Numerical modelling of pipe umbrella system for shallow tunnels (en ce compris une introduction à la méthodologie de la recherche)

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Abstract

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Context

Shallow tunnels represent a very delicate condition during excavation. To reinforce the ground, pre-support techniques are therefore often adopted to improve soil stability and reduce deformations. Among these techniques, the pipe umbrella system consists of installing steel pipes in the ground in order to improve the mechanical properties of the soil.

Objectives

The modelling of the pipe umbrella system is a complex problem, for which simplified two-dimensional approaches represent a practical and computationally efficient solution. This thesis aims to investigate and test different 2D strategies to represent the effect of the pipe umbrella in axisymmetric conditions, evaluating their consistency, limitations and relative reliability. Explicit three-dimensional models, although potentially more accurate, require a significantly higher computational cost and are not included within the scope of this work.

Methodology

An analytical model based on the Convergence-confinement method was first developed to define a preliminary tunnel response. Subsequently, a reference problem based on the same assumptions was implemented in the FEM software Lagamine and Plaxis 2D under axisymmetric conditions, modelling different excavation stages. In the numerical models, three simplified equivalent strategies were introduced to represent the behaviour of the soil reinforced with pipes. The three techniques are: linear elastic equivalent volume, anisotropic material and enhanced soil. The results are then compared with each other in terms of stresses, deformations and deconfinement.

Results

The methods produce different deformation responses, depending on the adopted strategy. The linear elastic equivalent volume shows a very high stiffness and may be poorly representative of the real behaviour. The anisotropic material presents a more beam-like behaviour, being able to better capture the greater bending stiffness in the axial direction introduced by the pipes. The enhanced soil shows a less beam-like behaviour, but in terms of deformation magnitude it provides results comparable to those of the anisotropic material.

Conclusions

The results show that some 2D strategies are able to capture part of the global effect of the pipe umbrella system, although they do not directly represent its real three-dimensional nature. As a future perspective, it would be interesting to develop an equivalent 3D model reproducing the same assumptions, conditions and excavation stages. Moreover, it would also be worthwhile to implement the same problems with different initial assumptions, introducing for example anisotropy of the stress state and gravity.

Keywords: shallow tunnel, convergence-confinement method, deconfinement, pipe umbrella system, tunnel reinforcement, axisymmetric modelling, homogenization, Plaxis 2D; Lagamine.