A Study on Usage of Waste Tire Chips in Highway Construction

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Abstract This study investigates the use of crumb rubber and tire chips, derived from recycled tires, in pavements and highway embankments to address environmental concerns over tire waste and the demand for sustainable construction materials. Through laboratory tests, the geotechnical properties of clay soils stabilized with tire chips and crumb rubber-modified bitumen were evaluated. Results indicated that tire-derived materials enhanced the strength, ductility, and stability of pavements, with crumb rubber improving bitumen's resistance to deformation. Tire chips were shown to increase soil ductility and load distribution without compromising permeability, making them suitable for hydraulic structures. Incorporating these materials into construction offers a sustainable solution to tire disposal challenges and enhances pavement durability, with potential for widespread field applications in regions with weak subgrades. Future research should focus on large-scale testing and optimizing crumb rubber content in bitumen for cost-effective performance.

Key Words: Crumb Rubber, Tire Chips, Pavement Construction, Highway Embankments, Geotechnical Properties, Clay Soil Stabilization, Recycled Materials, Sustainable Construction, Bitumen Modification, Environmental Impact, Laboratory Tests, Engineering Properties, Ductility, Load-Bearing Capacity, Permeability.

1.INTRODUCTION

Over naturally occurring dirt, a somewhat solid crust known as a pavement is built to support and distribute wheel loads and to serve as a suitable wearing surface. Due to variations in the qualities of the soil and the frequent application of wheel loads, which causes excessive settling, these pavements frequently sustain damage quickly. Furthermore, fluctuations in the water content of clay soils, frost action, and variations in moisture all contribute to the deterioration of pavement and need expensive repairs.

The rapidly running out of regularly used resources has caused construction expenses to rise. Finding novel materials and creating better methods for processing locally available resources are therefore of increasing importance. The best course of action when low-quality soil is available at a building site is to alter the soil's characteristics.
Therefore, it is recognized that pavement construction requires cost-effective technology. Numerous factors, including size distribution, dry density, ideal moisture content, and California bearing ratio, were determined by laboratory testing. Crumb rubber's advantages for building pavement were enumerated, and the use of leftover tire chips to surface courses, subgrades, and embankments was explained. There was also discussion about the current study's goals and purpose.

Crumb rubber is made by either mechanically or cryogenically (Using very low temperature to change the tire material properties) reducing the size of the tires. Cryogenic size reduction is costly and does not produce an optimum rubber for use in CRM asphalt binders. Mechanical sizing, by chopping and grinding, is most often used. Tires are shredded to particles of about ¾ in. and magnetic separators and fiber separators are used to remove steel and polyester fragments.

The rubber chips are reduced further to pebble size by grinders or granulators. Additional grinding and screening operations produce crumb rubber in the desired size range. At present a significant amount of crumb rubber is obtained from buffing and peels from tire retread shops or other industrial operations that produce waste rubber. Crumb rubbers and other tire-derived products can be manufactured from various tire components. Definitions of the types of rubber obtained from tires can be found.

Over the last 15 years, the chemical composition of tires, as viewed from the stream of scrap tires, has changed significantly. The United States has moved from predominantly bias tires to predominantly radial tires. Individual companies change their compounds for specific tires. As more uses are found for recycling this stockpile of material, older tires will be mixed into the stream. The different compounds used for radial and bias tires will change the chemical composition of the recycle stream, introducing additional variations. The physical and chemical properties of the processed scrap tires determine, to a degree, their end use.

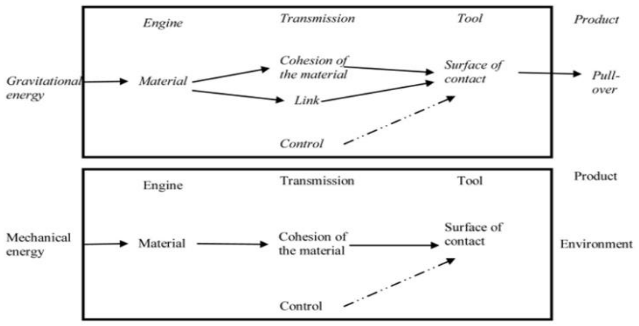

Fig. 1 Purpose of Synthesis

2. OBJECTIVES OF THE WORK

This study's goals are to assess the viability of using leftover tire chips to build embankments and investigate the usage of crumb rubber as a bitumen substitute. To do this, the research is designed with the following goals in mind.

Objectives.

- Research the chosen clay subgrade's engineering characteristics.
- Examine the tire chips and 60/70 grade bitumen's engineering qualities.
- Examine the rubber powder gradation between 30 and 40 mesh.
- Evaluate how the engineering qualities of the soil stabilized by tire chips have improved.

2.1 Scope of the work:

Most of the works as soil-tire chips properties have been concentrated as sandy soils and gravely soils. As pavements laid along canals are supported by clay embankments, the present study is intended to assess the effect of addition of tire chips in clay soil. The study is intended to assess the effect of gradation of crumb power on the properties of crumbs rubber modified bitumen.

Most research focusing on the properties of soil-tire chips has predominantly concentrated on sandy and gravelly soils. However, many pavements, particularly those constructed along canals, are supported by clay embankments, which exhibit different mechanical and physical properties compared to granular soils.

Therefore, the present study aims to assess the impact of adding tire chips to clay soil, exploring how this addition influences the soil's characteristics and overall performance.

Additionally, the study will examine the effect of gradation of crumb rubber on the properties of crumb rubber modified bitumen. The inclusion of crumb rubber in bitumen can significantly alter its rheological properties, enhancing the flexibility, elasticity, and durabilityof the binder. By investigating the interaction between tire chips and clay soil, as well as the influence of crumb rubber gradation on modified bitumen, this research seeks to provide valuable insights into improving pavement performance and longevity in areas with clayey subgrades.

The findings could lead to more effective pavement design strategies that incorporate recycled materials like tire chips, promoting sustainability in construction practices while also addressing the challenges posed by clay soils in pavement applications. This research is vital for developing innovative approaches to improve the structural integrity and performance of pavements built over clay embankments, ensuring their durability and resilience under varying environmental conditions.As pavements laid along canals are supported by clay embankments, the present study is intended to assess the effect of addition of tire chips in clay soil. The study is intended to assess the effect of gradation of crumb power on the properties of crumbs rubber modified bitumen. Most research focusing on the properties of soil-tire chips has predominantly concentrated on sandy and gravelly soils.

3. THEORY AND METHODOLOGY

As embankments/ bunds for canals and revivers arc formed with impervious soils, the pavements proposed to be laid over them face problems due to low strength.

Hence, clay soils used in embankments supporting pavements are to be stabilized such that strength is improved without losing impervious character of clay as they are meant for seepage control.Hence in the present study clayey soil is stabilized by adding 10 mm size waste tire chips to improve ductility of soil for better resistance to dynamic loads.

The methodology involves determination of engineering properties of clay and then determining compaction characteristics of clay understudy with addition of varying percentages of tire chips.The CBR specimens are prepared at OMC and MDD condition and are tested after 4 days of soaking. The tire chips have been proposed to be added in increments of 5% up to 20% (by weight).

3.1Methodology for crumbs rubber modified bitumen

As 60/70 grade bitumen is preferred for use in surface courses, in the present work the maximum percentage of crumb rubber that can be added to bitumen without compromising on ductility requirements (50 cm minimum) specified by IRC.

For the commercial 60/70 grade bitumen, engineering properties namely viscosity, penetration, softening point and ductility are performed in laboratory by conducting tests as per relevant codes of practice.

In the present study 30 mesh and 40 mesh crumb rubber powder is proposed to be added to bitumen in varying proportions in the range of 0 to 15% in the increments of 5%. The effect of addition of crumb rubber powder on ductility,

softening point, penetration and viscosity of bitumen has been assessed through laboratory test. Based on the results of the test the maximum percentage of crumb rubber powder that can be blended with 60/70 grade bitumen has been finalized.

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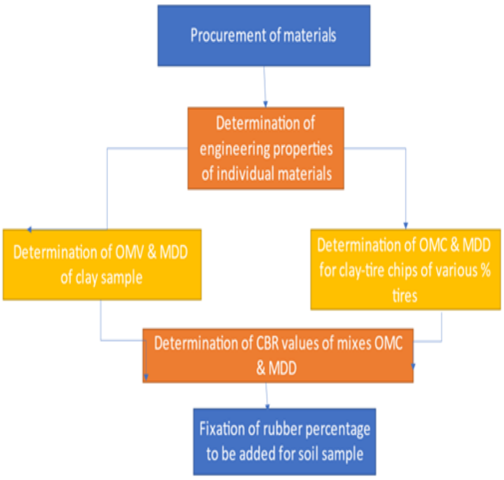


Fig. 2 Flow Chart for Methodology

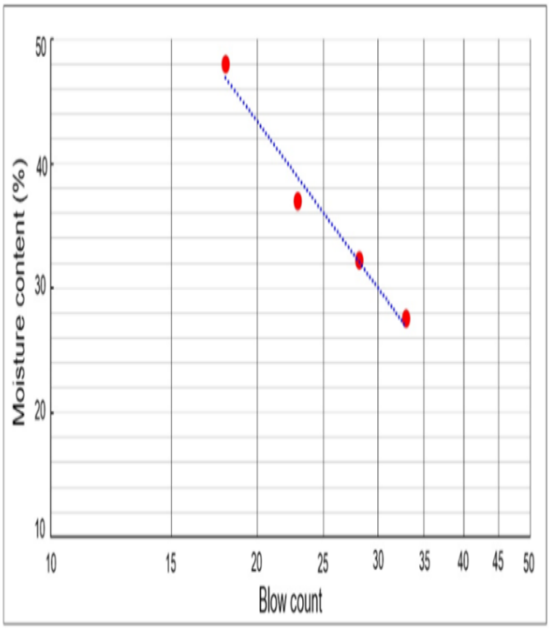
4.RESULTS AND DISCUSSIONS

4.1 Sub grade Soil

The sub grade soil used in the study is clay of intermediate plasticity (fines 97%, Liquid Limit 50% and plastic limit 26.4%).

The clay has differential free swell of 30% and hence has moderate swell potential.

The soil has maximum dry density of 1.58% g/cc at optimum moisture content of 22.2%. The soil has low California Bearing Ratio (2.9%), the low CBR value is due to its fine-grained character and poor drainage conditions.



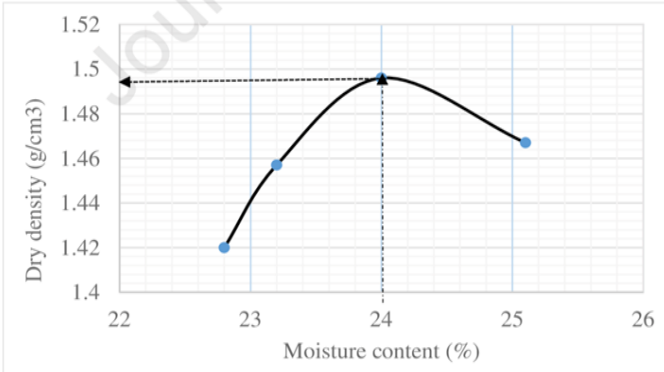


Fig. 3 Flow Curve of Sub Grade Soil

4.2 Crumb Rubber

The specific gravity of crumb rubber used in the study is 1.1. The maximum and minimum dry density of the material arc 1.26g/cc and 1.08g/cc respectively.

4.3 Bitumen

The 60/70 grade bitumen used in the study has penetration value of 61 mm, ductility of 163 cm, softening point of 50^0c and viscosity of 348s.

4.4 SUMMARY OF TESTS ON SOIL STABILIZED BY TIRE CHIPS

The sub grade soil used in the study has been stabilized with tire chips of (10mm size) in various proportions (5%,10%,15%, and 20%). The results of various tests conducted as soil-tire chip mixes are summarized below**.**

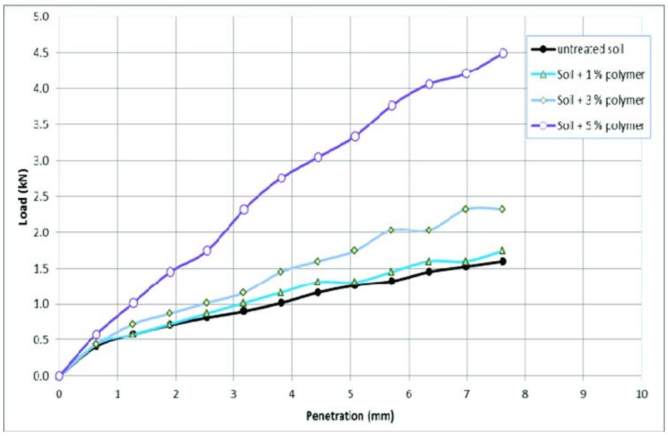


Fig. 4 Load Penetration Curve of Soil

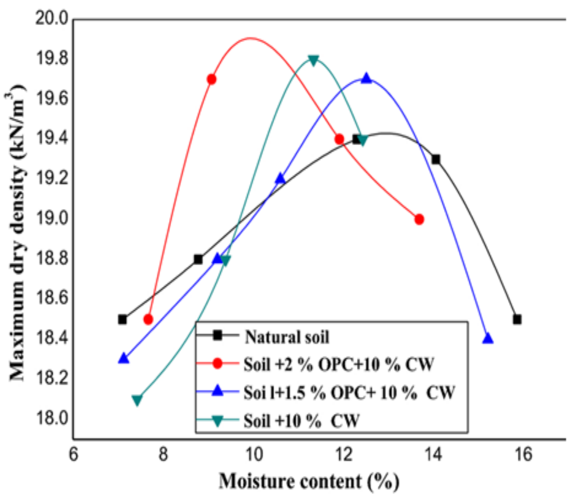
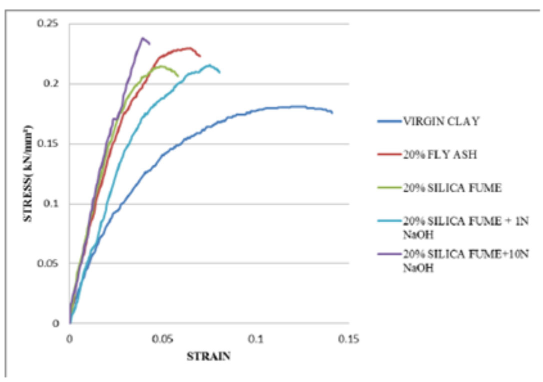


Fig. 5 Compaction Curve of Soil Stabilized by 10%

4.5 Compaction characteristics

I.S Light compaction tests are conducted in the laboratory indicated that maximum dry density values and optimum moisture contents decreased with increase in addition of tire chips.



5. California Bearing Ratio

Soaked CBR values increased from 2.9% to 5% an addition of tire chips (0% to 15%) and CBR value decreased to 45% with addition of tire chips by 20%.

Hence it can be concluded that the optimum percentage of tire chips to be added to soil for stabilization is 15%.

5.1 Ductility

The stress-stain diagram revealed that ductility of clay with increase in tire chips addition. At 15% tire chips addition ductility increased by about 30%.

Hence the soil stabilized with tire chips can absorb impact / dynamic loads in a better manner.

5.2 SUMMARY OF TESTS ON CRUMB RUBBER MODIFIED BITUMEN

The 60/70 grade bitumen used in the study has been blended with 30 mesh and 40 mesh crumb rubber in different proportion.
The effect of addition of crumb rubber powder to bitumen is summarized below.

5.3 Penetration Value

Penetration value decreased with increased in percentage of crumb rubber added. Hence, it can be inferred that the bitumen sample becomes stiffer. More viscous with the addition of crumb rubber.

Bitumen modified with 40 mesh crumb rubber is more compared to that of 30 mesh crumb rubber. Penetration value of 30 mesh crumb rubber is 49 mm for 40 mesh crumb rubber.

5.4 Ductility

A significant reduction in ductility value is observed with addition of crumb rubber (of both sizes) to bitumen.

The bitumen sample becomes brittle with the addition of rubber. Ductility of bitumen modified with 30 mesh crumb rubber is more compared to that of 40 mesh rubber.

As minimum recommended by IRC is 50 cm, the maximum percentage of crumb rubber powder for use in bitumen blending are 10% and 7% respectively.

5.5 Softening Point

It is observed that the softening point increased with percentage of crumb rubber. Hence, bitumen becomes less susceptible to temperature with addition of rubber and can be used even in hot climates. Softening point of bitumen modified within 40 mesh crumb rubber is 56^0c and 54^0c for 30 mesh.

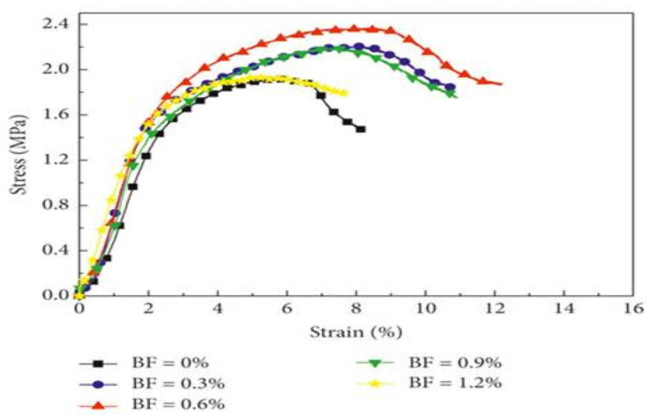


Fig. 7 Stress –Strain Curve of Soil Stabilized bt Tire Chips

5.6 Viscosity

The viscosity increases with increase in percentage of crumb rubber added to bitumen. Hence it can be attributed to decreased fluidity of the bitumen with addition of crumb rubber. Viscosity of bitumen modified with 40 mesh crumb rubber is 400 s and 300 s for rubber. Hence 40 mesh crumb rubber is more viscous than 30 mesh.Hence it can be concluded that 30 mesh crumb rubber is more effective for bitumen modification compared to 40 mesh rubber.

6. CONCLUSION:

Based on the experiments carried out in laboratory, the following conclusions are drawn.

(A) Suitability of soil-tire chip mixes for Embankment and Sub grade construction.

1. Optimum percentage of tire chips for stabilizing clay sub grade of intermediate compressibility under study is 15%.
2. The hydraulic conductivity at optimum percentage of tire chips added is $3.8X10^{-7}$ cm/s.
3. The percentage improvement in CBR value of clay subgrade at optimum percentage of tire chips is 40%.
4. The ductility improved by about 30% at optimum percentage of the chips.
5. CBR values of tire chips stabilized clay soil are meeting the AASTHO requirements specifications for road embankments and hence tire chips stabilized clay can be advantageously using in construction of highway embankments.

(B) Crumb Rubber Modified Bitumen

1. Maximum percentage of crumb rubber powder that can be added to bitumen is 10% for 30 mesh rubber and 7% for 40 mesh rubber.
2. Crumb rubber modified bitumen is more useful to high in temperature as it has higher softening point and penetration lesser value compare to crumbed bitumen. Hence, can be used in semi-arid and arid regions.
3. The ductility of clay subgrade improved with increase in addition of tire chips. Crumb rubber modified bitumen offers higher resistance to deformation at elevated pavement temperatures.
4. 30 mesh crumb rubber shall be preferred to 40 mesh crumb rubber for producing crumb rubber modified bitumen.

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