Performance Enhancement of Railtrack Ballast with Rubber Inclusions: A Laboratory Simulation

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• **Railtracks**: rails, sleepers, railpads, fastenings, ballast, sub-ballast and subgrade.

• All the components constitute the **superstructure** of a railtrack while the **subgrade** consists of a formation layer and the base of the track.
Ballast, essentially angular hard stones, could be sourced from granite, limestone, recycled slag or other crushed stones.

The ballast layer, with depths of 30-50 cm, functions as a support to the track structure against deformation from dynamic loads transmitted by the passing trains.
INTRODUCTION

• Considering the cost-effectiveness, availability and practicality of ballast, advancement in railway technology would arguably outrun the material substitution or total replacement in the near future.
INTRODUCTION

- **Problems** with ballasts:

  - *vertical and horizontal movements* caused by traffic loads are attributed mainly to the *deformation* and *densification* of the ballast

  - compromised *ride quality*, requiring either *speed restrictions* or *maintenance* to realign the tracks
• **Expectations** of ballasts:

- tough, dense, weather-resistant and mechanically stable...

- ...*particle size of ballast* significantly affect the overall resilient modulus, volumetric and shear behaviour...

- ... track settlement is very much dependent on the *ballast quality* and its *response to traffic load*.
INTRODUCTION

• Track settlement... volume reduction caused by

1. Densification: involves phases of particle rearrangement, penetration into ballast voids, particle breakdown and abrasive wear,

2. Non-elastic behaviour of ballast-subgade system: encompasses inter-particle microslips as well as movement of ballast and/or sleepers.
INTRODUCTION

• Track settlement also involves...

- initial packing of the ballast: strong influence on the long term track performance

- crushed ballast do not only indent and roughen the metal, but inadvertently increase the traction level and reduce the residual fatigue life of the contact
• THIS project…

- **Prolong** ballast life, enhanced long term performance of railtracks.

- Examines the potential of **rubber inclusions** in increasing the shear resistance of ballast, hence reducing the wear-and-tear effect of traffic loads.

- ONLY **static load** was applied using a conventional shearbox tests setup in this exploratory work.
MATERIALS AND METHODS

Downsized particles (granitic aggregate 5-20 mm): to fit in shearbox.

Average crushing strength of the aggregates: at 85 kN.

Simulation of aggregate-rubber mixture under poor drainage conditions (in prolonged wet weather), a batch of aggregates only were soaked in water for 7 days prior to mixing and testing.
The rubber inclusions, in strips and shreds, were prepared from new inner tubes of motorcycles.

The thickness of the inner tube was approximately 1 mm.
MATERIALS AND METHODS

Test configurations

<table>
<thead>
<tr>
<th>5-20 mm</th>
<th>8 mm x 30 mm</th>
<th>2-8 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Control (C)" /></td>
<td><img src="image2" alt="Strips (ST)" /></td>
<td><img src="image3" alt="Shreds (SH)" /></td>
</tr>
</tbody>
</table>

- **Control (C)**
- **Strips (ST)**
- **Shreds (SH)**
MATERIALS AND METHODS

Shearbox Test

- Shearbox: **60 mm x 60 mm x 25 mm**; shearing rate: **0.2 mm/minute**
- Width to thickness ratio of **2.4** (large width compared to the thickness): eliminates **edge effects** and ensures **shearing on the flat contact surfaces**.
- Minimum specimen **width** and initial **thickness** should be kept \( \geq 10 \) times and \( \geq 6 \) times the maximum particle diameter respectively, while the minimum width should be at least twice the thickness.
- The 3 **vertical stresses** applied for each test was 5, 7 and 9 kPa.
RESULTS & DISCUSSIONS

\[ \tau - \varepsilon_v \text{ plots.} \]
RESULTS & DISCUSSIONS

$\varepsilon_v - \varepsilon_h$ plots.
RESULTS & DISCUSSIONS

Table 1. Summary of friction angle ($\phi$).

<table>
<thead>
<tr>
<th>Specimen</th>
<th>$\tan \phi$</th>
<th>$\phi$ ($^\circ$)</th>
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<tbody>
<tr>
<td></td>
<td>DRY (D)</td>
<td>WET (D)</td>
</tr>
<tr>
<td>Control (C)</td>
<td>26.83</td>
<td>26.76</td>
</tr>
<tr>
<td>Strip (ST)</td>
<td>32.30</td>
<td>25.82</td>
</tr>
<tr>
<td>Shred (SH)</td>
<td>27.94</td>
<td>28.11</td>
</tr>
</tbody>
</table>

$\tau - \sigma_v$ plots.
CONCLUSIONS

• Rubber inclusions are effective in enhancing shear resistance of ballast.

• Wet condition somehow impeded the mobilization of shear resistance, but the overall deformation of the composites was reduced, with higher shear resistance mobilized too.

• Future work could include more detailed rubber-aggregate configurations, surface treatment of the rubber elements to improve the frictional contact, protection of the train’s metal wheels with reduced ballast breakage from the cushion effects of the rubber elements.
THANK YOU