Project D	**Re-use of Ballast**
Part of	**Part of theme RC1, TRACK4LIFE;** sub-theme RC1C, Life extension of ballast.
Project timing	September 2016 – ongoing
More information from	Dr Antonis Zervos
Project partners	Network Rail (NR)
Associated project	EU project In2Rail, H2020-MG-2014: Grant agreement 635900. WP3, Deliverable 3.3: T2F researchers wrote section 4.4.3 on re-use of ballast

Project aims

Large quantities of ballast are disposed of or “downcycled” when track is renewed, on the basis that it is “spent”. However, if the degradation in mechanical performance can be quantified and taken into account in design or mitigated by other interventions, such ballast could be re-used in track. This project develops an improved understanding of the behaviour of re-used ballast and the underlying reasons through:

1. laboratory rig tests to investigate the mechanical performance of recovered ballast
2. grain-scale shape studies and laboratory contact mechanics experiments
3. numerical discrete element analysis (DEM) to explore possible fundamental mechanisms for any deterioration in ballast performance (e.g. attrition, loss of surface roughness, increased grain roundness, change in PSD).

Progress to date

Project aim 1. Rig tests have been carried out to compare the performance of recovered, screened and cleaned ballast with that of fresh ballast in terms of resilient modulus and the development of permanent settlement. Results indicate that the performance of the recovered ballast is at least as good as that of fresh material (Fig.D1), although the generality and range of uncertainty of this finding needs to be tested.

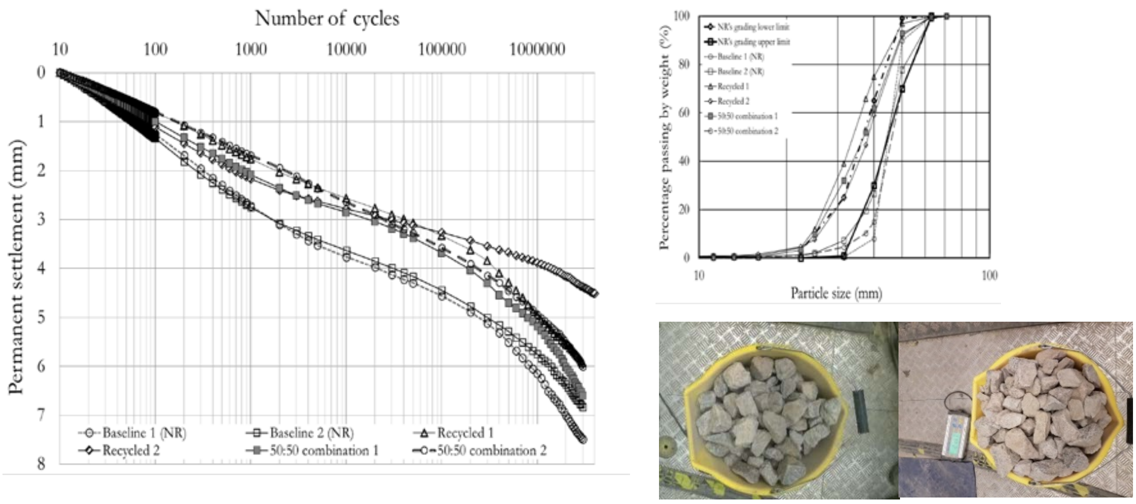

Fig.D1: (a) Plastic settlement vs log no. of loading cycles and (b) PSD for fresh and recovered ballast; (c) fresh and (d) recovered ballast

Project aim 2. A study of ballast grain shapes has led to the development of two new parameters to characterise particle form. These are the platyness, $\alpha = 2(I - S)/(L + I + S)$, and the elongation, $\xi = (L - I)/(L + I + S)$, where L, I, and S are the longest, intermediate and shortest diameters of a particle's equivalent scalene ellipsoid. Longer and platier particles lead to a higher aggregate strength, but also to more sliding contacts. This suggests that in reusing ballast, grains that have become rounded or polished by usage should be avoided; this will be tested in future work. Contact mechanics experiments (Fig. D2) have been carried out to assess the effect of surface damage on grain interaction properties, to inform DEM.

Fig.D2: Ballast grain contact mechanics tests

Project aim 3. A "conical damage" contact model [D8] has been developed to represent ballast grain abrasion and asperity breakage in numerical discrete element method (DEM) analyses, complementing the conventional approach [D9]. This gives excellent agreement with monotonic tests and significantly improved agreement with cyclic tests (Fig. D3).

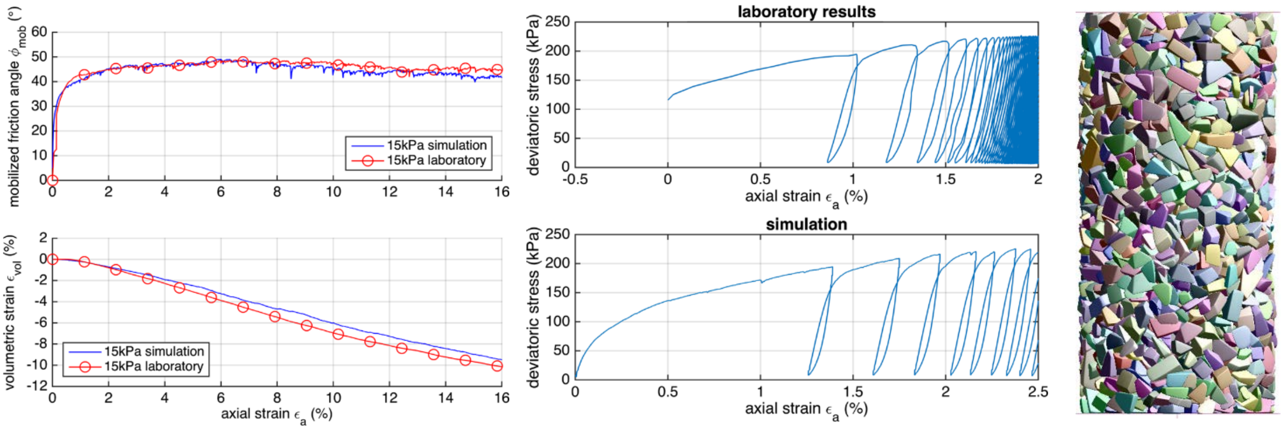

Fig.D3: Comparison of conical damage DEM and laboratory triaxial test results in (a) monotonic and (b) cyclic loading; (c) numerical triaxial test specimen

Planned further work (Programme objectives in brackets)

- advanced monotonic and cyclic triaxial tests on full size and scaled ballast to evaluate the relative performance of new and spent ballast. Fouling will also be considered (1C.1)
- field measurements of dynamic and continuing track movements before and after a renewal (1C.3)
- further laboratory ballast contact tests to refine the input variables for the improved contact mechanics model and numerical discrete element method (DEM) models already developed. This will enable more accurate reproduction of cyclic behaviour for both fresh and used ballast. DEM will then be used to explore further the effects of how changing contact mechanics between new and spent ballast may be responsible for any deterioration in ballast performance (1C.4)
- development of use / acceptance criteria for recovered ballast (1C.5)
- incorporation of results into integrated performance and maintenance models (1C.6)
- possibility of a field trial of re-used ballast (dependent on support from Network Rail) (1C.3).

Journal papers

[D8] Harkness, J, Zervos, A, Le Pen, L, Aingaran, S, & Powrie, W (2016). Discrete element simulation of railway ballast: modelling cell pressure effects in triaxial tests. *Granular Matter* **18** No.65, 1-13. doi: 10.1007/s10035-016-0660-y

[D9] McDowell, G R & Li, H. (2016). Discrete element modelling of scaled railway ballast under triaxial conditions. *Granular Matter* **18** No.66*, pp. 1-10.* doi:10.1007/s10035-016-0663-8

Related publications

Abadi, T, Le Pen, L & Powrie, W (2018 - in review). Re-using "life expired" railway ballast, laboratory testing. *Extended abstract, 4th International Conference on Railway Technology: Research, Development and Maintenance (Railways 2018), Barcelona, Spain, 3-7 Sept 2018*

Potticary, M, Zervos, A, & Harkness, J (2016). The effect of particle elongation on the strength of granular materials. 239-242. *Paper presented at 24th Conference on Computational Mechanics, UK*

Potticary, M, Zervos, A, & Harkness, J (2015). An investigation into the effect of particle platyness on the strength of granular materials using the discrete element method. 767-778. *Paper presented at IV International Conference on Particle-based Methods. Fundamentals and Applications, Spain*