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Cyclic Behaviour of Soil Behind Integral Bridge Abutments

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Background

The integral bridge typology is one that has **no bearings between the abutments and deck, or expansion joints within the deck**. By removing these metallic components, susceptible to corrosion, the integral bridge has become a **first - choice form of construction** over highways with asset owners benefitting from **significantly reduced maintenance requirements,** helping to meet cost and Net Zero 2050 targets.

Problem & Research Aim

Use of integral bridges is **limited to spans of 60 m and skews of 30°** owing to **stress build up in the retained backfill after thermal movements**, no longer accommodated by joints. The distribution of these **lateral stresses is not well understood** and thought to be mischaracterised in current PD 6694-1 design code prescriptions. Furthermore, the influence of **relative abutment and backfill stiffness is not sufficiently accounted for** in this soil-structure interaction problem.

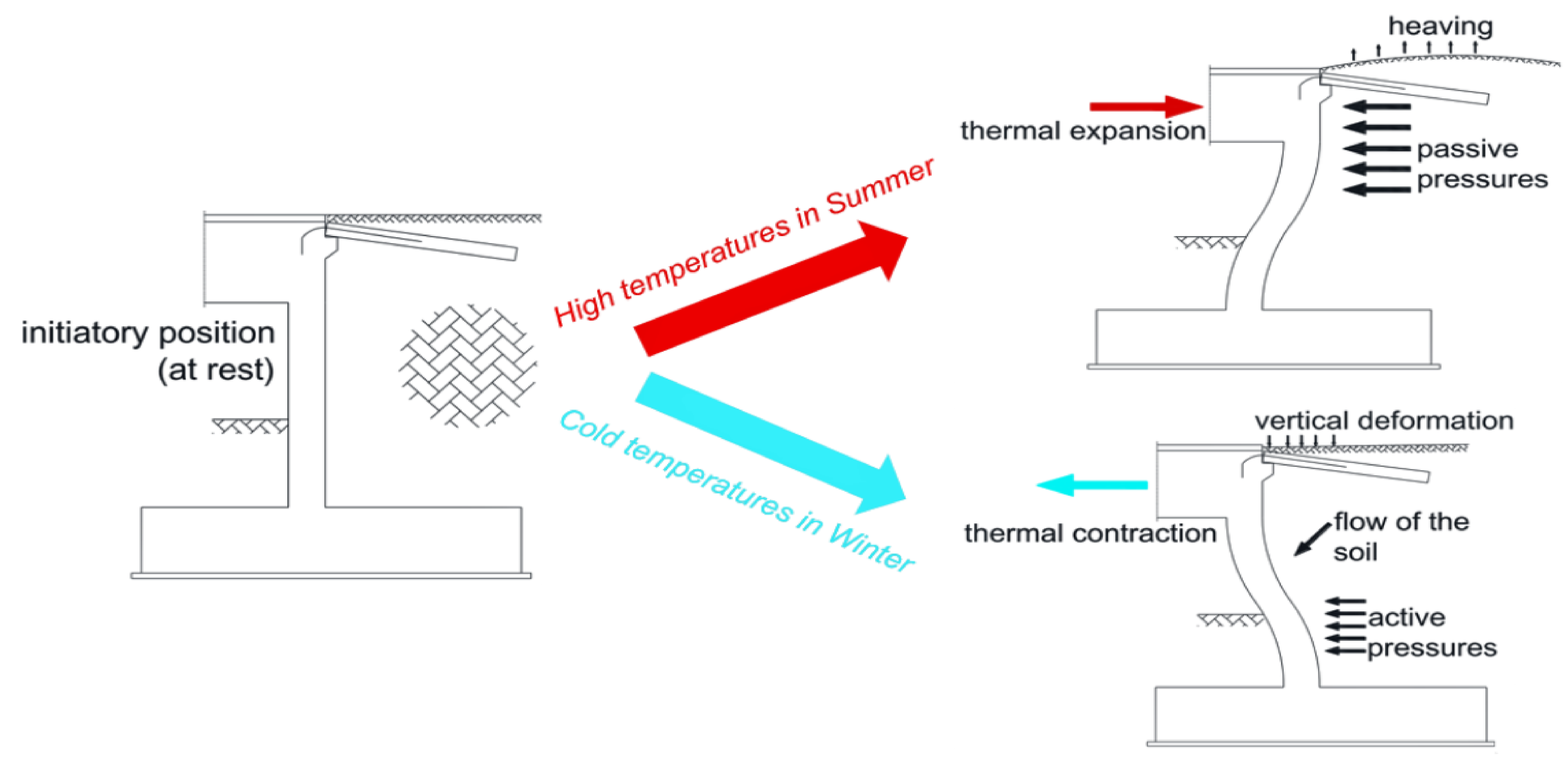

Figure 1: Integral bridge concerns (modified from Argyroudis et al. (2016)).

This research aimed to **formalise the gaps in integral bridge SSI knowledge** directing future work to better characterise the stress ratcheting behaviour, allowing for **greater adoption and reduced conservatism of integral bridges** to **improve the resilience of U.K. infrastructure**.

Methodology: Centrifuge Modelling

- Small-scale physical model designed for testing within the 10 m Turner beam centrifuge at Cambridge.
- Scaled 9 m abutment with spread footings loaded by force and displacement control with an actuation system mimicking thermal deck movements; with actuator capacity determined from a numerical analysis.
- Earth pressures, bending moments and displacements measured.

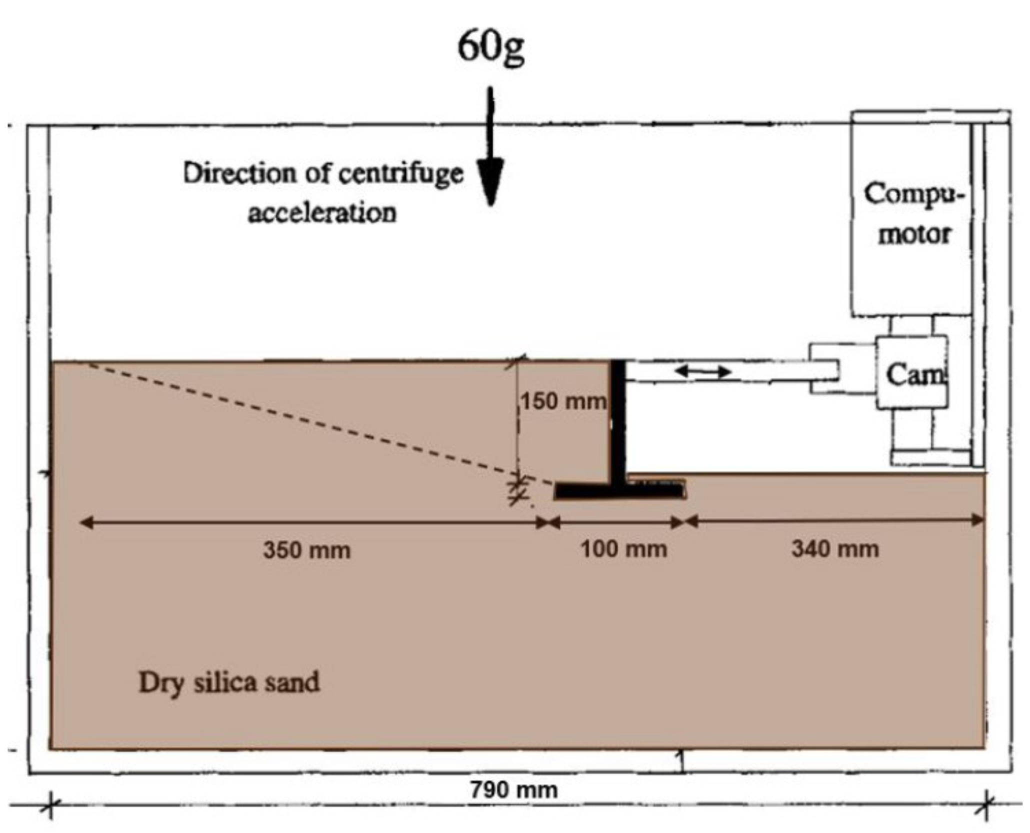

Figure 2: Physical model setup (modified from Ng et al. (1998)).

Figure 3: Strong box and camera for PIV imaging to obtain soil and wall displacements.

Methodology: Numerical Modelling

- SWANDYNE FE analysis replica of the centrifuge model.
- Applied 120 cycles of 40 mm thermal movement reflecting design life.
- Parametric analysis of abutment and backfill stiffness.

Results: Lateral Stress Generation

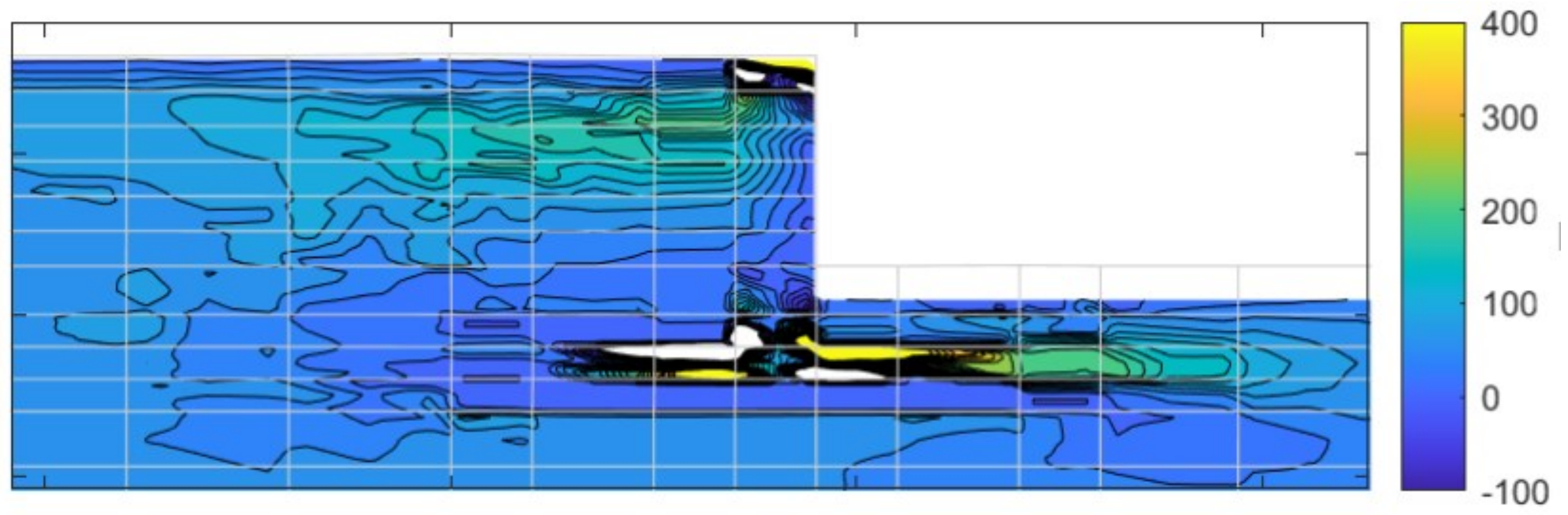

Figure 4: Lateral stress build up after 120 cycles.

Results: Abutment Stiffness Variation

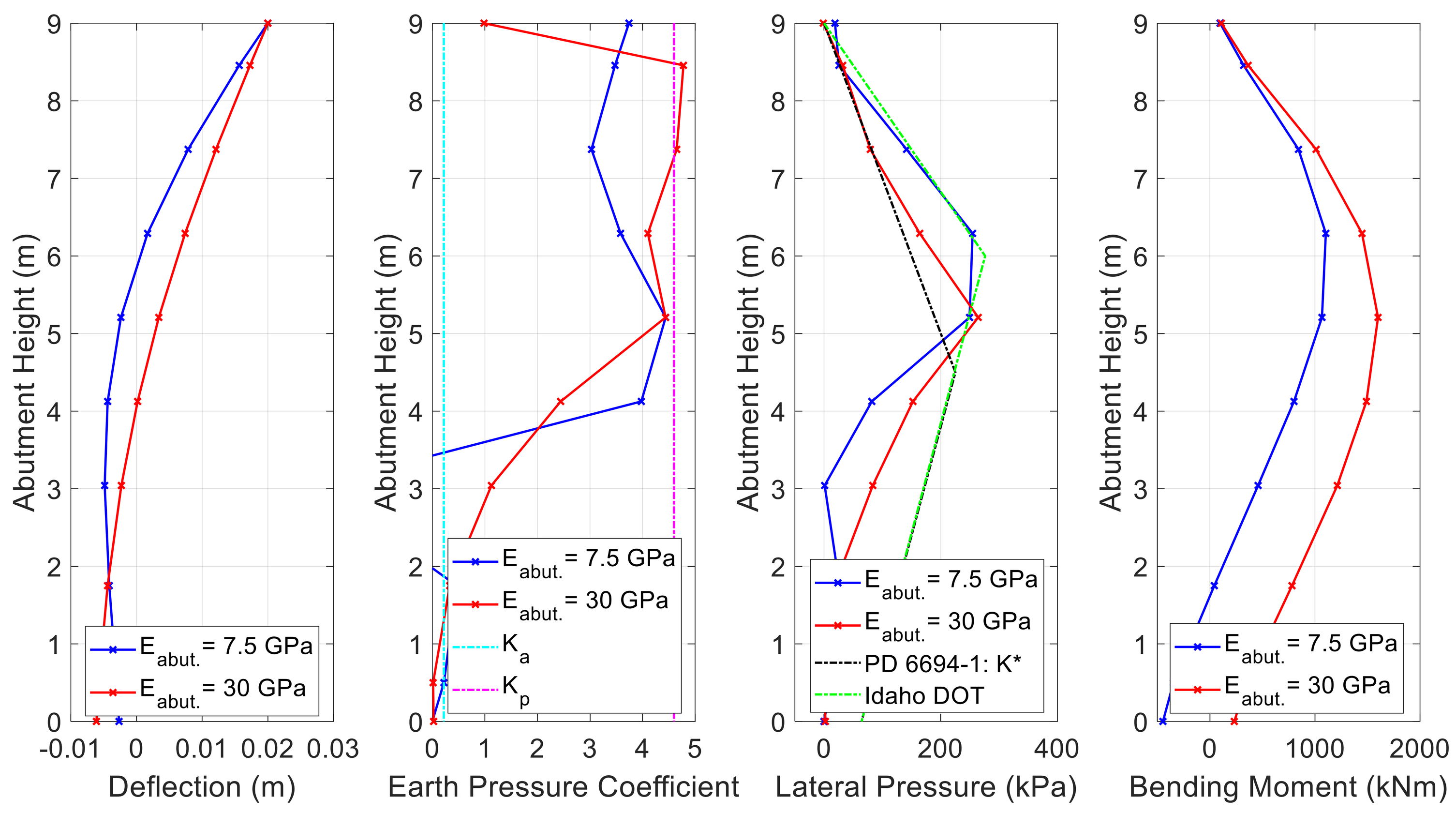

Figure 5: Comparison of altered abutment stiffness distributions.

Results: Backfill Stiffness Variation

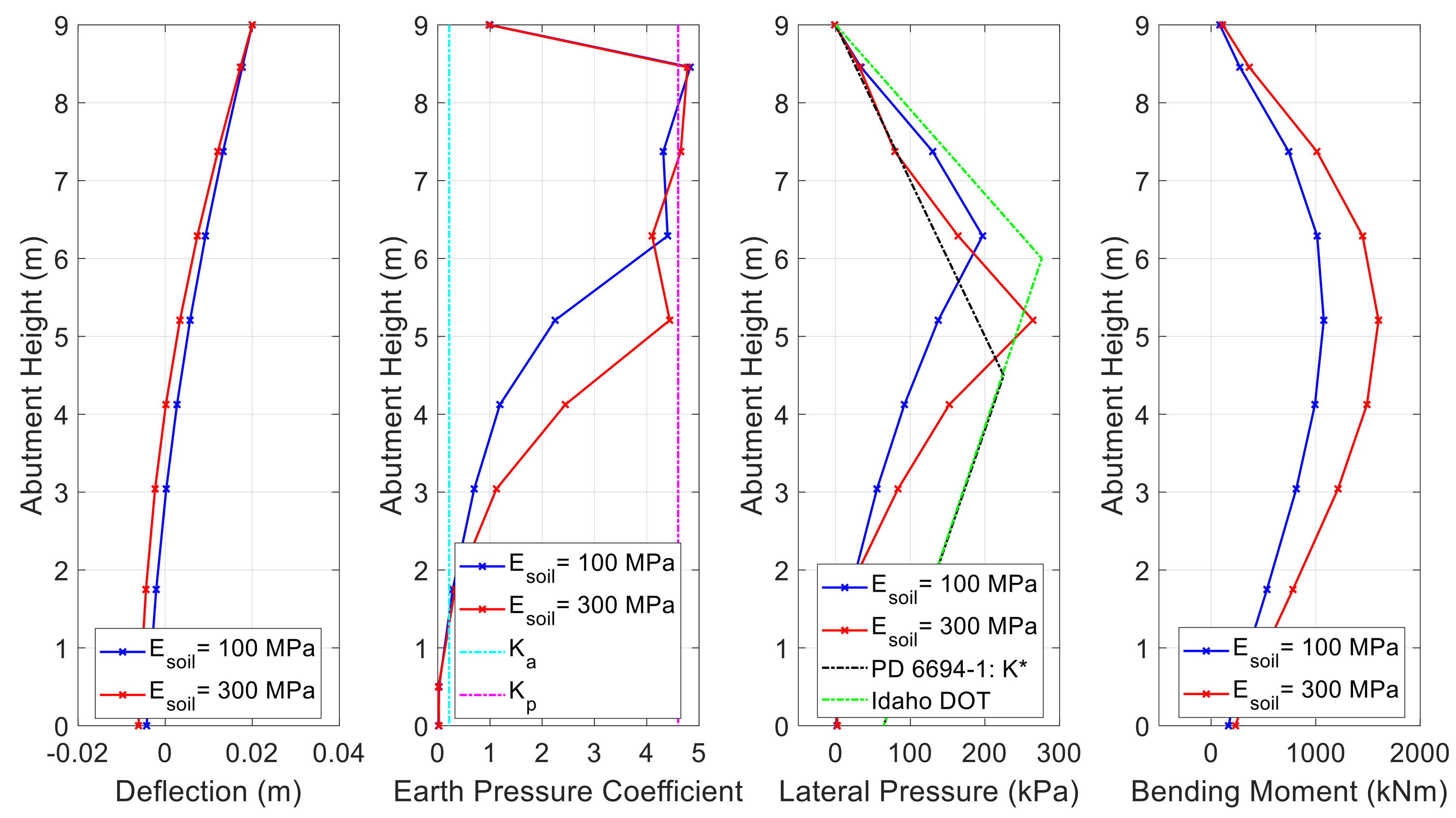

Figure 6: Comparison of altered backfill stiffness distributions.

Conclusions

1. U.K. integral bridge codes inappropriately characterise the peak magnitude of lateral pressure and its distribution down the abutment.
2. Influence of relative stiffness is inadequately accounted for in design.
3. 30% reduction in bending moment from: reduced abutment stiffness, backfill stiffness or appropriate representation of low base pressures.

References

Argyroudis, S., Palaiochorinou, A., Mitoulis, S., & Pitilakis, D. (2016). Use of rubberised backfills for improving the seismic response of integral abutment bridges. Bulletin of Earthquake Engineering.

Ng, C., Springman, S., & Norrish, A. (1998). Soil-structure interaction of spread-base integral bridge abutments. Soils and Foundations, 38(1), 145–162.

Acknowledgements

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