



Assessment the Stability of Tunnels in Y Shaped Intersections with Regard to the Intersection Angles Case Study: Penstock Tunnels of Rudbar Dam

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ABSTRACT

Stress analysis and stability control in tunnel intersections is a very complicated issue due to stress concentration and three-dimensional situation. During tunnel construction, increase in load on support, extra tunnel deformations and disordering in rock around of intersection zone is unique and instability may occur in this sections. In order to control extra deformation and stress, these sections need stronger support system than other sections. Extra deformations and stress values in Y shaped intersections are influenced by tunnel intersection angle. The effect of intersection angle on the length of extra support has been studied in this paper by three-dimensional modeling of penstock tunnel intersection of Rudbar Dam in FLAC3D. Numerical analysis results for three intersection angles of 60, 75 and 90 degrees show an increase in length of extra support by decreasing in intersection angle.

KEYWORDS:

Y Shape Intersection, Penstock Tunnel, Extra Support, FLAC3D

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1- INTRODUCTION

Stress Analysis and stability control in underground spaces is very complicated due to many uncertain factors and rock mass behavior, especially when the underground space is Y shaped. In tunnel intersections, the state of stresses is three-dimensional and 2D analysis of stresses may lead to undesirable results, therefore 3D modeling is necessary for stress and deformation study in these tunnels. Increasing support loads and additional tunnel deformations are often observed during construction, due to further disturbance of rock masses surrounding the intersection area. A support system stronger than the conventional support was adopted to counter the adverse effects of complicated stress conditions.

Most of the previous studies on tunnel behavior in the intersection areas have been conducted by studying stress concentration factor using elasticity theory. Photo-elasticity experiments were performed by Riely (1964) and Panet (1971) to study stresses surrounding the tunnel intersection areas. Due to rapid development in modeling techniques, 3D analysis were used more widely by researchers, such as Thareja et al. (1980, 1985) and Takino et al. (1985), on the displacements and stresses in the intersection area by considering various rock properties and intersection angles [1].

Tsuchiyama et al. (1988) examined the excavation of a subsidiary tunnel intersected to the main tunnel with an angle of 45 degrees for the design of the support system through a 3D numerical analysis. They found that the affected area along the main tunnel, which requires additional support, is about one tunnel diameter on the obtuse angle side and about three tunnel diameters on the acute angle side from the point of intersection [2].

Nonomura et al. (2004) suggested a rough estimate of support requirement with additional reinforcement for the intersection area [3]. Chen et al. (2002) and Hsiao et al. (2004) conducted 3D elasto-plastic analysis of tunnel behavior in the intersection area [4]. These studies, However, were only limited to some case studies.

2- METHODOLOGY, DISCUSSION AND RESULTS

Studying the effect of intersection angle on tunnel behavior in Y-shapes intersections needs creation some models with different intersection angles. In this research, three Y-shaped tunnel intersection

with 60, 75 and 90 degrees created by FLAC-3D (one of the best geotechnical simulation softwares). The intersection of intake tunnel as the main tunnel and two penstock tunnels as the subsidiary tunnels of Roodbar-Lorestan dam selected as the case study for this purpose. This intersection situated about 360 meters below surface. Elasto-plastic model of Mohr–Coulomb criterion was used for numerical simulation. According to geological reports, average of RQD was 87 for the rock mass, therefore classified as very good rock mass. Table 1 briefly shows properties of rock mass around the intersection.

Table 1. Rock mass properties in Intersection zone

Lateral stress ratio (K)	0.7
Poisson's ratio	0.25
Modulus of elasticity (Gpa)	4.8
Joint friction angle (D)	30
Joint Cohesion (Mpa)	0.5
specific weight (kg/m ³)	2716

Various mesh generations were used for different intersection angles. The boundary from the main tunnel was considered about 8 times of tunnel diameters in the horizontal and vertical directions. The length of models is 60 meters.

Using an empirical safety criterion, proposed by Sakurai (1993) [5], showed that excavation steps with 2 meters advance would be suitable.

Support system consists of shotcrete as temporary support and a concrete layer with the thickness of 50 centimeters as the final support.

Simulation shows 3 critical zones for every intersection:

- 1) Tunnel crest before and after intersection centre
- 2) Middle wedge (including acute angle)
- 3) Side wedges (including obtuse angle)

38 points with two meters distance were marked before and after intersection centre on the wall and crest of the tunnel. These points were used for interpretation of deformations and stresses on tunnel structure.

The results show that decreasing in intersection angle causes an increase in both stresses on support system and tunnel deformation on the crest (figure 1). This is happened for the wall in the middle wedge as well, meaning that support should be elongated in these directions. For the side wedges, however, this

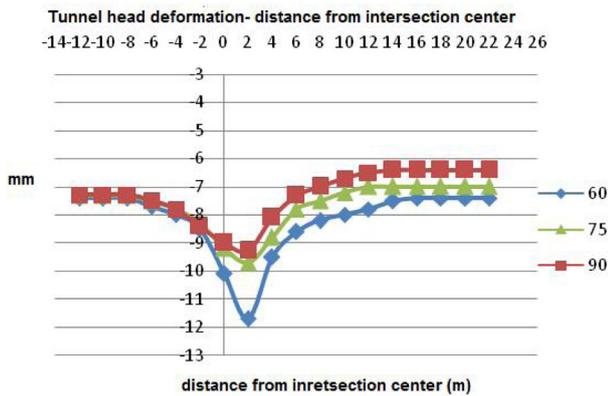


Figure 1. Variation of tunnel crest deformation with distance from intersection centre for different intersection angles

effect is inverse.

3- CONCLUSIONS

According to the modeling, maximum displacement occurred in intersection centre that affected on deformation of intersection zone. In this area, tunnel needed stronger support system that related to angle of intersection so that by decreasing in intersection angle, stronger support system would be needed.

Maximum stresses on support system occurred in the middle wedge, due to stress concentration and acute angle in comparison with side wedges. Stresses on tunnel lining reach to a constant value, in certain points of the wedge centre with regard to intersection angle. Modeling results show that the maximum length required stronger support system was related to the intersection with 60 degrees. This length was 20 meters or 3.5 diameter of main tunnel.

In side wedges zone, increase in middle angle of intersection, causes an increase the amount of bending on lining, therefore extra support system length increase, too. Values of bending for 60 degrees intersection reach to a constant in lesser distance in comparison to 90 degrees intersection.

Analysis results show that for side wedges maximum extra support system length for 90 degrees intersection is 16 meters or 2.5 diameter of main tunnel.

Maximum stress exists on tunnel crest. By distance from intersection centre, the stresses on tunnel crest decrease. Increase in intersection angle decreases stresses on tunnel crest. Therefore, maximum extra support system length for 60 degrees intersection is 23 meters or 4 diameter of main tunnel. Table 2 shows

all result of maximum extra support system length for different intersection zones by 60, 75 and 90 degrees intersections.

Table 2. Extra support system length according to distance from intersection centre

K	0.7		
	90	75	60
(Intersection angle (degree			
extra support system length in (middle wedge (meter	16	18	20
extra support system length in side (wedge (meter	16	14	10
extra support system length in tunnel crest (meter	18	20	23

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