Numerical Simulation of Bank Protection Structure Deformation Due to River Level Fluctuations

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Abstract

Bank protection structure has been widely used in wharf construction, cofferdam excavation and waterway engineering. This structure is an important barrier to maintain the safety of the embankment. The deformation of bank protection structure is not only affected by soil pressure caused by the excavation of the river way, but also by the water pressure caused by the seasonal river water level fluctuations. Furthermore, the depth of the groundwater table will affect the mechanical parameters of the soil. Therefore, the deformation analysis of bank protection structure, in addition to calculating the classical soil mechanics, should also consider the impact of groundwater seepage in embankment.

In this work, according to the change of the river level, we firstly calculated the seepage field in the embankment. Subsequently, based on strength reduction method, the shear strength parameters of soil were adjusted by the groundwater table. Finally, the deformation was calculated by COMSOL Multiphysics®.

Based on the Deep Excavation model in the COMSOL Application Libraries we developed it by coupling the Darcy's Law interface. The geometry of this model is shown in Figure 1. As the river water level fluctuates, the lateral water pressure on the steel sheet pile will change. We defined a depth-dependent hydraulic pressure on the left side and added the steady-state seepage field data to the Solid Mechanics interface as an initial condition. Besides that, the soil mechanical parameter is modified through the groundwater level (P=0) calculated by Darcy's Law.

With scenarios of various river water levels, the deformation of the bank protection structure was calculated. As an example, the result of one scenario (Figure 2, river water level at -6m) shows the distribution of total stress field and seepage field and the white line represents the groundwater level (pore-water pressure = 0). Based on the Drucker-Prager yield criterion, we achieved the displacement of the steel sheet pile (Figure 3) and plastic deformation of the structure (Figure 4). The maximum displacement in this case is about 60mm.

The simulation results show that the river water level fluctuation has clear influence on the maximum lateral displacement of the pile. Meanwhile, the distribution of plastic zone is related to the depth of groundwater level. For the next step, we will validate and develop this model by comparing the results with long-term in-situ displacement measurements in order to analyze the structural stability under extreme river water level scenarios.

Reference

[1] E. M. Dawson et al., Slope Stability Analysis by Strength Reduction, Geotechnique, Vol. 49 (6), p. 835 (1999)

Figures used in the abstract

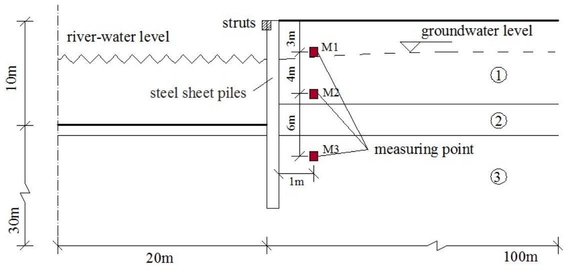

Figure 1: The geometry of the model of bank protection structure.

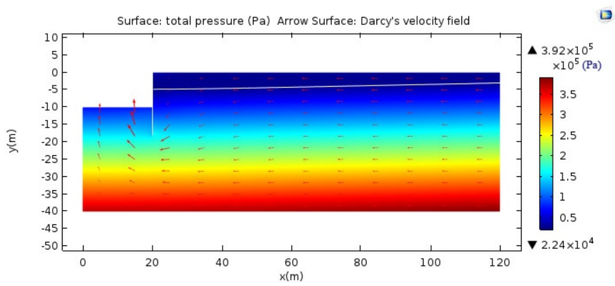

Figure 2: The distribution of total pressure field and seepage field at the river level of -6m.

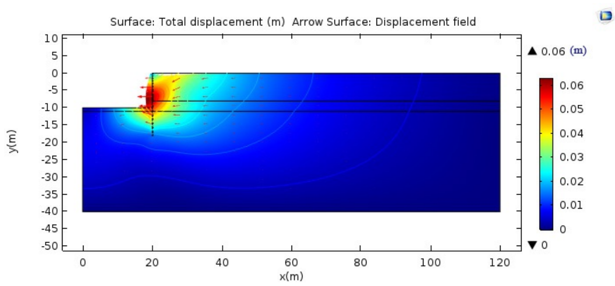

Figure 3: The displacement of the structure at the river level of -6m (scale factor: 30).

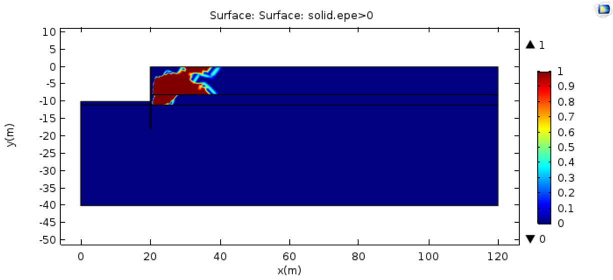

Figure 4: The plastic deformation of the structure at the river level of -6m.