THE EFFECT OF ROCK MASS DAMAGEON STABİLİTY OF CONCRETE LİNED TUNNELS WITH MOHR-COULOMB FAILURE CRITERION

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Abstract: Drill and blast excavation method is commonly used in mining, quarrying, and tunneling, around the world. Despite the fact that drill and blast method has witnessed significant technological advancements, it has inherent disadvantage of deteriorating surrounding rock mass, due to the development of a blast induced damage zone, with reduced strength and stiffness parameters. Traditional tunnel analysis adopts a single value of blast damage factor D for the Hoek-Brown (HB) criterion for the entire rock mass, leading to an underestimation of the tunnel stability. However, the blast damage zone with finite thickness is significant in tunnel design and stability analysis. In this paper, the behavior of tunnels under different damage conditions is examined. In this regard, a fully analytical solution is used. The solution is presented for tunnels excavated in elastic-brittle-plastic rock masses with Mohr-Coulomb failure criterion. The damaged zone is assumed to have cylindrical shape with a varied damage factor D. Results obtained by the proposed solution indicate that the alteration of rock mass properties may considerably affect the damaged zone.

Keywords: Concrete lined tunnel, Rock masses, Excavation-damaged zone, Elastoplastic analysis, Mohr-Coulomb criterion.

1- INTRODUCTION

The excavation impact (e.g. due to blasting or TBM drilling) induces an excavation damaged or disturbed zone around a tunnel. The presence of the damage zone around a tunnel boundary is of significant concern mainly considering the safety, stability, costs and overall performance of the tunnel. The damaged zone is essentially characterized by a reduction in strength and stiffness, and an increase in permeability. Thus, the disturbance of a rock, due to a blasting impact, can significantly influence the overall performance of an underground excavation. The characteristics of a damaged or disturbed zone (EDZ) vary with the rock mass properties, excavation method, and opening geometry. The extent of the damaged zone induced by excavation impact is finite, and depends on the rock properties, shape of the tunnel, excavation method, and its quality, but it can range from few centimeters to several decimeters (in tunnels with TBM) or to several meters (with drill and blast). Generally, in analytical methods, the damage induced in the rock masses is taken into account by using the damage factor D, introduced by Hoek et al.. In these methods, damage factor D is applied to the entire surrounding rock mass; while, the extent of the damaged zone is finite. However, this is a common method which can greatly underestimate the strength and stiffness of the surrounding rock mass. Currently, other limited analytical solutions are available that consider the effect of the damaged zone to a limited extent, with reduced strength and stiffness parameters. Nevertheless, only a single fully-analytical solution is currently available, which considers all possible cases. Zareifard and Fahimifar introduced three different cases depending on the radii of the blast-induced damaged and the plastic zone. However they did not present the boundaries between these three cases and didn't propose any formulations for defining lining internal pressures. Thus in order to investigate the characteristics of EDZ (Excavation Damaged Zone) developed during construction of tunnels, a new analytical solution is proposed considering the interactions between the lining and rock masses.

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2- METHODS

The solution is presented for a tunnel excavated in elastic–brittle–plastic rock masses with Mohr-Coulomb failure criterion. The rock mass was homogeneous and isotropic beyond a disturbed zone around the tunnel (outer zone) and homogeneous and cylindrically disturbed around the tunnel (inner zone). The damaged zone was assumed to have cylindrical shape with varied parameters. Since the radius of the plastic zone was unknown initially; three different cases were introduced depending on the radii of the blast-induced damaged and the plastic zones (Fig. 1). In addition, the boundaries between different cases were also derived.

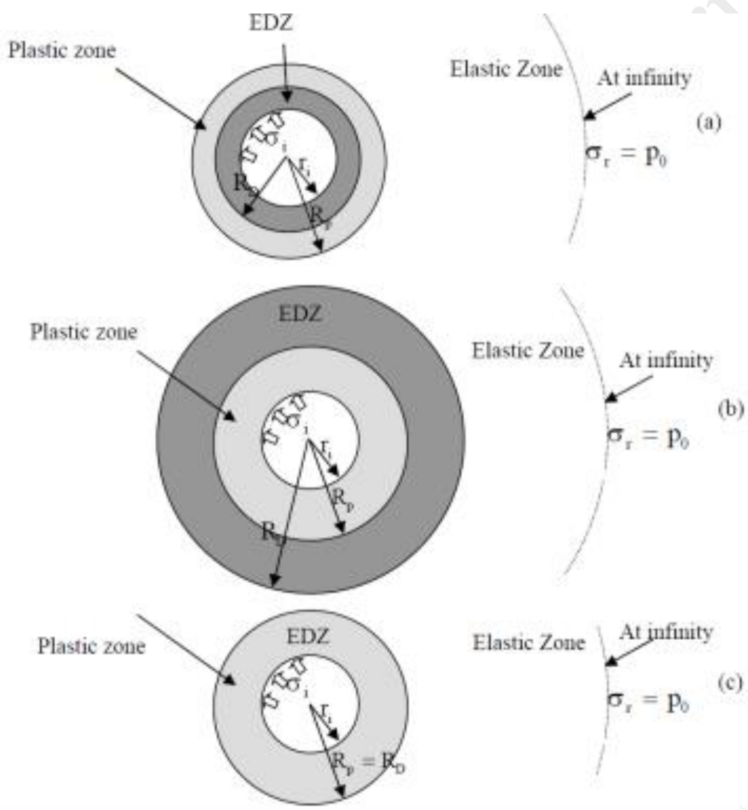

Figure 1. The circular deep tunnel with a cylindrical EDZ: (a) $R_p > R_D$ **(b)** $R_p < R_D$ **(c)** $R_p = R_D$

3- FINDINGS AND ARGUMENT

The procedure proposed in this paper, was implemented in a code written in Fortran90 language.

In order to show the applicability and accuracy of the proposed solution, and also to investigate the influence of damaged zone in any of the two cases, analyses were carried out for a sample tunnel with different damage radii. Results obtained for different damage radii have been briefly compared in Table 1. According to the data, effect of the damage zone is significant.

Maximum lining's tangential stress (MPa)	Rock-lining boundary pressure (MPa)	Final convergence (mm)	Plastic Radius (m)	case	R_D (m)
1.6	0.0938	50.27	9.53	Without damage	5
14.3	0.834	52.4	8.66	Case 1	6
48.8	2.84	58.4	8	Case 3	8
68	3.96	61.6	7	Case 2	12
84.8	4.939	64.5	6.51	Traditional method	∞

Table 1. A brief comparison of results for different damage radii.

4- CONCLUSIONS

Results obtained by the proposed solution indicated that a blast-induced damaged zone can significantly affect the stresses and displacements in the rock mass, especially when the disturbance and radius of the damaged zone were relatively high.

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