Experiments in tunnel–soil–structure interaction

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Urbanisation will require significant expansion of underground infrastructure, which results in unavoidable ground displacements that affect the built environment. Predicting the interaction between a tunnel, the soil and existing structures remains an engineering challenge due to the highly non-linear behaviour of both the soil and the building.

This thesis investigates the interaction between a surface structure and tunnelling-induced ground displacements. Specifically, novel three-dimensionally printed building models with brittle material behaviour, similar to masonry, were developed and tested in a geotechnical centrifuge. This enabled replication of building models with representative global stiffness values and realistic building features including strip footings, intermediate walls, a rough soil–structure interface, building layouts and façade openings.

By varying building characteristics, the impact of structural features on both the soil and building response to tunnelling in dense sand was investigated. Results illustrate that the presence of surface structures considerably altered the tunnelling-induced soil response. The building-to-tunnel position notably influences the magnitude of soil displacements and causes localised phenomena such as embedment of building corners. An increase of the façade opening area and building length reduces the alteration of the theoretical greenfield settlements, in particular the trough width. Moreover, the impact of varying the building layout is discussed in detail.

For several building–tunnel scenarios, building distortions are quantified and the crucial role of building features is demonstrated. Structures spanning the greenfield inflection point experienced more deformation than identical structures positioned in either sagging or hogging, and partitioning a structure either side of the greenfield inflection point is shown to lead to unconservative damage assessments. Results also quantify the significant extent to which structural distortions increase as façade openings and building length increases. Observed building damage and cracking patterns confirm the reported trends.

The experimental results are used to evaluate the performance of available methods to assess the behaviour of buildings to tunnelling. Predictions ignoring soil–structure interaction are usually overly conservative, while approaches based on the relative stiffness of a structure and the soil result in inconsistent predictions, though some methods performed

better than others. Practical improvements to consider structural details when assessing this tunnel–soil–structure system are finally proposed.