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# A STUDY ON BLACK COTTON - SHREDDED TYRES MIXTURE PROPERTIES

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## ABSTRACT

One of the various problems which mankind faces in this century is the problem of waste disposal management. Since polymeric materials do not decompose easily, disposal of waste polymers is a serious environmental problem. Large amounts of rubbers are used as tyres for aero planes, trucks, cars etc. But after a long run, these tyres are not serviceable and discarded. Stockpiles of scrap tyres, whether in dumps or in recycling facilities, pose serious fire protection challenges to fire departments across the country. Major approach to solve this problem is the recycle and reuse of waste rubber tyres. Since highway construction requires large volume of materials, highway agencies have been encouraged to participate in the recycling effort. Shredded tyres are used in many civil engineering applications nowadays, because these tyres have properties like Lightweight, Low earth pressure, Good thermal insulation, Good drainage and etc. These Shredded tyres are used as Lightweight fill for highway embankments, retaining wall backfill etc.

Experimental work has been carried out in this area to find out the geotechnical characteristics of the black cotton soil and shredded tyres mixed with different percentages (5 and 25%) and sizes (15 and 30mm) to investigate the relative strength gain. The results showed that the compacted dry density reduced solely due to the lighter weight of the tyre, Permeability of the mixture increased, bearing ratio was maximum when 5% of 15mm shredded tyres are added to the soil

**KEYWORDS:** Black Cotton Soil, California Bearing Ratio Test, Compaction Test, Clay Soil, Shredded Tyres

## INTRODUCTION

In developing countries like India, transportation sector plays a vital role in uplifting the national economy. To provide both mobility and accessibility all weather roads should connect every nook and corner of the country. The performance of the pavement mainly depends on the quality of the materials used in the road construction.

As the world population grows, so do the amount and type of waste being generated will be more. The creation of nondecaying waste materials, combined with a growing consumer population, has resulted in a waste disposal crisis. One solution to this crisis lies in recycling waste into useful products. With the ongoing rise in use of motor vehicles, hundreds of millions of tyres are discarded each year throughout the world. Highway construction requires large volumes of materials, highway agencies have been encouraged to participate in the recycling effort. Recovering these materials for use in construction requires an awareness of the properties of the materials and the limitations associated with their use.

In the present, an attempt has been made through a laboratory study to understand the potential of shredded tyres in soil stabilization. In this project it is aimed to examine the strength characteristics of the black cotton soil by using the shredded tyres of different sizes. A series of experiments were conducted by hand mixing the shredded tyres with the soil and test their changes in properties.

## OBJECTIVES OF THE WORK

In this project it is aimed to study

- To examine the suitability of shredded tyres for stabilizing the soil
- In this study, the changes in the engineering properties of the soil with the addition of shredded tyres.

## STABILIZATION BY SHREDDED TYRES

Shredded tyre can be mixed with different soils to improve their engineering properties for specific applications.

### Tyre Composition, Characteristics and Disposal Practices

The average scrap automobile tyre weighs approximately 20 pounds. Heavy truck and industrial tyres can weigh from 35 pounds to several hundred pounds. A typical tyre casing is composed of 83% carbon, 7% hydrogen, 1.2% sulphur and 6% ash. Primary constituents of tyres include polymers, carbon black and softeners. Currently, three main options available for the disposal of scrap tyres are land filling, recycling/re-use and incineration.

### Advantages and Disadvantages of Shredded Tyres

Shredded Tyres exhibit many advantages as a construction material. Some of them are Lightweight, Non-biodegradable and so stable for long time periods, Free draining, Good thermal insulator (8 times better than gravel), Low cost.

Though shredded Tyres appear to be an excellent choice for a lightweight fill material, they do have some drawbacks. First, the use of shredded tyres as a lightweight fills material is a fairly new concept and design guidelines/standards are not yet available. Second, waste Tyres do require some preparation before they can be used as a road building material. The tyres must be cleaned so that they are free from oils and grease in order to avoid soil and groundwater contamination.

## ENGINEERING PROPERTIES OF SHREDDED TYRES

In order to analyse the feasibility of shredded tyres as a potential construction material, the engineering properties of the shredded tyres must first be established. The engineering properties needed to be studied include (1) Particle Size and Shape; (2) Specific Gravity and water absorption capacity (3) Unit weight (4) Shear Strength (5) Permeability.

The results of past research have provided estimates for several engineering properties of shredded tyre material. Newcomb and Drescher (1994) have reported the bulk unit weight of small-size (30 mm mean size) shredded tyre pieces to be 4.9 kN/m$^3$. Unit weights in other studies ranged from 3.1 to 5.2, kN/m$^3$ for uncompacted shredded tyre material and from 5.3 to 7.4 kN/m$^3$ for compacted material (Humphrey et al., 1992; NAPA, 1993) By comparison, the unit weight of water is 9.81 kN/mm$^3$, about twice the value for shredded tyres

### Particle Size and Shape

Particle size distribution can be determined by performing a standard sieve analysis. No modification of the standard test method is required, except that tyre shreds larger than 76 mm cannot be screened through standard sieves. A limited amount of geotechnical analysis has been performed on different sizes of tyre chips. Grain size analyses have indicated that the tyre chips can be classified as a well-graded, coarse-grained material.

### Specific Gravity and Water Absorption Capacity

The specific gravity is the ratio of the particle unit weight or unit weight of solids of the tyre chips divided by the unit weight of water. The specific gravity of tyre chips is expected to be in the 1.1 to 1.3 ranges, with higher specific gravity values for chips containing steel belts. Absorption capacity is the amount of water adsorbed onto the surface of the tyre shreds and is expressed as the percent water based on the dry weight of the shreds. Water absorption capacity of tyre shreds generally ranges from about 2% to 4%.

### Compacted Unit Weight

Depending on the size of the chips, compacted unit weights can range from as low as 322 kg/m$^3$ to as high as 725 kg/m$^3$. Determination of compacted density of air-dried tyre chips is best made by an adaptation of ASTM D1557 (Modified Proctor test). A 254 mm diameter by 254 mm high mould is recommended instead of the usual 101 mm diameter high mould. Since the level of energy applied is not critical, 60 percent of standard Proctor compaction effort is recommended.

### Shear Strength

The shear strength of tyre chips may be determined in a direct shear apparatus using a 305 mm square shear box or using a triaxial shear apparatus. The friction angle of tyre chips varies from 19° to 25°. Cohesion values range from 7.6 kPa to 11.5 kPa, although significant deformation was required to develop cohesion. Tyre chips with a greater amount of exposed steel belts tend to have a higher angle of internal friction. Typical granular soils have friction angles between 30° and 40° with little apparent cohesion. Wu et al. (1997) measured the shear strength of tyre chip/soil mixtures using triaxial shear and concluded that under some circumstances, adding tyre chips increased the shear strength.

### Permeability

The coefficient of permeability of tyre chips varies in the range of 1.5 to 15 cm/sec, depending on their void ratio. For mixtures of tyre shreds and soil with 30 % to 50 % soil by weight, hydraulic conductivities approach those of the soil itself.

## RESULTS AND DISCUSIONS

A brief review of various experiments conducted using shredded tyres to improve the engineering properties like bearing strength, Compaction, permeability, stress-strain behavior; free swell and swelling pressure are explained

## MATERIALS

Black cotton (BC) soils are highly clayey soils, greyish to blackish in colour found in several states of India. For this study the soil was brought from k.jaganathpuram, a place near chodavaram in Visakhapatnam district. The liquid limit and plasticity index values ranges from 40 to 100% and 20 to 60% respectively. Black cotton soils have low shrinkage limits 10 to15% and high optimum moisture content 25 to 30%. The black cotton soils are found to contain montimorillonite clay. The shredded tyre used in this study was obtained commercially in two size groups of 1.5 and 3.0cm size square pieces free of scrap metal. These shredded tyres are mixed with the black cotton in percentages of 5 and 25 by weight.

## COMPACTION TEST

**Table 1: Variation of Maximum Dry Density and Moisture Content for Different Sizes of Shredded Tyres at Different Percentages**

| Size of shredded Tyre (cm) | Percentage of Shredded Tyre | Moisture Content (%) | Dry Density (gm/cc) |
|---|---|---|---|
| 1.5 | Clay alone | 18.27 | 1.7 |
| | 5 | 18.12 | 1.69 |
| | 25 | 18.09 | 1.64 |
| 3.0 | 5 | 18.10 | 1.67 |
| | 25 | 18.15 | 1.63 |

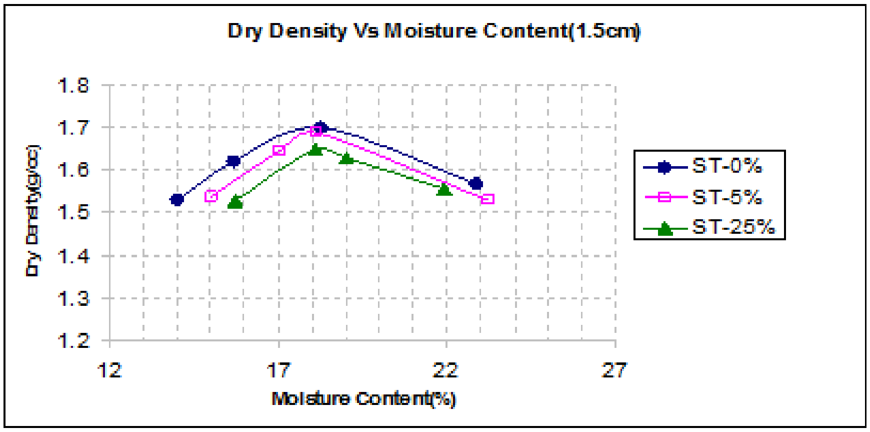


**Figure 1: Compaction Behaviour of Black-Cotton and Black Cotton-shredded Tyre Mixture of Size 1.5 cm**

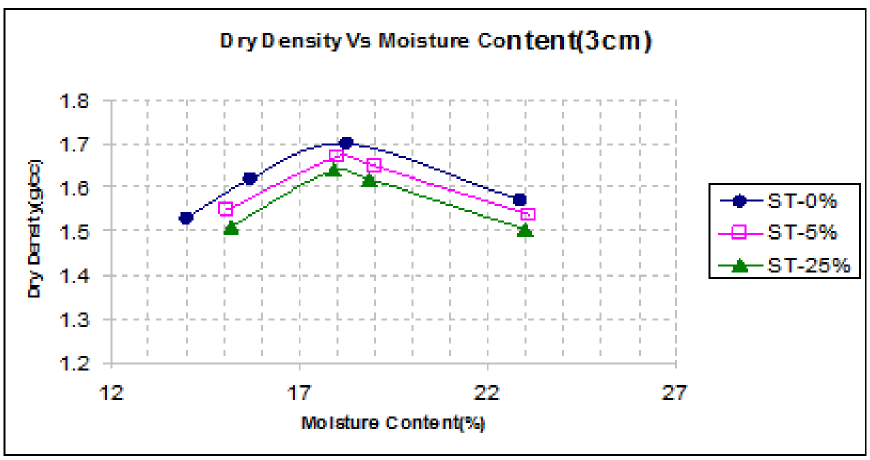


**Figure 2: Compaction Behaviour of Black-Cotton and Black Cotton-Shredded Tyre Mixture of Size 3.0 cm**

From the graphs plotted above we can state that as the percentage and size of the tyre increases the dry density decreases and the optimum moisture content almost remains same. A decrease in dry density was expected due to the lighter weight of tyre compared to the soil. The decrease in dry density was found by calculations to be mainly due to that effect which shows that the presence of tyre did not have a detrimental effect on the compaction of the soil.

## CALIFORNIA BEARING RATIO TEST

**Table 2: Variation of CBR Value with Respect to Percentage of Shredded Tyres for 1.5 cm and 3.0 cm Size**

| Material | % OF Shredded Tyre | CBR Value (%) |
|---|---|---|
| Black cotton | 0 | 5.24 |
| Black cotton and shredded tyre(1.5cm) | 5 | 11.27 |
| Black cotton and shredded tyre(1.5cm) | 25 | 10.28 |
| Black cotton and shredded tyre(3.0cm) | 5 | 11.51 |
| Black cotton and shredded tyre(3.0cm) | 25 | 10.26 |

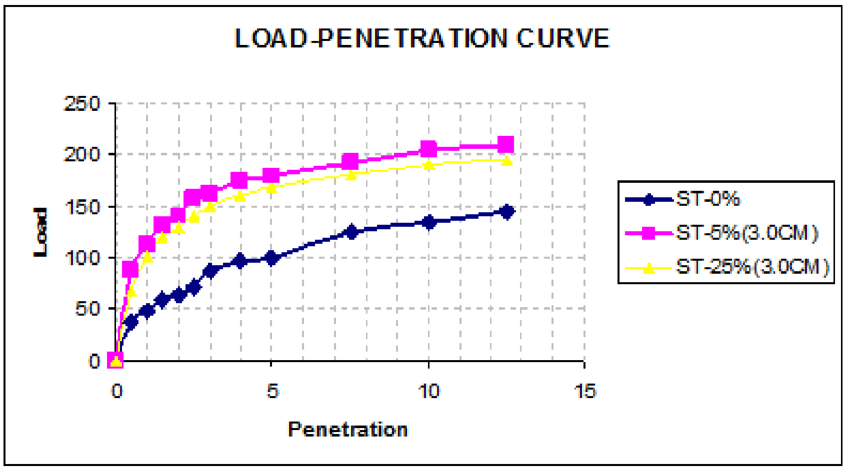


**Figure 3: Penetration – Load Curves with Respect to Percentage of Shredded Tyres for 3.0cm Size**

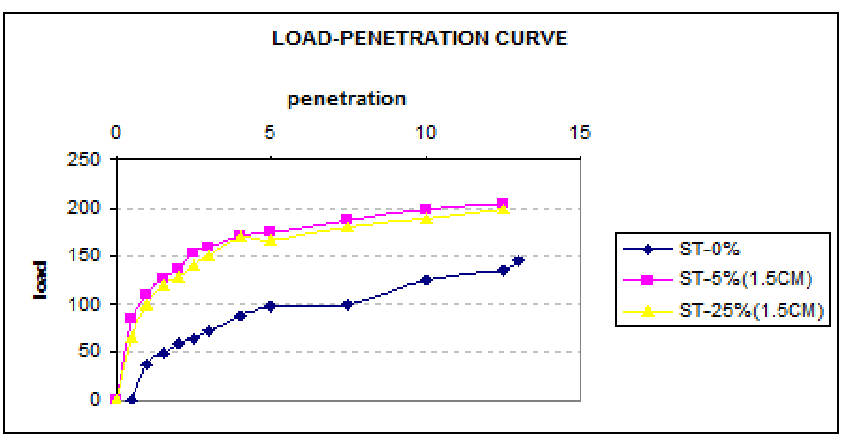


**Figure 4: Penetration –Load Curves with Respect to Percentage of Shredded Tyres for 1.5cm Size**

The CBR value for Black Cotton alone is very low compared with the CBR values for black cotton-tyre mixture. When the soil is mixed with shredded tyres the strength increased gradually. It has been observed from the test conducted that the CBR value generally increased as the size and percentage was increased.

## PERMEABILITY

**Table 3: Permeability (cm/sec) of Black Cotton and Black Cotton–Shredded Tyre Mixture**

| Type Of Sample | Permeability |
|---|---|
| SOIL ALONE (ST-0%) | $4.6\times10^{-7}$ |
| ST-5%(1.5CM) | $4.7\times10^{-7}$ |
| ST-5%(3.0CM) | $6.82\times10^{-7}$ |
| ST-25%(1.5CM) | $5.43\times10^{-7}$ |
| ST-25%(3.0CM) | $6.73\times10^{-7}$ |

In this test it was observed that as the length of shredded tyres increase the permeability of Black cotton–shredded tyre mixture increased. The maximum permeability obtained was for shredded tyre with size 3cm. However, if the increase is not significant it indicates 'good bonding' between the black cotton and shredded tyre and that the development of large pores and cracks was minimal.

## CONCLUSIONS

Experiments were conducted with the addition of 5 and 25% by weight of shredded tyre in two different sizes of 1.5 and 3.0 cm pieces to black cotton soil, at a moisture content of 18% around the optimum value, and these are the following observations made:

- Compacted dry densities of black-cotton and shredded tyre mixture were found to vary between 1.63 and 1.67 gm/cc which is around 90% of that the soil alone. The reduction was purely due to the lighter weight of the tyre indicating minimal detrimental effect.
- Due to the lightweight of the shredded tyres these can be used for construction on weak, compressible soils where slope stability or excessive settlement is concern.
- High permeability allows free drainage and prevents build-up of hydrostatic pressures.
- The CBR value of soil-tyre mixture also increased compared to that of the soil alone. But as the size of tyre increases sometimes the CBR value may get reduced.

The range of results produced shows the high dependency of the behaviour of the soil-tyre mixtures on the moisture content and tyre content. Hence, each situation needs to be considered separately to arrive at black cotton –tyre mixture suitable for the site and problem conditions

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