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Numerical Statical Analysis of Umbrella Drain Performance in Deep Circular Unlined Tunnel for Steady-State Seepage

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1-Introduction

One of the major issues in tunnels is seepage which has been modeled by an extra force which is generated by pore water pressure and applied on the tunnel walls. Since this extra seepage force may lead to instability in soils and weak rocks with low permeability, the need for drainage in such tunnels is obvious. There are different types of drainage systems in tunnels. The most common ones are peripheral filter and pin-hole drainage systems. Despite their importance, very limited studies have been conducted on these systems (especially pin-hole type) and the factors that affect their performance.
In this study, the new umbrella drainage system is introduced. The arrangement of the system is a combination of pin-hole drainage and forepoling support systems (Fig. 1).

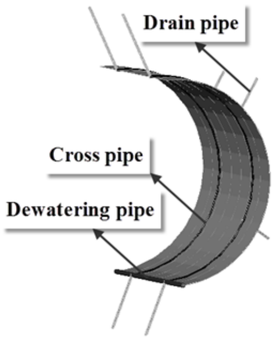

Fig.1 Umbrella drain system

2- Simulation in the Software

The factors affecting the system performance include number (n), length (l), distance (d) and angle (a) of the drains. Therefore, an abbreviation is introduced as NnLlDdAa (Fig. 2). Also a basic primary model for the drains is assumed based on the research by Shin and coworkers. The model includes 6 4m-length drains having a distance of 4 m and an angle of 45 degrees with the tunnel axis (N6L4D4A45).

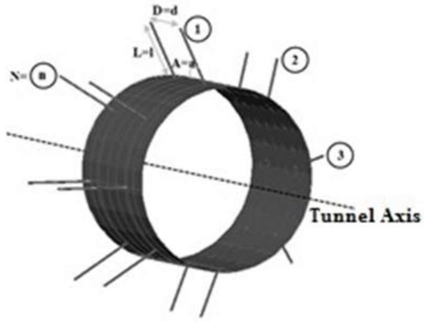

Fig.2 NnLlDdAa model

In this study, the performance of the drainage system is investigated through numerical statical analysis in deep circular unlined tunnels subjected to steady-state seepage by using the ABAQUS finite element software.

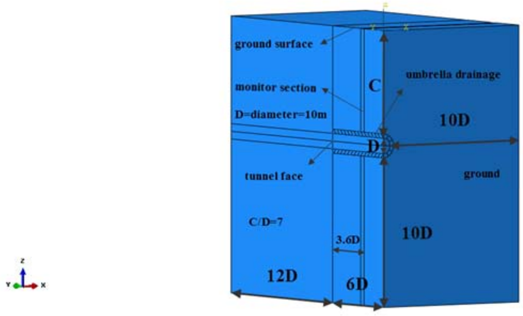

Fig. 3 The domain

The domain dimension is a very important parameter in any numerical analysis. A domain with optimum dimensions is assumed based on the results of stabilization of various analyses for variation of important parameters (Fig. 3). A monitoring section for extracting stabilized outputs is assumed at 3.6D distance from the tunnel face in-between the drains. Also, based on the sensitivity analysis of the model, the need for 3D modeling of the issue is underlined.

1-The effect of drains' parameters

In this study, a series of parametric studies were conducted using the basic model, i.e., by changing one of the effective parameters while the others were held constant. The parameters values included number (1-14), length (1-7 m), distance (1-9 m) and angle (5, 25, 45, 70, 90) of the drains.

The factors affecting the performance of the tubes as the main parts of the umbrella (pin-hole) drainage system are investigated by choosing the maximum effective principle strain as the monitoring parameter. Moreover an optimum arrangement for the drainage tubes of the system is presented. Also, the effects of changes of the tubes' parameters on the hydraulic outputs such as hydraulic gradient and pore water pressure are studied.

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4-Conclusions

In this study, for the first time, the factors affecting the performance of the tubes as the main parts of the umbrella (pin-hole) drainage system are investigated using the 3 monitored outputs, i.e., maximum effective principle strain, hydraulic gradient and pore water pressure. The following conclusions are made based on the presented results:

1. There is only one optimum pattern (out of many patterns assumed for various numbers of the drains) that produces the least maximum effective principle strain. The pattern does not necessarily the same optimum pattern for the least hydraulic gradient.

2. There is a need for adverse drainage system in the tunnels with different patterns assumed for various numbers of the drains.

3. If we assuming an even number of tubes in the umbrella drainage system, then there is an effective reduction in the hydraulic gradient.

4. The behavior of the hydraulic parameters (hydraulic gradient and pore water pressure) is very similar for the different values of the tubes parameters. This indicates that hydraulic parameters are dominant as compared to mechanical parameters in tunnels under seepage.

5. The three monitored parameters (maximum effective principle strain, hydraulic gradient and pore water pressure) are reduced with increase in number, length, angle of the drains and with decrease in distance.

6. The length, number and distance are the most important parameters in the design of the drain tubes.

7. The optimum pattern for the tubes in the umbrella drainage system includes number (n=10), length (l=4 m), distance (d=8 m) and angle (a=90°) of the drains. The optimum pattern is applicable for the tunnels excavated in the materials with properties assumed in the current paper.