

## **Face stability of shallow shield tunnels in dry sandy ground: model tests, discrete element method simulations and theoretical model**

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### **Summary**

Face stability is critical in the underground tunneling. In this report, large-scale model tests on the face stability of shallow tunnels for various cover depths ( $C/D = 0.5, 1, \text{ and } 2$ ) in dry sandy ground were firstly introduced. Then, a series of three-dimensional DEM models were built to simulated the process of tunnel face failure. The results of the model tests and DEM simulations reveal that a chimney like failure zone appears during the tunnel face failure. It was founded that with the increase of the horizontal displacement of the tunnel face, the support pressure decreases to the limit support pressure and then increases to the residual support pressure. The results demonstrate that limit support pressure tends to be constant when cover depth  $C/D$  is larger than 1. It was also founded that soil arching occurs in the upper part of the failure zone and the soil becomes loosened in the failure zone. Finally, a theoretical model for calculating limit support pressure which considers soil arching effect was proposed. Consequently, the comprehensive analysis of tunnel face failure may help to guarantee safe construction during tunneling.

