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An investigation of tunnel-soil-structure interaction using hybrid centrifuge modelling

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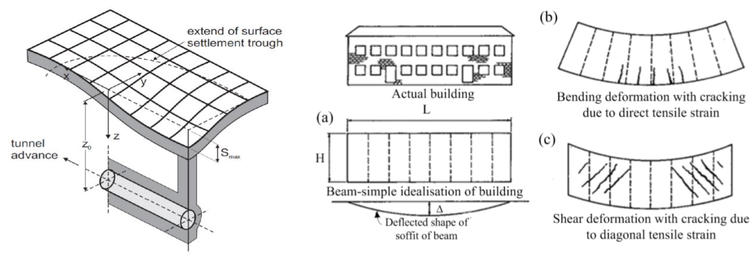
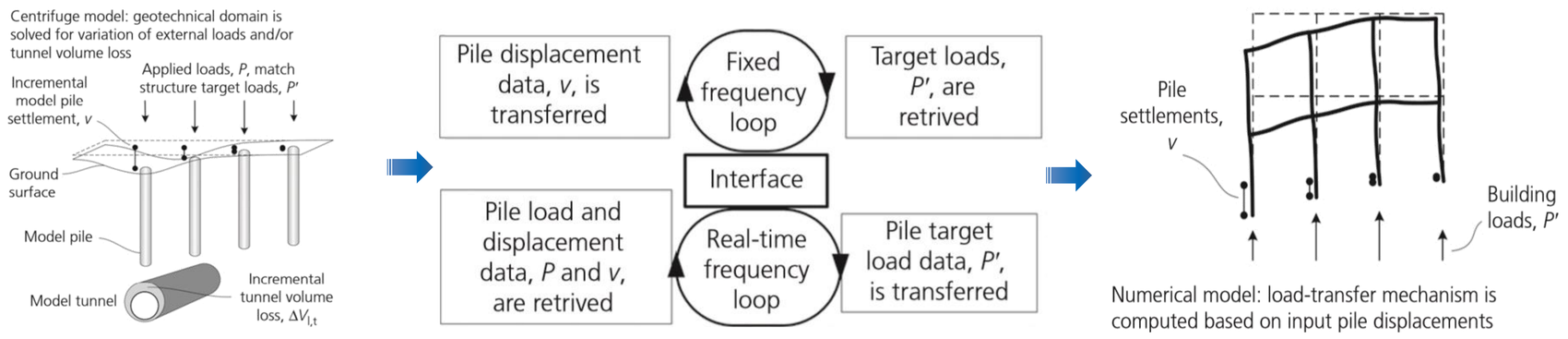
Background: Population growth has resulted in the development of vast and often complex infrastructure systems. However, especially in densely populated areas, underground construction of tunnels causes movements and stress relief of the ground that adversely affect existing infrastructure and structures. Predicting tunnelling-induced deformations of buildings and assessing their risk of damage are essential parts of planning and design of tunnelling projects in an urban environment.



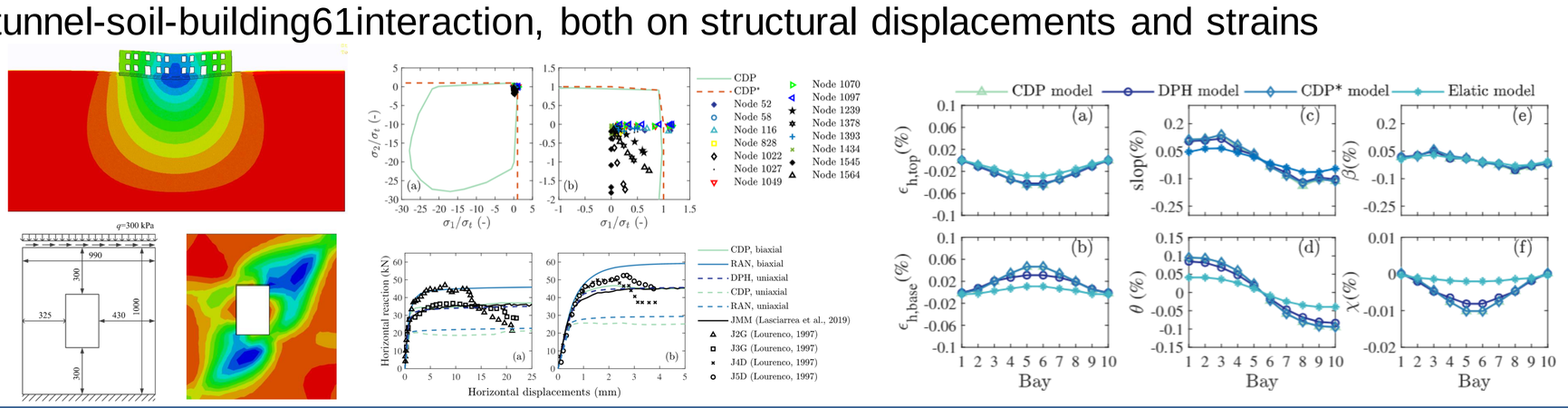
Aim: This project aims to investigate the tunnel-soil-structure interaction as well as tunnelling-induced building deflection pattern and damage category by adopting the coupled centrifuge-numerical modelling method (CCNM), a novel hybrid testing approach developed in Nottingham.

Methodology: Small-scale centrifuge tests can replicate the stress environment and soil behaviour of a full-scale scenario by increasing the acceleration field. The centrifuge is used to model the complex non-linear soil and soil-foundation interaction behaviour. A numerical model is run in real-time alongside the centrifuge test to simulate a connected building.

CCNM Process: Measurements of foundation displacements are transferred from the centrifuge test to the numerical model. The numerical model provides an output of foundation loading to the centrifuge tests based on calculations of load redistribution within the building. This research will implement realistic non-linear models of building materials within the numerical model. The hybrid CCNM model of the global tunnel-building interaction problem provided levels of fidelity and accuracy that are not achievable using physical or numerical models along.



Numerical modelling: First, the masonry panel-scale, the sensitivity of the non-linear response of a masonry panel under shear deformations is investigated. Both element- and panel-scale analyses are compared with experimental data, providing conclusions as to the most suitable model for implementation within subsequent tunnel-building interaction analyses. Then, the TSAM numerical model is first adopted in analysing the tunnelling-induced masonry facade response. The TSAM is subsequently used to conduct a parametric study60to investigate the significance of the assumed biaxial failure mode on the tunnel-soil-building61interaction, both on structural displacements and strains



Analytical study:

Yield criterion of Drucker-Prager

$$f_{DP} = \left(\frac{m-1}{2}\right) \times (\sigma_1 + \sigma_2 + \sigma_3) + \left(\frac{m+1}{2}\right) \times \times \frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2} = \sigma_c$$

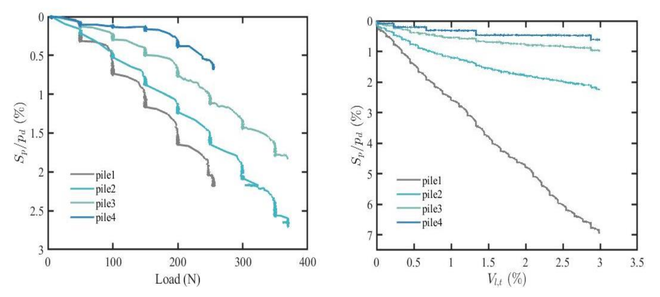
Concrete Damaged Plasticity

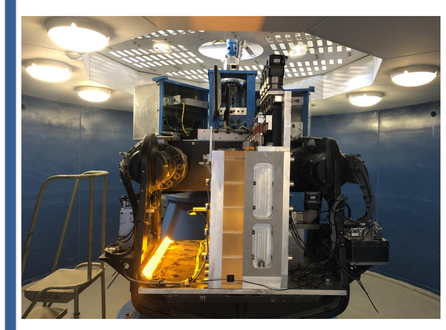
$$f_{CDP} = \frac{1}{1-\alpha}(q - 3\alpha p + \beta\sigma_{max}\rangle - \gamma\sigma_{max} - \sigma_c = 0$$

Rankine

$$f_{RAN} = \frac{2}{3}cos\theta q - p - \sigma_t = 0$$

Centrifuge modelling: The tunnel-soil-structure interaction with a five layered steel structure with pile foundation was investigated in the centrifuge modelling, with the relative soil density of 90% and a centrifugal acceleration of 80g. pile loads of 255N, 370N, 370N, 255N (determined by the structure's self-weight) are applied to the four piles step by step. Then the masonry structure with strip foundation will be considered in the centrifuge modelling to elucidate the effects of different constitute models on the nonlinear behaviour of masonry structures as well as soil-structure interaction.





Conclusions: This project studies the impact of different elastic perfectly plastic constitutive models for the masonry biaxial failure on tunnelling-induced deformations and damage of wall-bearing buildings. Masonry buildings with different constructures and constitutive models will be replicated in the Finite Element (FE) analysis software Abaqus and the tunnelling process will be modelled in the centrifuge test. The response of tunnelling to the superstructure is investigated according to the CCNM method while considering the presence of openings and floor beams.