Closure to “Enhancing Rail Track Performance Using Recycled Rubber Energy Absorbing Grids: Laboratory and Field Evidence”

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Authors’ Response:

The authors would like to express their appreciation for the feedback provided by the Discusser, and for raising some relevant discussion points. While the Authors are generally in agreement with the Discusser’s comments, some points warrant further clarification as highlighted and elaborated below:

Measured Lateral and Vertical Deformation of Ballast

The discusser makes a valid observation, which the Authors fully acknowledge. A woven geotextile was indeed placed at the ballast–capping interface in the large-scale cyclic loading test program. This fabric was used consistently in all tests, both with and without the REAG, to ensure comparable boundary conditions. The woven fabric served primarily to prevent ballast particles from penetrating into the capping layer and to minimize the upward migration of fine particles from the capping layer into the ballast. The Discusser is also correct in noting that if nonwoven geotextiles had been used instead of woven ones, there would have been a higher likelihood of puncture by the ballast particles, since woven geotextiles typically exhibit greater tensile strength and puncture resistance than nonwoven alternatives (Koerner, 2012). As detailed in Hettiyahandi et al. (2025), the REAG effectively reduced both lateral displacement and settlement of the ballast across all applied load magnitudes and loading frequencies, outperforming conventional polymer geogrids and under-ballast mats in terms of deformation control and energy dissipation.

Ballast Breakage

The Discusser’s observations regarding ballast breakage are consistent with the findings presented in Fig. 7. The Ballast Breakage Index (BBI) decreased across all ballast layers when the REAG was introduced, with the greatest reduction observed in the bottom layer directly above the grid. This reduction results from the REAG's ability to attenuate dynamic stresses and absorb impact energy, thereby limiting particle degradation (Siddiqui et al. 2023). Consequently, the measured reductions in BBI correlate well with the corresponding decreases in settlement and lateral displacement, reaffirming the effectiveness of the REAG in improving ballast stability and durability under cyclic loading.

Field Testing

A drainage layer and a subsurface drainpipe were incorporated in the field test section to address the heavy rainfall and periodic saturation of the subgrade encountered during the construction process, which were conditions that were not present in the controlled laboratory environment. In the field, nonwoven geotextiles were placed both on top of the subgrade and over the capping layer. The geotextile placed above the subgrade served to prevent upward migration of fine particles into the overlying layers, while the one above the capping layer minimized contamination of the ballast by underlying fines and restricted ballast intrusion into the capping material (Indraratna et al. 2025). The Discusser is also correct in observing that nonwoven geotextiles were used in field trials, whereas woven geotextiles were adopted in laboratory tests. Although woven fabrics are generally stronger, the use of nonwoven geotextiles in the field was recommended by the technical team at the Chullora Rail Precinct to ensure adequate drainage through the layers under wet site conditions, since woven geotextiles could have impeded vertical water flow. The authors wish to clarify the maximum dry densities of the ballast and capping layers are 1.6 and 2.2 tonne/m^3, respectively, and these values are presented in Table 1.

Energy Dissipation and Damping Ratio of the Track

The Authors acknowledge the Discusser's further elaboration on the comparison of energy dissipation between the REAG and the conventional under-ballast mat (UBM). As noted, the UBM, being a solid rubber sheet without apertures, possesses a larger rubber volume than the REAG, which inherently allows greater energy absorption per cycle of loading (Navaratnarajah et al. 2018). However, it should be emphasized that the REAG, despite its smaller rubber volume, also enhances internal confinement and reduces particle displacement, leading to improved long-term performance, particularly in maintaining track geometry stability under repeated train loading (Qi et al. 2024).

The Discusser is correct in noting that the woven geotextile layer placed beneath the REAG could have a minor effect on the measured energy dissipation. Nevertheless, this contribution is considered negligible compared to that of the REAG itself. The woven geotextile is not viscoelastic in nature and therefore does not undergo significant resilient deformation under cyclic loading. Furthermore, no visible deformation or damage was observed in the geotextile layer after the testing, confirming that its influence on the overall track performance was minimal. The primary mechanism of energy dissipation arises from the viscoelastic deformation of the REAG (i.e, damping property) and frictional interactions at the ballast–grid interface, as discussed in Hettiyahandi et al. (2025).

Concluding Remarks

The authors thank the Discusser for their constructive comments and valuable insights regarding the cost implications associated with producing REAG and UBMs, as well as the availability of source materials for their manufacture. It was observed that the REAG outperforms the UBMs in reducing ballast breakage because of the additional confinement and interlocking restraint it provides to the ballast particles. This enhanced confinement minimizes particle displacement, leading to improved deformation control and prolonged track stability. In Australia, large quantities of discarded rubber conveyor belts are generated annually from the mining sector, particularly in Western Australia, making them a readily available and sustainable resource for manufacturing REAG. Nevertheless, the authors acknowledge that the availability of discarded conveyor belts for REAG production may be constrained in regions lacking a substantial mining industry. The fabrication of REAG employed water jet cutting technology, which could entail marginally higher production costs compared to the direct reuse of recycled conveyor belts for UBMs. However, such additional costs are expected to diminish with large-scale commercialization and the establishment of an open market.

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