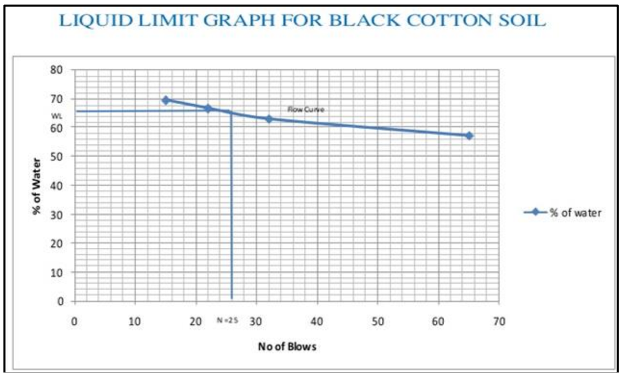

Fig 8: Liquid limit graph

2.2.4 Plastic Limit

The plastic limit has been determined according to the IS: 2720- (Part V-1970). Different percentages of rubber powder ranging from 0, 5, 10, 15 and 20% by dry weight are mixed with the soil and the liquid limit were determined as per IS: 2720 (part-5)-1985.

Plastic limit is the moisture content at which a soil when rolled into thread of smallest diameter possible, starts crumbling and has a diameter of 3mm.

The Plastic limit (w_p) is expressed as a whole number by obtaining the mean of the moisture contents of the plastic limit.

Plastic limit is the water content below which the soil stops behavinglike a plastic material.

Fig 9: Plastic limit test

2.2.6 Light Compaction

Compaction has been carried out as per the IS: 2720- (Part VIII-1980). Compaction means pressing of the soil particles close to each other by mechanical methods. Air, during compaction is expelled from the void space in the soil mass and, therefore, the mass density is increase.

Bulk density(ρ) = mass/volume

Dry density(Υ_d) $= \frac{\rho}{1+wc}$

Where w_c= water content

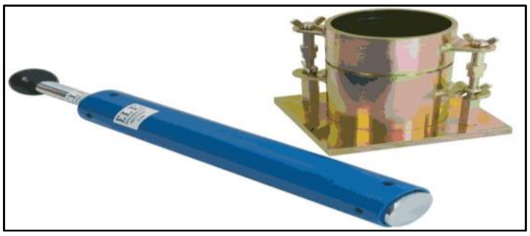

Fig 10: Proctor's compaction mould

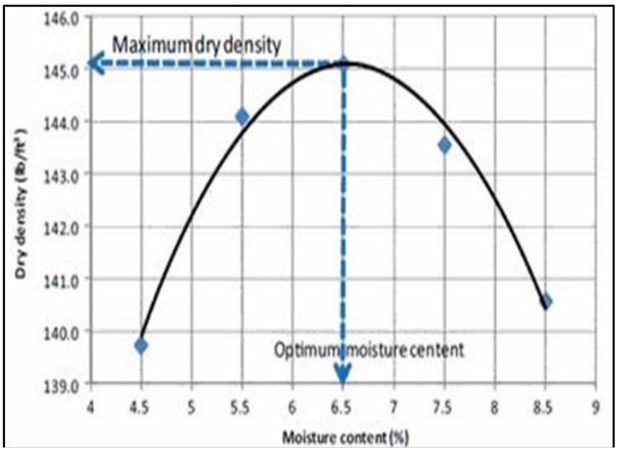

Fig 11: Dry density Vs water content curve

2.2.7 California Bearing Ratio (CBR) Test

California Bearing Ratio (CBR) test as described in IS: 2720 (Part XVI, 1979). The California bearing ratio test is conducted for evaluating the suitability of the subgrade and the materials used in sub-base and base of a flexible pavement.

The plunger in the CBR test penetrates the specimen in the mould at the rate of 1.25mm per minute.

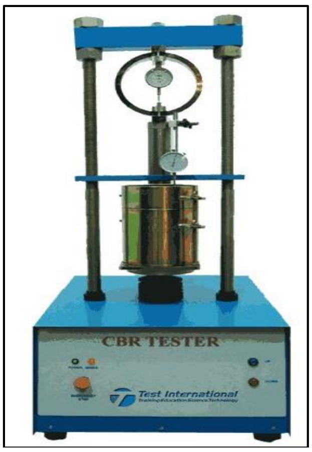

Fig 12: CBR test apparatus

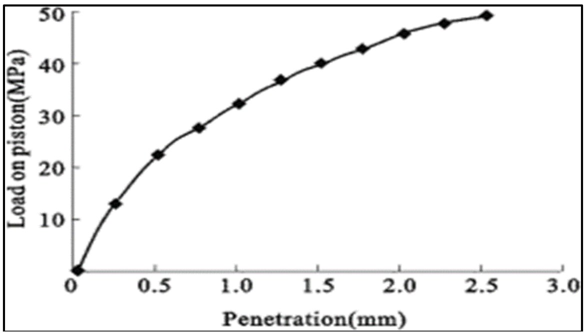

Fig 13: Load Vs penetration curve

Results and Discussions

3.1 Introduction

Details of the laboratory experimentation carried out by stabilizing expansive soil with rubber powder had been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from laboratory experimentation are presented.

3.2 Test Results

3.2.1 Specific Gravity

3.2.1(a) Specific Gravity for Black cotton soil

Table 3: Specific gravity test results for Black cotton soil

S. No	Observations	Trail-1	Trail -2	Trail-3
1	Mass of empty pycnometer (M_1)	0.656	0.656	0.656
2	Mass of pycnometer + soil (M_2)	1.029	1.02	1.047
3	Mass of pycnometer + soil + water(M_3)	1.754	1.751	1.758
4	Mass of pycnometer + water (M_4)	1.54	1.54	1.54
5	Specific gravity G=(M_2-M_1)/(M_2-M_1)-(M_3-M_4)	2.34	2.37	2.26

Avg. specific gravity of Black cotton soil $=\frac{2.34+2.37+2.26}{3} = 2.32$

3.2.1(b) Specific Gravity for Ground rubber powder

Table 4: Specific gravity test results for Ground rubber powder

S. No	Observations	Trail-1	Trail -2	Trail-3
1	Mass of empty pycnometer (M_1)	0.656	0.656	0.656
2	Mass of pycnometer + crumb rubber powder (M_2)	0.862	0.898	0.806
3	Mass of pycnometer + crumb rubber poweder + water(M_3)	1.48	1.48	1.52
4	Mass of pycnometer + water (M_4)	1.540	1.541	1.540
5	Specific gravity G=(M_2-M_1)/($M_2$$M_1$)-($M_3$-$M_4$)	0.77	0.79	0.88

Avg. specific gravity of Ground rubber powder $=\frac{0.77+0.79+0.88}{3} = 0.813$

4.2.1 Grain Size Distribution

Table 5: Particle size distribution curve for black cotton soil

S. No	IS Sieves	Weight of soil retained	% Weight of soil retained	Cummulative % weight of soil retained	% Of finer
1	4.75mm	0.507	25.35	25.35	74.65
2	2.00mm	0.146	7.29	32.64	67.36
3	1.18mm	0.556	27.8	60.44	39.56
4	1.00mm	0.122	5.10	72.6	27.4
5	600µ	0.213	10.65	83.25	16.75
6	300µ	0.235	11.75	95	5
7	150µ	0.078	3.90	98.09	1.1
8	Pan	0.021	1.05	100	0

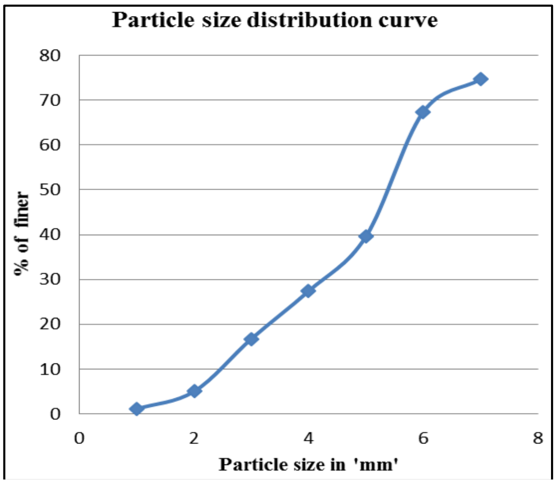

Fig 14: Particle size distribution curve for black cotton soil

4.2.1 Liquid Limit

Table 6: Liquid limit test results for black cotton soil

S. No	Observations	Trail-1	Trail -2	Trail-3	Trail-4	Trail-5
1	No.of blows	46	41	36	30	20
2	Mass of empty container (m_1)	44	45.3	46.8	46.5	47.9
3	Mass of container + wet soil (m_2)	74.81	78.9	94.6	81.4	74.12
4	Mass of container + dry soil (m_3)	66.9	68.2	78.9	69.1	64.6
5	Mass of water (m_2-m_3)	7.91	10.7	15.7	12.3	9.52
6	Mass of dry soil (m_3-m_1)	22.9	22.9	32.1	22.6	16.7
7	Water contentw=((m_2-m_3)/(m_3-m_1))*100	34.54	46.72	48.9	54.42	57

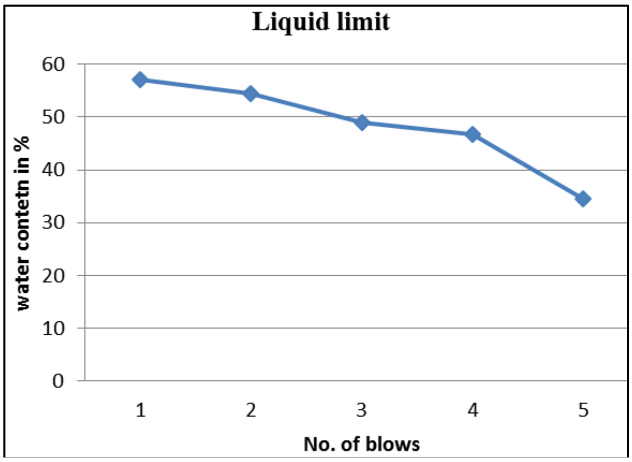

Fig 15: Liquid limit graph for black cotton soil Liquid limitfrom the graph = 54 %

3.2.3 Plastic Limit

Table 7: Plastic limit test results for black cotton soil

S. No	Observations	Trail-1	Trail-2	Trail-3
1	Mass of empty container (M_1)	47	46.8	44.9
2	Mass of container + wet soil (M_2)	107	98.2	102.6
3	Mass of container + dry soil (M_3)	90	83	81.3
4	Mass of water (M_2-M_3)	17	15.2	21.3
5	Mass of dry soil (M_3-M_1)	43	36.8	36.4
6	Water content w=((M_2-M_3)/(M_3-M_1))*100	39.53	41.3	58.51

Plastic limit $=\frac{39.53+41.3+58.51}{3}= 46.44\%$

Plasticity Index = Liquid limit - Plastic limit= 54 - 46.44=7.56 %

3.2.5 Proctor's Compaction test

Table 8: Proctor's compaction test results for black cotton soil with different proportions of rubber powder

S. No	Rubber powder percentage	Maximum dry density(g/cc)	Optimum moisture content(%)
1.	0%	1.513	24.88
2.	5%	1.629	22.13
3.	10%	1.534	22.48
4.	15%	1.51	17.64
5.	20%	1.102	19.53

From the above results, the maximum dry density of black cotton soil is obtained with 5% rubber powder replacement only.

3.2.6. California Bearing Ratio (CBR) Test

Table 9: California Bearing ratio test results for black cotton soil with different proportions of rubber powder

S. No	Rubber powder percentage	CBR value for 2.5mm penetration (%)	CBR value for 5mm penetration(%)
1.	0%	21.57	21.32
2.	5%	25.28	24.29
3.	10%	23.80	22.80
4.	15%	23.05	21.81
5.	20%	22.31	21.81

From the CBR test results it is clear that there is a considerable improvement in California Bearing Ratio (CBR) of black cotton soil with addition of 5% of rubber powder. where as in all remaining cases there is decrease in CBR value with addition of rubber powder. Therefore adding of 5% rubber powder to soil can improve the CBR test values there by increases the soil bearing capacity.

Conclusion

- From this study it is concluded that there is a considerable improvement in California Bearing Ratio (CBR) of black cotton soil with addition of 5% of rubber powder as soil stabilization when compared to only black cotton soil.
- As the percentage of rubber powder increases, the CBR (California Bearing Ratio) value decreases.
- Only at a range of 5 % rubber powder may gives effective dry density and will give higher CBR values. Dry density and CBR values goes on decreasing with 10%,15%,20% of rubber powder.
- Therefore adding of 5% rubber powder to soil can improve the CBR test values there by increases the soil bearing capacity.
- Observing its economic cost and quality of stabilization improvement, it is clear that this type of stabilization may be applicable in stabilization of black cotton soil in construction of road or in shoulder portion of highways.

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