Ground movements due to excavation in cohesionless soil: physical and analytical models

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Abstract

The design of excavations in sands for serviceability is a challenge. It is difficult to make a quick and reasonable prediction of the movement of retaining structures and the surrounding soil. In this research, centrifuge models were made and tested to study the behaviour of supporting structures and soil during excavation, which assisted the development of a simple design tool that allows a quick prediction of movement at the design stage.

Excavations with cantilever walls and walls propped at the top were simulated in the centrifuge tests. The influence of soil density and wall flexibility were also investigated. Soil movements, wall bending moments and prop loads were measured. A new type of pressure cell was introduced into a centrifuge model for the first time, and it was shown to provide reliable earth pressure measurements. The errors arising from strong box side friction were analysed, and the cyclic stresses induced by in-flight scraping were assessed.

A MSD energy model for excavation with cantilever walls is proposed based on the soil displacement mechanism observed in the centrifuge tests. It is shown that energy balances within 10% in the two tests. The main energy flow happens on the active side of the wall, where potential energy loss is roughly equal to work done during sand shear and contraction. However, the model was not capable of predicting movements, as the shear stress was mobilised in passive support so quickly that the work was negligible. Another MSD model based on equilibrium model was proposed. K_0 consolidated lateral loading and unloading triaxial tests were used to represent the soil on both sides of the wall. Based on wall friction estimation and moment equilibrium at wall toe, the MSD equilibrium model was capable of predicting wall top deflection within a factor of 2.

Test observations in walls propped at the top are also presented. It is shown that soil relative density is the dominating factor for different movements in the tests, while both prop stiffness and wall stiffness are also important in restricting movements. The passive earth pressure coefficient mobilised at shallow depth is always larger than the coefficient at large depth. Wall toe friction is also an important factor in the global equilibrium of top-propped walls.

Observations of the centrifuge models are compared with published physical tests, field data and design curves. A normalization factor was used so that deflections of different walls can be directly compared.