Ballast/sleeper fundamentals, Lab integration Industry Steering Group, July 2014

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PROGRAMME GRANT EP/H044949/1 ~ WWW.TRACK21.ORG.UK

TRACK 21

Railway Track for the 21st Century

Fundamentals: Ballast and sleepers

Objectives

1. To develop a complete understanding of the role and requirements of **ballast grading** in terms of internal stability, strength, resilient modulus, drainage and fines capacity in the context of a modern railway
2. To investigate “soft” techniques such as fabric wrapping of the ballast (ballast bags), gluing, resin injection, geogrids and **random fibre** reinforcement
3. To investigate different **sleeper types** and sleeper/ballast interface modifications such as **under-sleeper pads**

Fundamentals: Ballast and sleepers

Methods

- "Full scale" rig tests: reproduce track geometry and loads as realistically as possible in lab conditions.
- Triaxial tests on model ballast: investigate the possible benefits of fibre reinforcement.
- DEM modelling: insights on micro-mechanics of ballast.

Objective 1: Role and requirements of ballast grading

Conclusions

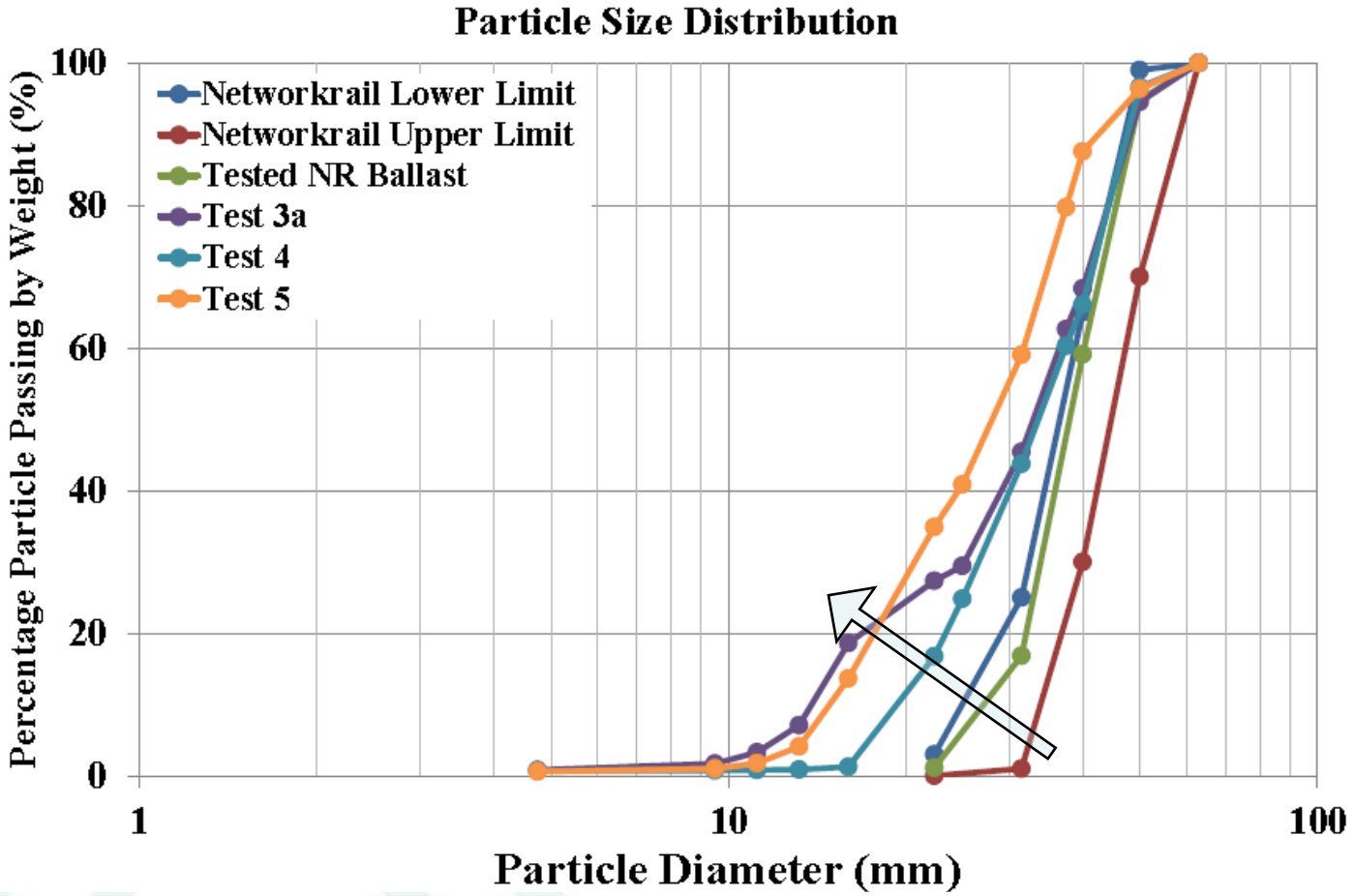
1. Introducing finer particles, mixed or as separate layer,
   a) reduces settlement,
   b) increases resilient stiffness, and
   c) increases contact area with sleeper.

2. Re-profiling the shoulder,
   a) reduces settlement, and
   b) increases resilient stiffness.

   – Rig tests on different ballast gradations and sleeper types.
   – Data from pressure-sensitive paper.

Full scale laboratory tests

Tests to investigate the influence of introducing finer material

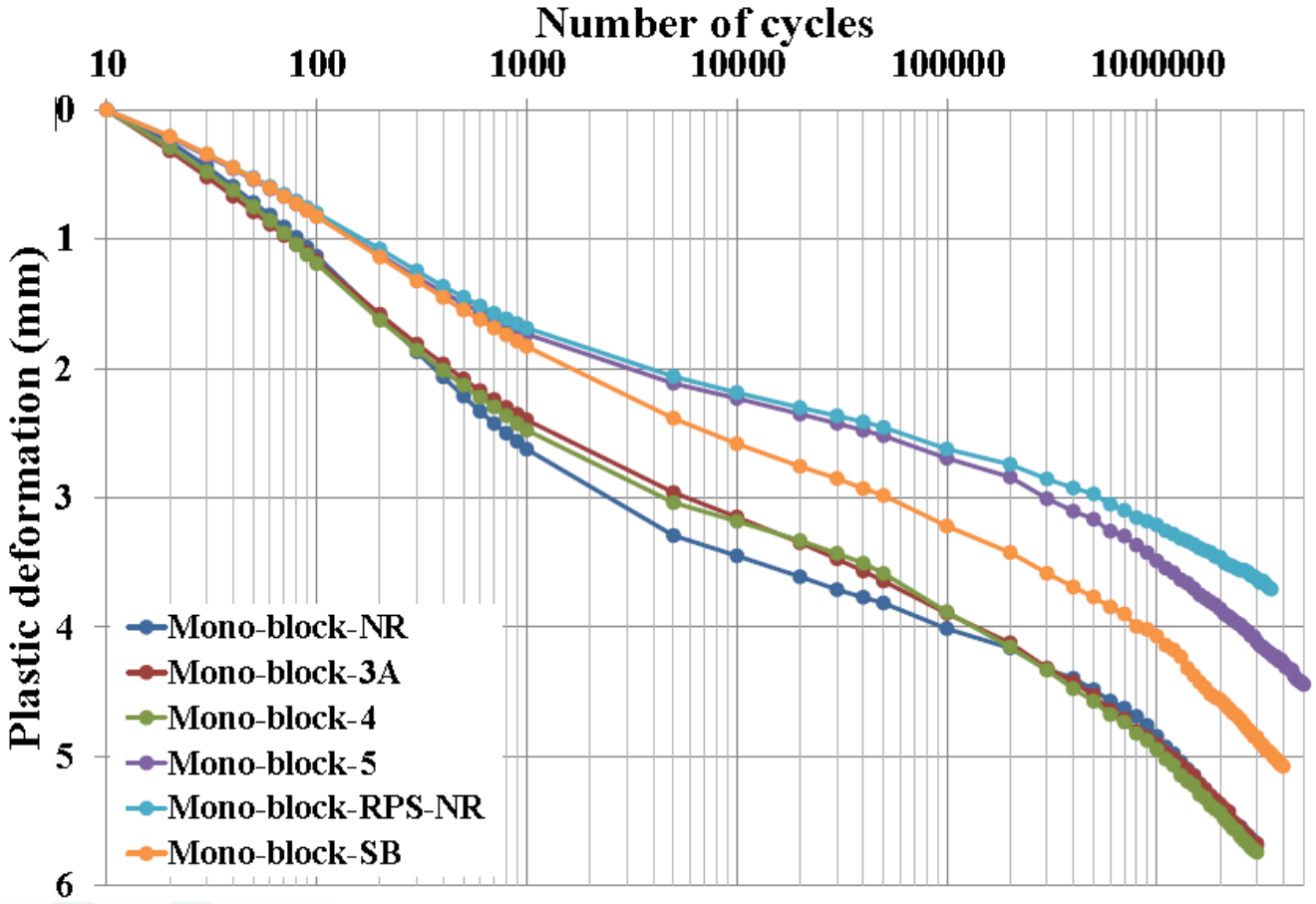


NR: 1639kg/m^3

3a: 1703kg/m3

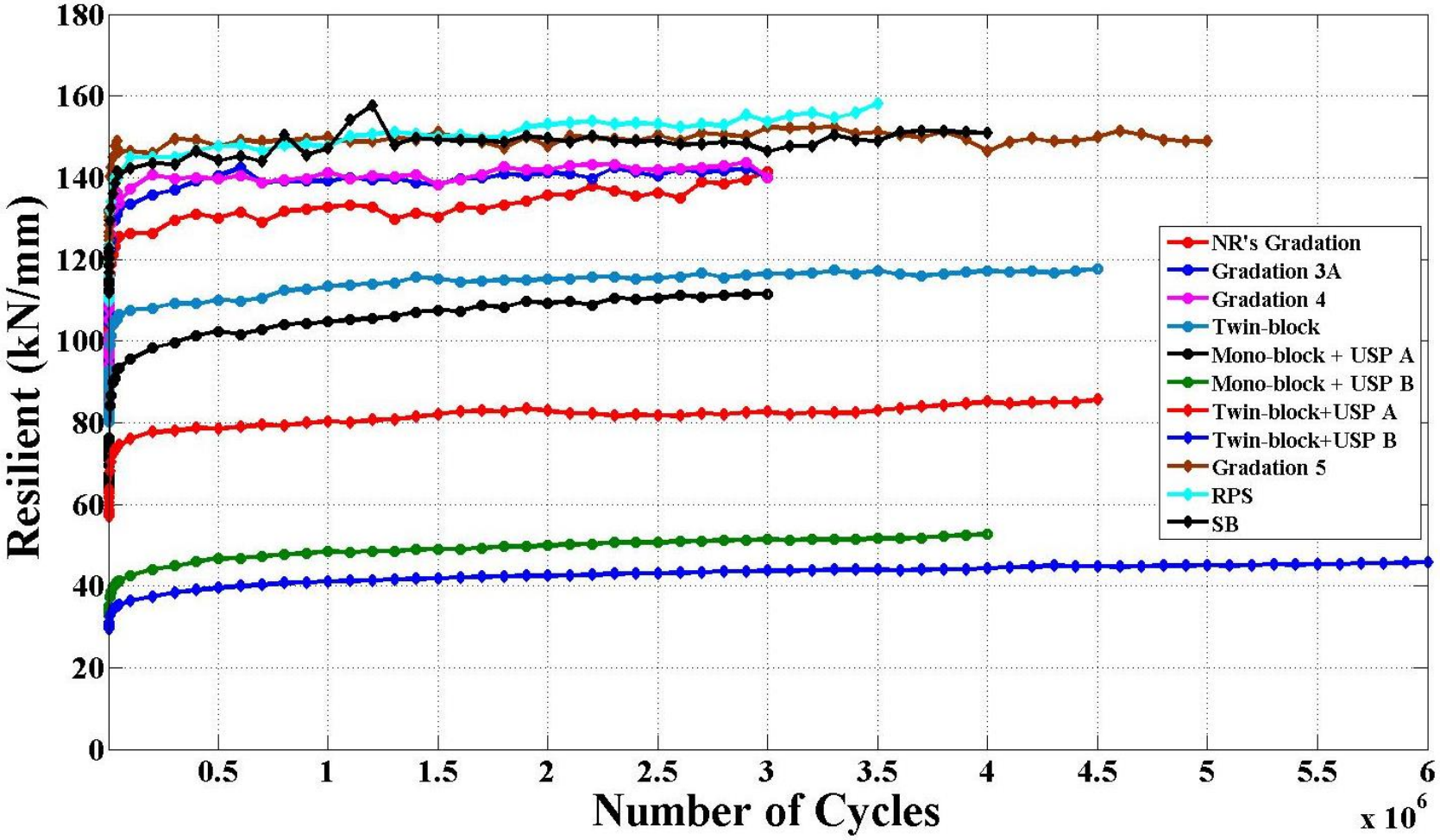
4: 1648kg/m3

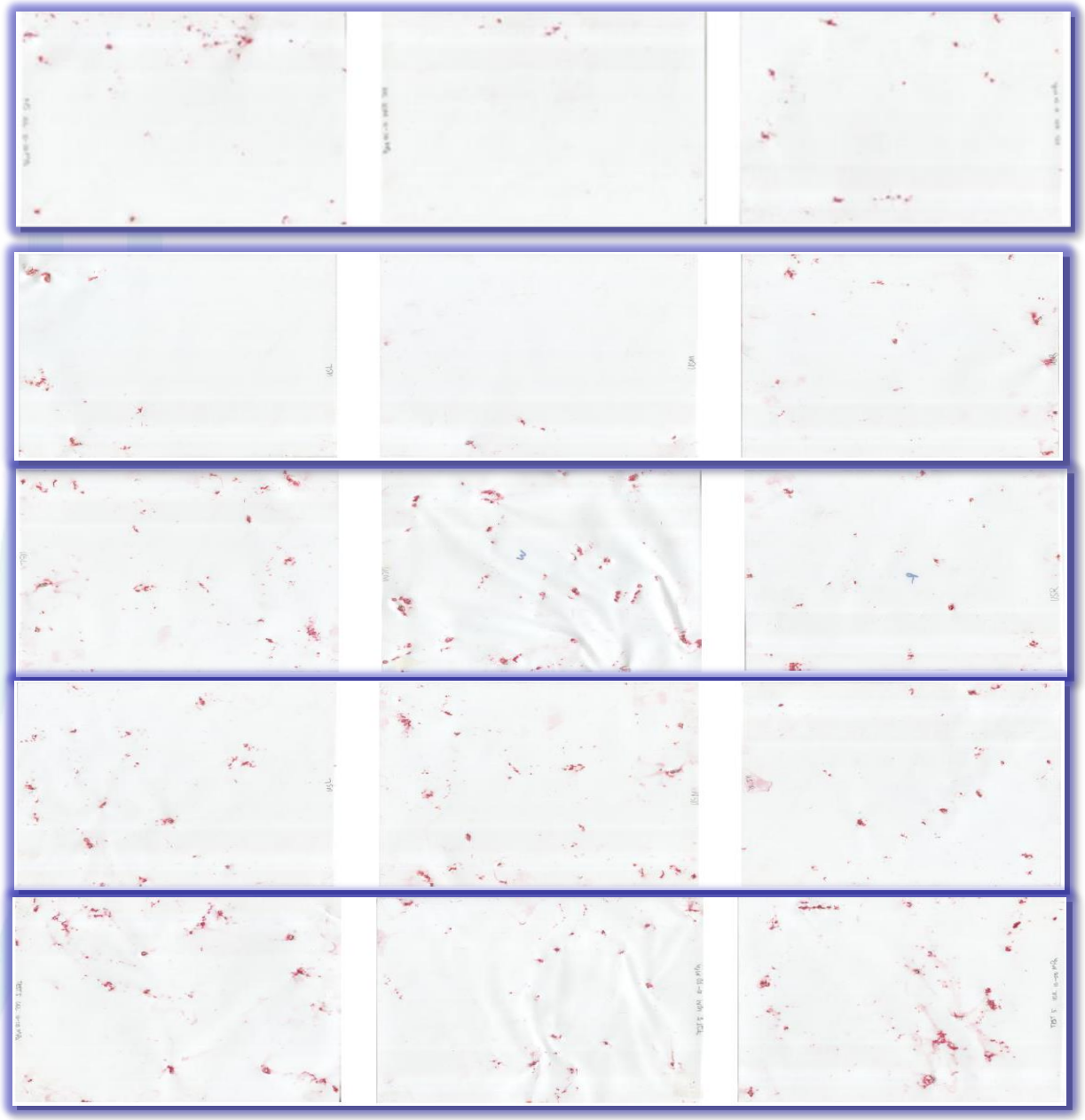
Settlement vs no. of cycles: effect of ballast gradation



- Mixing in finer material, or even placing finer particles on top, gives a more stable ballast layer.
- Even better: re-profile shoulders to 1:2 rather than 1:1

Resilient stiffness vs no. of cycles





Baseline test

Increasing finer proportion

Objective 1: Role and requirements of ballast grading

Possible further work considered

1. Effect of grading on ballast strength, i.e. $\varphi'_{crit.}$
   It could be explored using scaled, even full size ballast, but it is not a priority.

2. Effect of grading on drainage / fines capacity.
   Estimation using correlations from the literature is a possibility, but given the grain sizes involved the permeability should not be significantly affected.

Objective 2: Fibres, bags, gluing, resins, geogrids

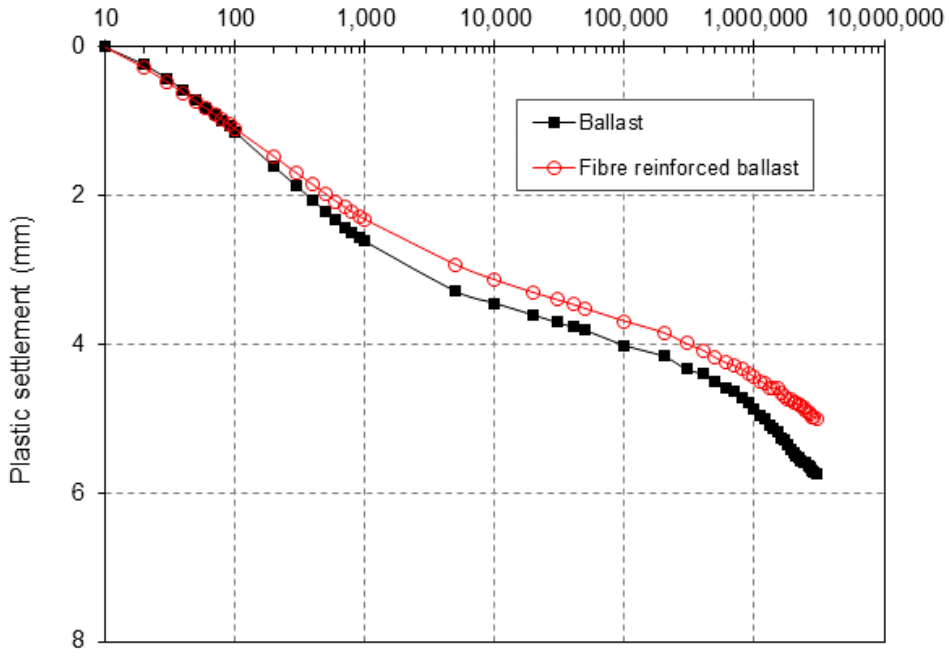
Conclusions

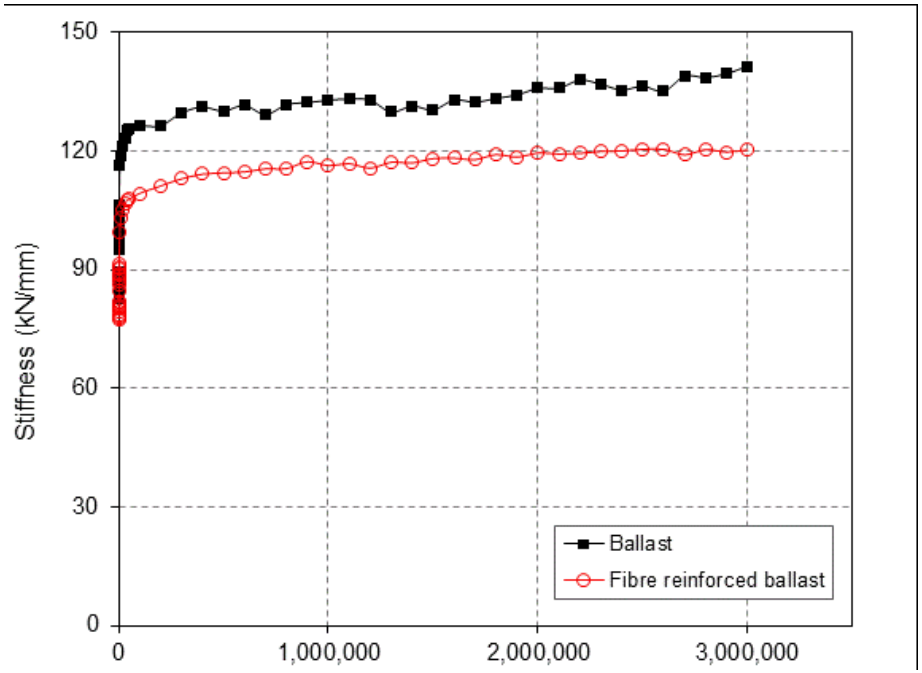
1. First results indicate that random fibre reinforcement:
   a) reduces settlement,
   b) reduces rate of settlement,
   c) reduces resilient stiffness, and
   d) prevents spreading of ballast.

2. Using a geogrid reduces settlement.

- Triaxial and pilot rig test on ballast at different scales at Soton.
- Rig tests at Nott.

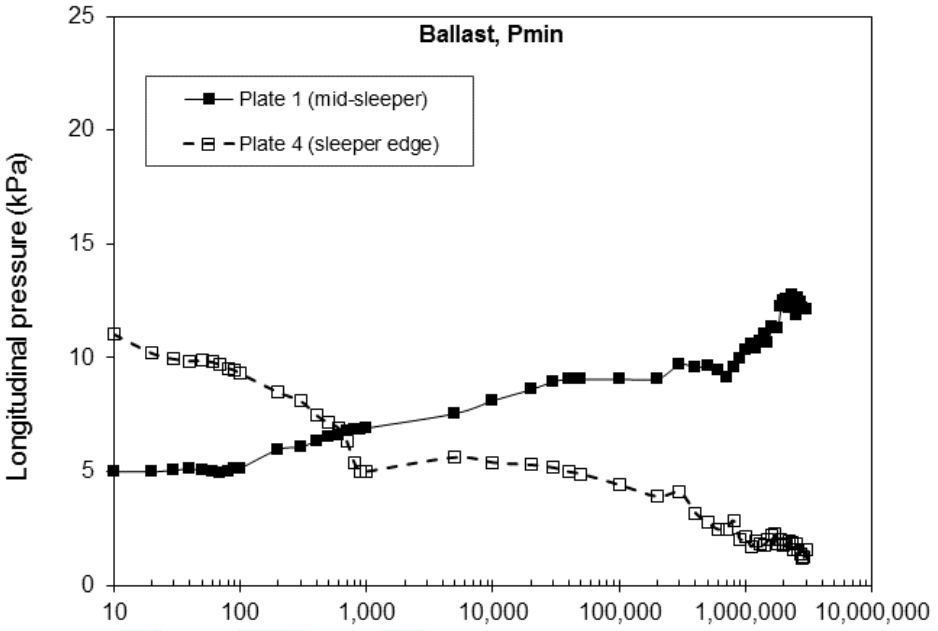
Effect of fibre reinforcement

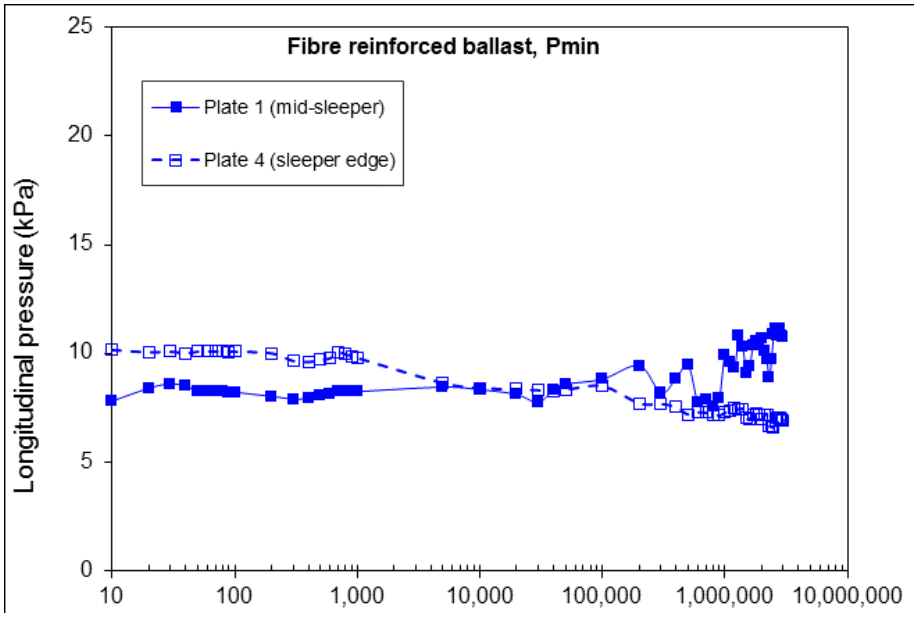




Fibre length/width/thickness: 300mm/100mm/0.5mm
Fibre number: 1.33%
Volumetric content: 0.6%

Effect of fibre reinforcement





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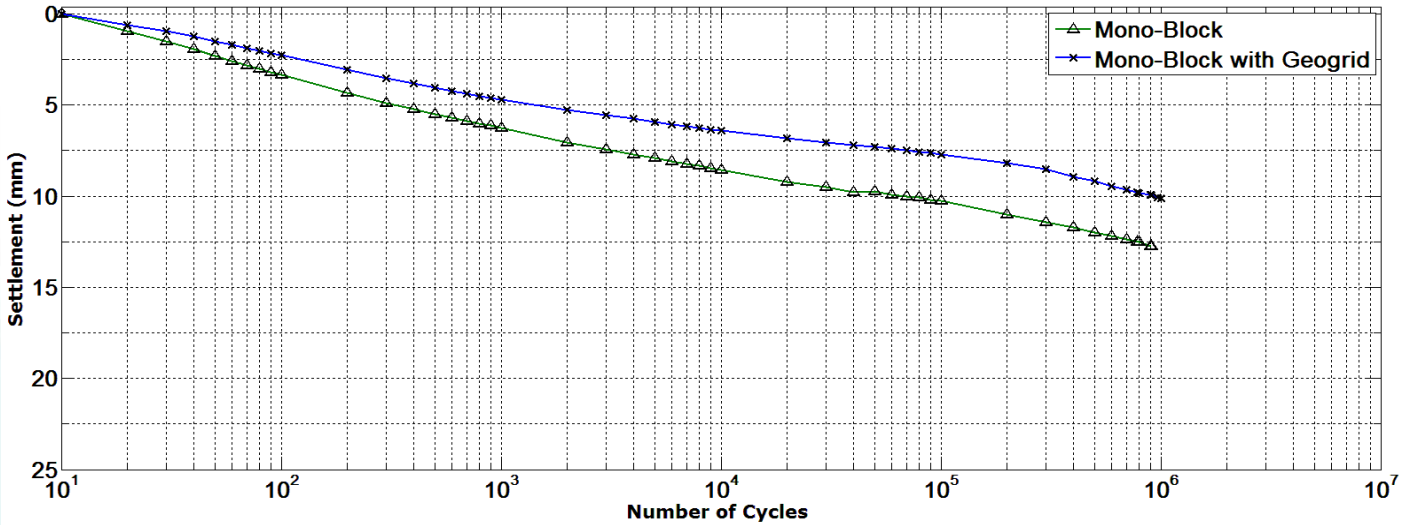
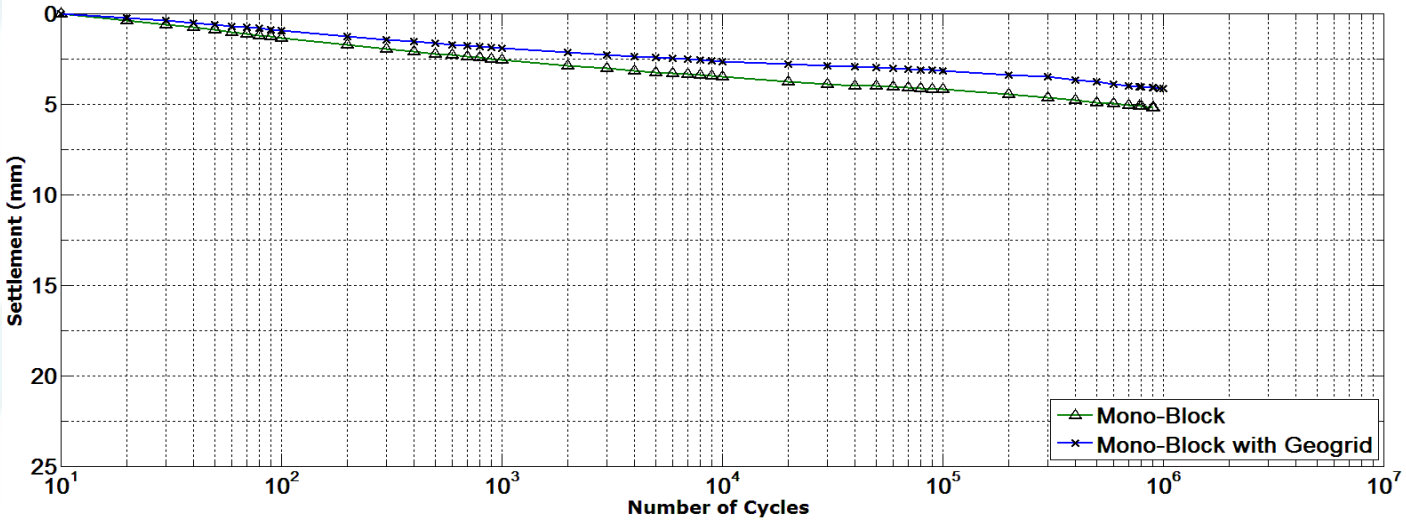
Geogrid Settlement Results: Mono-Block



Middle of sleeper



Sleeper rail seat

Objective 2: Fibres, bags, gluing, resins, geogrids

Further work considered

1. Focus on fibres and geogrids, not gluing/resin/bags.

2. Edgar to test fibre reinforced ballast in the SSTF.
    1. Show reproducibility/repeatability for standard configuration.
    2. Test fibre reinforced ballast for at least one, ideally two, configurations. (varying e.g. fibre content, fibre dimensions, sleeper type, ballast gradation.)

3. Sydney and Mo to finalise rig tests in the RTF to determine the effect of biaxial geogrids for different sleeper types.

Objective 3: Effect of sleeper type and USPs.

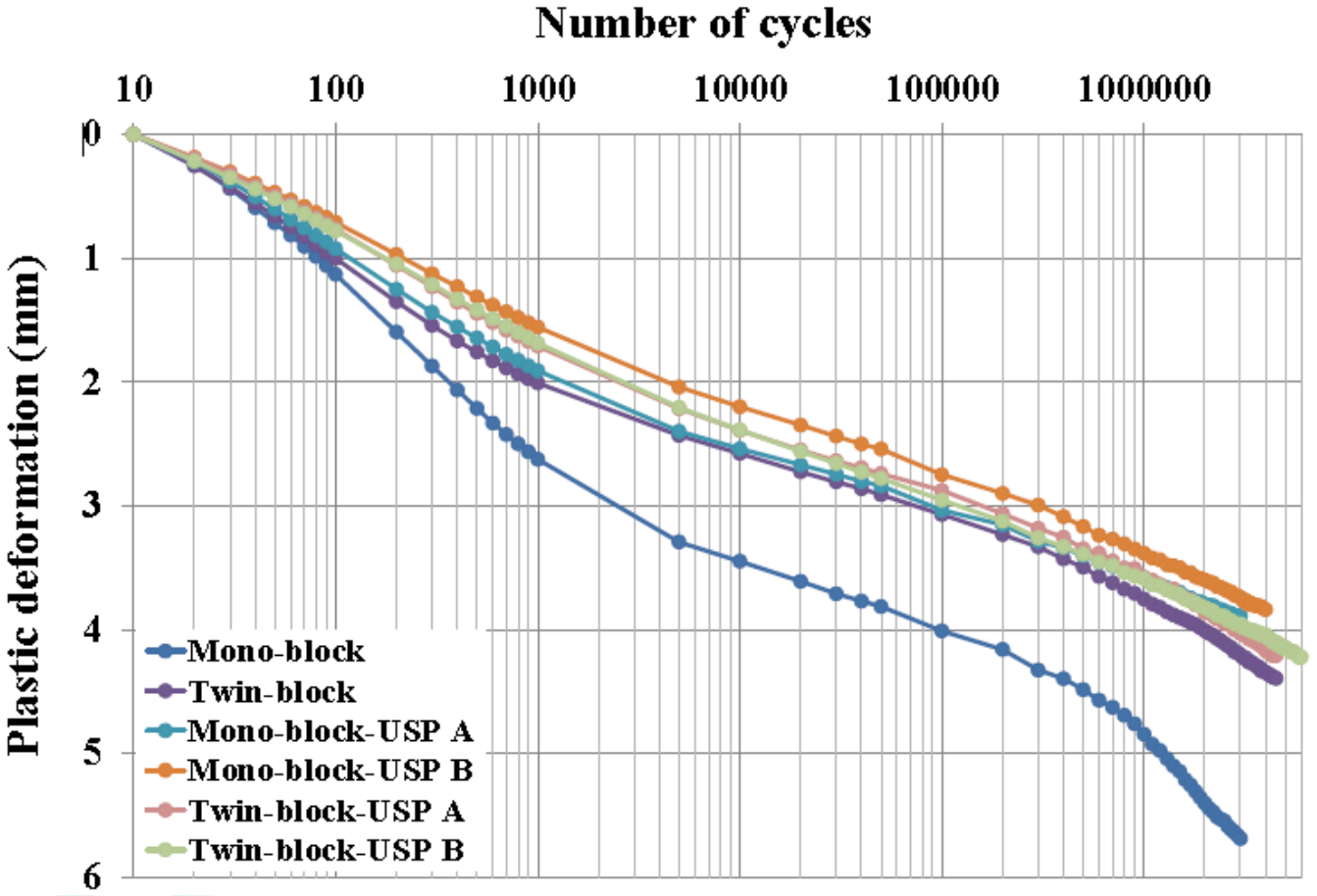
Conclusions

1. Duo-block settles less than monoblock.
   - Rig tests at Soton – Nott rig picture less clear.

2. USPs reduce settlement and rate of settlement, and almost remove the effect of sleeper shape on these.
   - Rig tests at Soton, box tests at Nott.

3. USPs reduce resilient stiffness.
   - Rig tests at Soton

Settlement vs no. of cycles: effect of sleeper shape



- Steel sleeper: installation in the rig is problematic.
- Plastic and timber sleepers: some results are available, however they are still being checked for consistency.

Objective 3: Effect of sleeper type and USPs.

Further work

1. Combined interpretation of SSTF and RTF results, including plastic, timber and steel sleepers.

   Half-day “lab integration” meeting: 7 August.

2. DEM analyses to explore possible effects of boundary conditions.

Deliverables by the end of the grant

PhD theses

Taufan Abadi, Sydney Laryea, (Femi Ajayi.)

Journal publications

1. Mechanics of fibre reinforced scaled ballast (x2).
2. DEM modelling of scaled ballast across a range of pressures - effects of attrition/polishing (x2)
3. Bi- and tri-axial geogrid performance for different sleeper sections.
4. Combined performance of USP & geogrids for different sleeper sections.

Deliverables by the end of the grant

Journal publications (continued)

5. Rig test results, some as joint papers. Indicative list:

a. Common paper, possibly describing tests of different sleepers or USPs, to establish comparability of the results of the two rigs.

b. Results from geogrid tests.

c. Results from gradations/reprofiled shoulder/best case.

d. (Results from fibre reinforced ballast tests may not reach publication stage during the term of the grant.)

6. Comparative tests of scaled vs full size ballast.

Thank you

Any questions?

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