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Numerical analysis of the influence of a river on tunnelling-induced ground deformation in soft soil

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Project overview

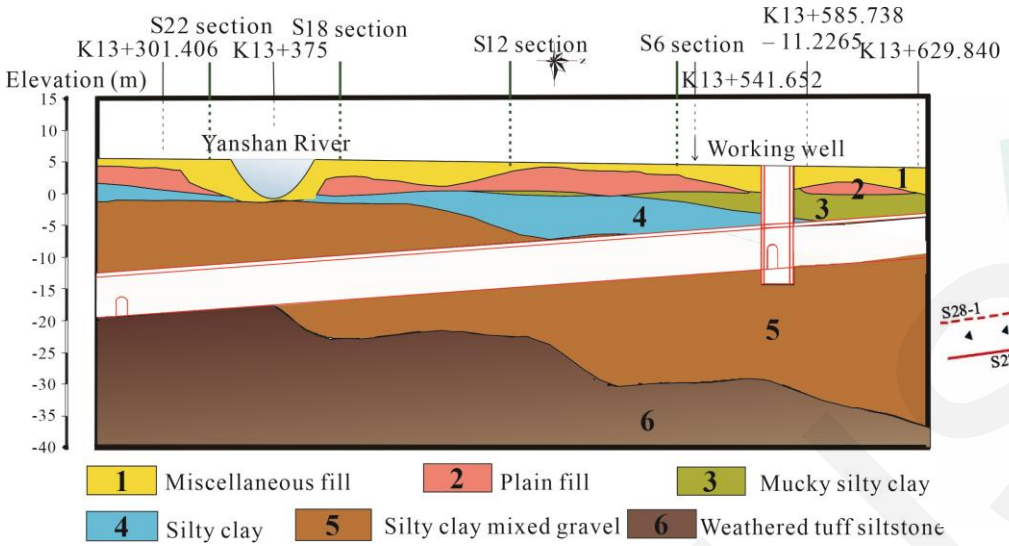


Fig. 1 Typical longitudinal profile

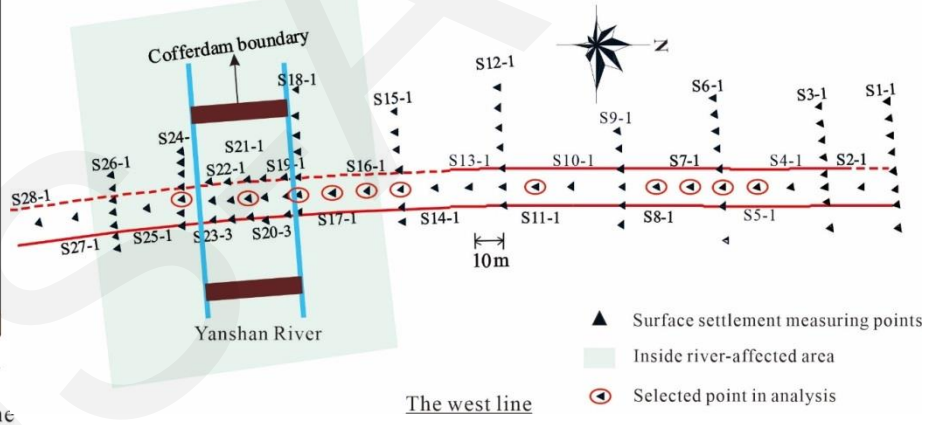
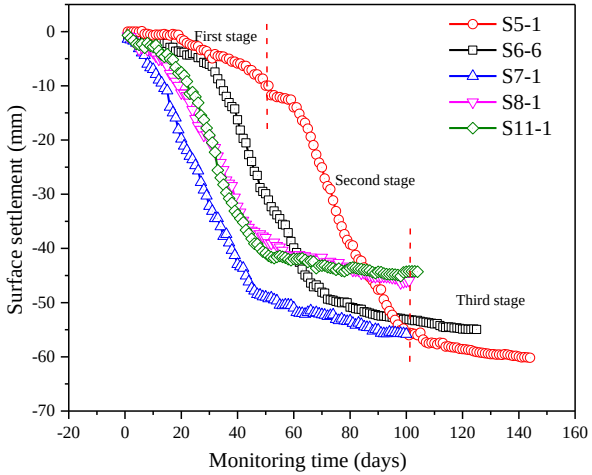


Fig. 2 Layout of monitoring points

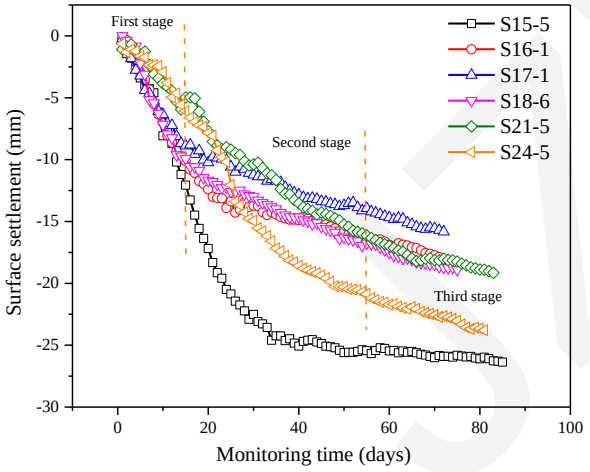
- This study is based on the project of Zizhi Tunnel, Hangzhou, China. The Yanshan River traverses above the tunnel. The tunnel excavation occurred mainly in a silty clay mixed gravel layer (Fig. 1).
- The tunnel was constructed using the CRD (cross diaphragm) method. During the excavation of the east and west line, the face of the tunnel was divided into four parts (Ⅰ, Ⅱ, Ⅲ, and Ⅳ), which were excavated in sequence.
- The research region was divided into two parts, namely inside the river-affected area and outside the river-affected area, according to the monitoring data (Fig. 2).

Measured settlements

Surface settlement inside and outside river-affected area

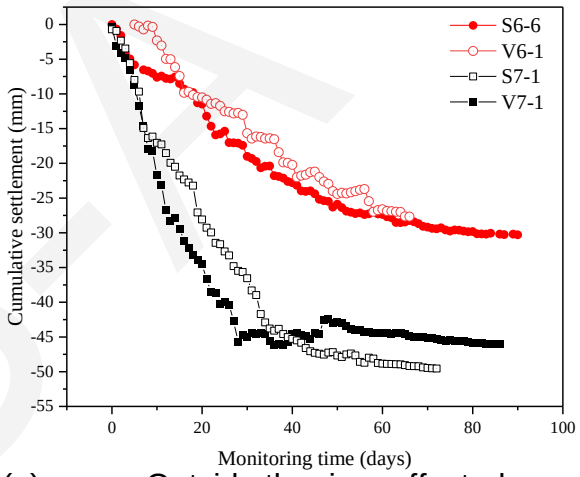


(a) Outside the river-affected area

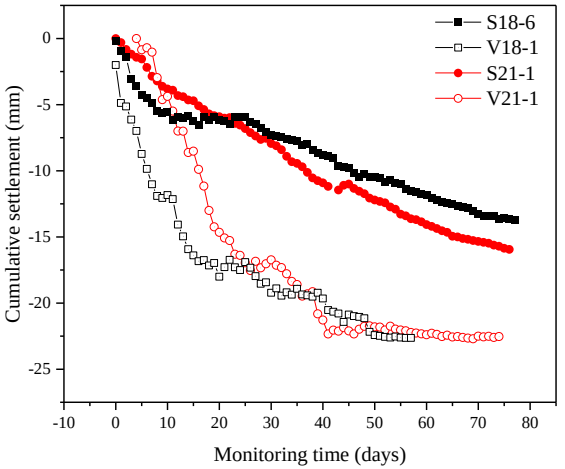


(b) Inside the river-affected area

Fig. 3 Development of surface settlement



(a) Outside the river-affected area



(b) Inside the river-affected area

Fig. 4 Comparison of surface settlement and vault settlement development

Numerical model

Numerical model of tunnel and cofferdam

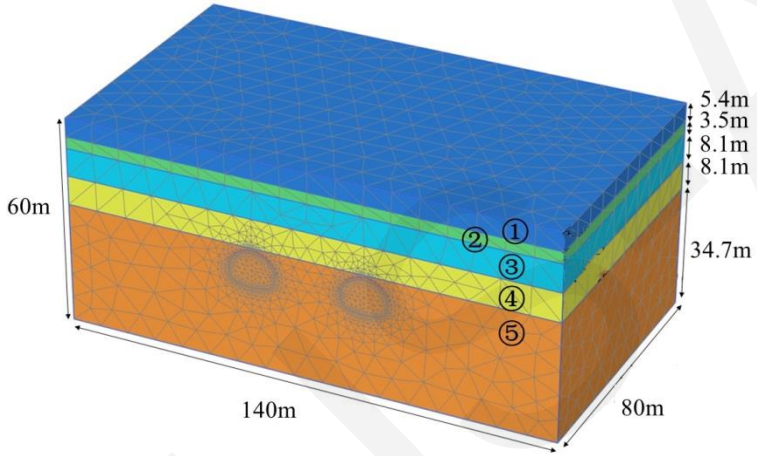


Fig. 5 Overview of the numerical model

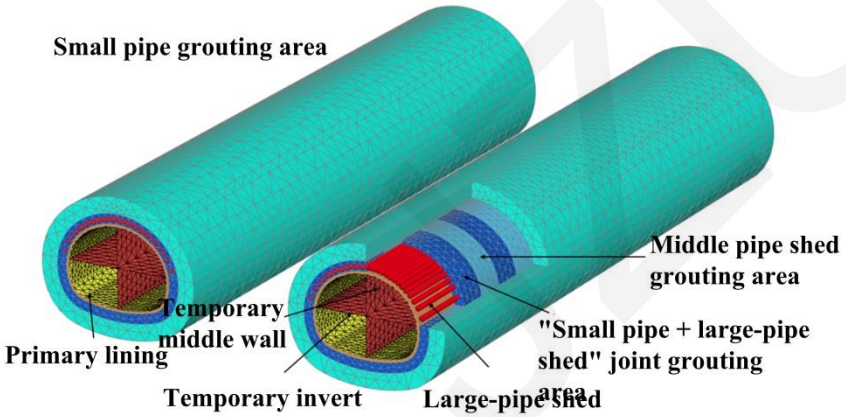


Fig. 6 The numerical model of the tunnel and the supporting system

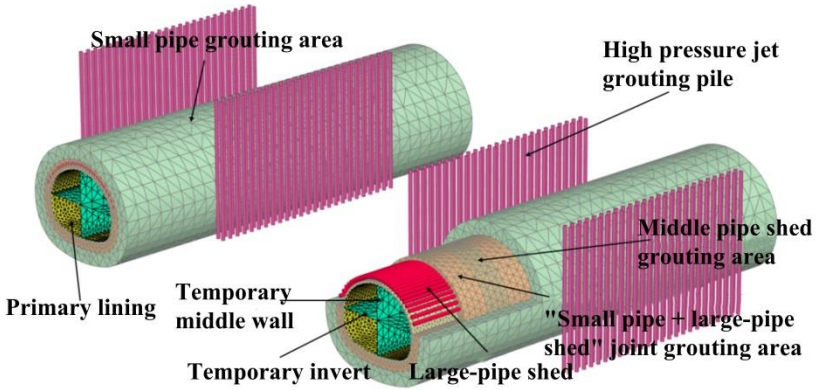
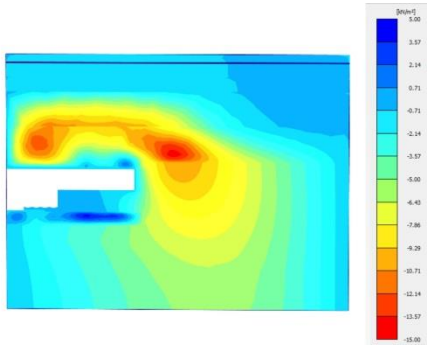


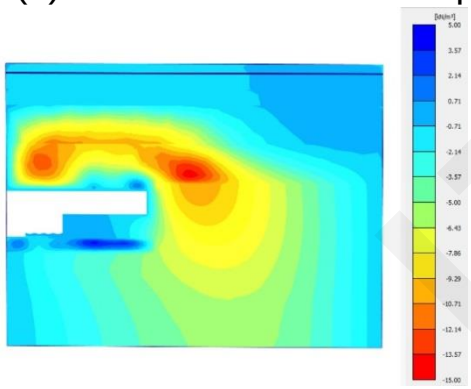
Fig. 7 Reinforcement of cofferdam

Results and discussions

■ Outside the river-affected area

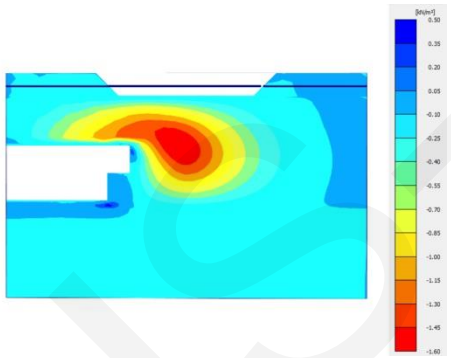


(a) The 15th excavation step

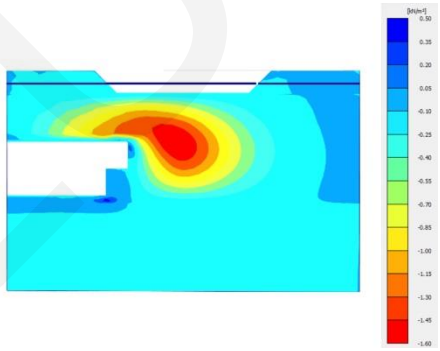


(b) The 55th excavation step

■Inside the river-affected area

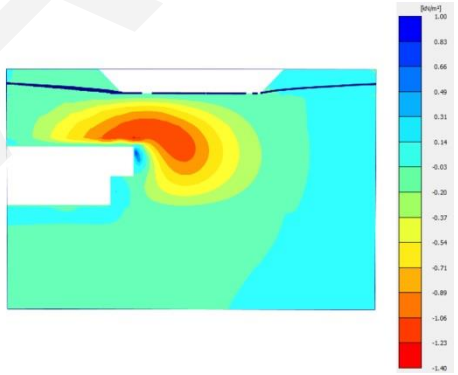


(c) The 11st excavation step

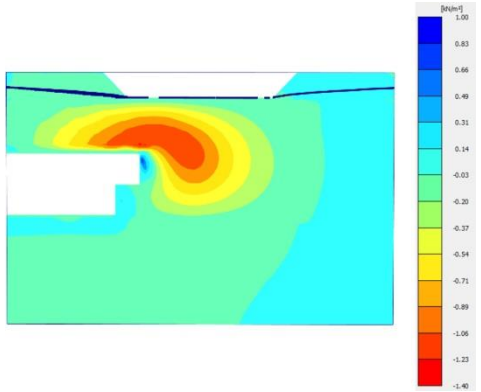


(d) The 36th excavation step

Without the cofferdam



(e) The 11st excavation step



(f) The 36th excavation step

With the cofferdam

Fig. 8 Excess pore pressure and distribution cloud map of outside and inside the river-affected area

Conclusions

- The development law of the surface settlement was different inside and outside the river-affected area. For a single point on the center line, the law of surface settlement over time could be divided into three stages, both inside and outside the river-affected area. When within the river-affected area, there was an asynchronization of the sinking rate and stability of vault settlements and surface settlement.
- The numerical results showed good agreement with the monitoring data, which proves the rationality of the numerical model. Outside the river-affected area, the main factor that influenced the stability of the tunnel face and the development of surface settlement was the excavation of the upper face of the tunnel. Inside the river-affected area, apart from the settlement caused by excavation, the consolidation settlement resulting from the dissipation of excess pore water pressure caused by cofferdam construction above the river was also important, extending the time needed for settlement to converge.
- Outside the river-affected area, the negative excess pore water pressure was distributed mainly in the range of 1.0~3.0 H_t behind the tunnel face, and 1.0~2.0 H_t in front of the tunnel face. Inside the river-affected area, the negative excess pore pressure was distributed in the range of 1.0~2.0 H_t before and behind the tunnel face, which is more concentrated. The construction of the tunnel cofferdam reduced the surface settlement by 39%, and the excess pore water pressure distribution generated by the construction of the cofferdam was more dispersed, which could reduce the tunnel construction risk. To better control the settlement caused by a tunnel undercrossing a river, reinforcements such as a cofferdam and pre-grouting support could be applied.