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The effect of topography on stability of shallow tunnels case study: The diversion and conveyance tunnels of Safa Dam

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ABSTRACT

Due to ignoring the role of real topography in the numerical modeling carried out for back analysis and considering that in the tunnel longitudinal profile the distance of tunnel roof to the ground surface is the maximum, some results inaccuracy may occur. This issue is especially critical for cases when two tunnels or underground structures are constructed next to each other. The purpose of the present research is to study the role of real topography on the obtained results of back analysis and determine the accurate geomechanical parameters of the rock mass using back analysis based on convergencemeter data. For this aim, 8 instrumentation sections were modeled using $FLAC^{3D}$ 5.0 and the real topography was determined. Next, another numerical model was built to study the role of real topography and the obtained modeling results were compared for cases with and without real topography; where a significant difference was obtained between the results. In the case of ignoring real topography, the error function obtained from monitoring and numerical method results are between 1.5 and 10 times more than the case of considering real topography, suggesting the significant role of real topography. Furthermore, stability analysis and optimization of tunnels support system performed in this study using the real topography data. The results showed that removing the designed rock bolts the tunnel was still stable through other designed supports.

Introduction

Variables such as the status of the in-situ stresses, groundwater pressure, and the jointed rock mass strength parameters are necessary for the design of underground structures and play a vital role in selecting geometry, tunnels stability analysis, and support system design. Without such information, the design process is impossible [2]. Also, overburden on the tunnel induced by topography can play a decisive role in presenting desirable results. Usually, for the best design by numerical modeling due to the difficulty of real topography modeling, overburden is not considered and rather it is estimated by taking the height of tunnel longitudinal profile as a maximum. Because of the mismatch with reality, this type of modeling does not rationally present desirable results. Moreover, the obtained results are not accurate enough especially for shallow tunnels. Although many researchers have focused on obtaining the accurate design by numerical methods, the effect of topography is not visible in their research.

The numerical back analysis is a powerful widely used method that can be considered as a complementary technique along with laboratory and in-situ tests to determine the rock mass geomechanical properties [6]. In order to determine geomechanical parameters, failure, displacement, and/or convergence can be incorporated in the back analysis. Comparison of back analysis results and in-situ tests data can be helpful in increasing the design engineers' confidence. Some researchers have focused on the back analysis of the underground structures. For example, Shang et al. [11] used intelligent back analysis to study the rock mass properties surrounding the tunnels. Based on the applied engineering programs of studying about 100 tunnels in China, it was found that Intelligent Back Analysis (IBA) technique might be successfully applied to predict the in-situ stresses and the deformation modulus. Dehghan et al. [5] used back analysis technique to optimize support system of Karaj subway tunnel using a 3D modeling. They modeled this problem using Plaxis 3D and considering multiple-stage excavation of the tunnel section using convergence meter data to obtain accurate parameters of the rock mass. Dadashi et al. [4] also used back analysis technique to study the water conveyance support system. Results of this study indicate the removal of a part of the shotcrete designed in the mentioned tunnel. Miro

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et al. [13] discussed the uncertainty of soil parameters on the results of the displacements around a tunnel using back analysis and probability analysis methods. They used the updated Bayesian method to enhance the results accuracy. Janin et al. [7] compared 2D and 3D numerical methods results and studied the stability and subsidence value of Talun tunnel in France using back analysis technique. The accuracy of the 2D method and the significance of the method were confirmed through fitness of 2D on 3D method results.

In the present work, the role of real topography in the stability of conveyance and diversion tunnels of Safa Dam in Kerman Iran was modeled using FLAC^{3D}5.0 software. In the following, for calibration of models and obtain the optimum parameters, back analysis of these tunnels was performed and accurate parameters of the rock mass were determined. Moreover, regardless of real topography, another numerical model was developed and its results in the case with and without real topography were compared. Finally, having accurate parameters of the rock mass, stability analysis, and optimization of the temporary support system of Safa dam tunnels (with real topography data) were performed.

Tunnels and site specifications

The study area is located in Kerman province about 30 km northeast of Baft city (56°58′N and 29°15′E). This dam is primarily used for supplying Kerman and Rabor drinking water. Two tunnels located on its left bank are used to convey and divert water in the dam. Tunnel No. 1 is about 595 m in length while the other one (Tunnel No. 2) is 621 m long and is located near to it. Moreover, there is a shaft inside the tunnel to convey water. The distance between these twin tunnels is 14 m (center to center). The tunnels section is horseshoe-shaped and maximum overburden of the tunnels is 38 m. Based on hydraulic considerations, there are 5 and 7 geometric sections along tunnel No. 1 and No. 2, respectively, which are created due to the intersection of the tunnel and conveying water shaft. Instrumentation sections of these two tunnels are placed in two geometric sections (Fig. 1). The method of the tunnel excavation is full face using traditional drilling and blasting. The initial support system is a combination of three types of support systems including lattice girder, wire mesh, shotcrete, and rock bolt, shown in Table 1, [12].

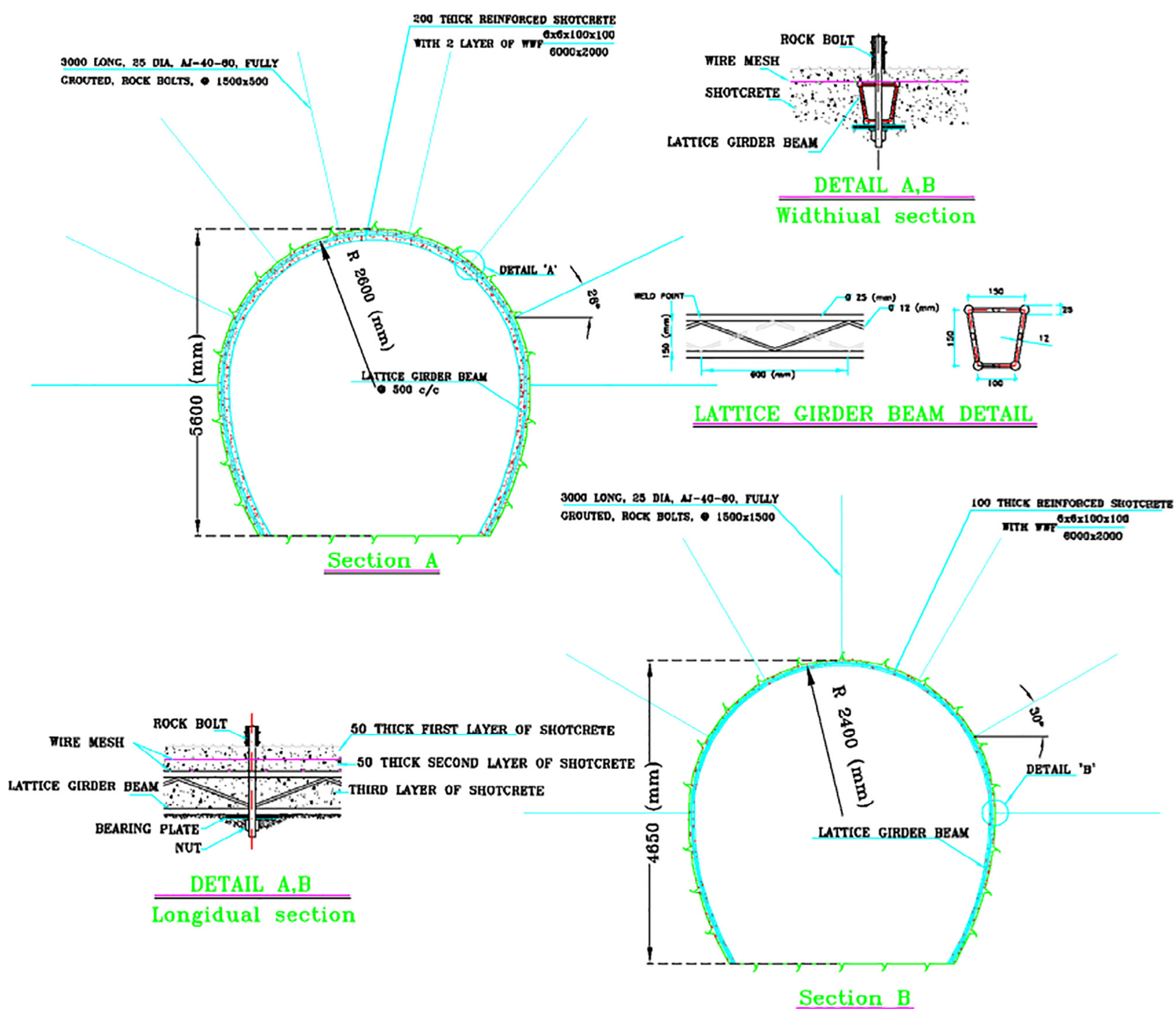

Fig. 1. Excavated sections and reinforcement design [12].