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A criterion for determination of minimum distance between twin tunnels by pillar reaction curve (PRC)

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Abstract

In this paper, an attempt has been presented a criterion for the design of pillar widths between twin tunnels. There are many empirical models to estimate width of the pillar, which have their own limitations. In the current study, the criterion for the design of pillar is based on the pillar reaction curve (PRC) by numerical modelling with different conditions. Pooneh twin tunnels was selected as a case study. Strain magnitude observed when normal stress (σ1) in the pillar reaches the value of compressive strength of the rock mass (σcm), denotes the allowable ratio of width to height (w/h) which shows the optimum distance between twin tunnels.

Keywords**:** *Twin tunnels, Pillar reaction curve and Pooneh tunnel.*

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Extended Abstract:

1. Introduction

Newer tunnels excavated in the vicinity of an existing tunnel profoundly affect the intensity of stress concentration and distribution of plastic zone (Sahoo and Kumar 2013).

As the distance between twin tunnels increases, it would result in higher construction expenses. The shorter the distance between twin tunnels, the higher will be the intensity of the load applied to the tunnel support due to occurrence of stress concentration and development of plastic zone which would necessitate a stronger and larger support system.

Although there are some empirical formulas for design of the rib pillar, they are not precise enough, as all these formulas have been obtained based on limited data available in a few specific projects. Therefore, in modern engineering usage, there is an urgent need for a new algorithm or method for optimum design of pillars (Frith and Reed 2018, Goshtasbi and Arshadnejad, 2008).

One of the best methods for determining suitable width of the pillar is computer simulation using a numerical method such as Finite Element Method (FEM).

The main goal of this paper is to suggest a criterion for the design of the pillar or optimum distance between two or more parallel tunnels in static model.

2. Materials and methods

2.1 Experimental models

Many experimental models for design of a pillar in hard and soft rocks were proposed. These formulas were obtained using information from some actual projects in different ground conditions with different tunnel geometries, it should be noted that the data extent used in statistical analysis had been limited and so the application and validation of these formulae are limited as well.

2.2 A criterion for pillar design

The criterion is based on shear strain of the pillar by a numerical model with a new diagram. As is shown, this graph depicts the reaction of the ground to excavation of the tunnel and it illustrates the ground displacements and subsequent pressure intensity applied to the support system. It is known that as more time passes, ground displacements will increase and so the ground pressure will reduce, in other words, stress release will occur.

Should the amount of the changes made to the stress and strain distribution as a result of excavation of two nearby tunnels be available, a better judgement can be done towards pillar stability design. Towards this end, a graph is introduced, the horizontal axis of which is shear strain available in the pillar and its vertical axis indicates the ratio of width to height (w/h) in the pillar.

The criterion for choosing allowable shear strain will be such that the strain magnitude will be calculated at the moment that the normal stress ($\sigma 1$) in pillar would become equal to the compressive strength of the rock mass (σcm). The respective point of the obtained strain on the graph which depicts (w/h) ratio will be selected as the minimum allowable (w/h) ratio. The compressive strength of the rock mass will be calculated based on various equations and their average will be selected as the compressive strength of rock mass.

3. Results and study of Pooneh twin tunnels

In order to investigate a real case, Pooneh twin tunnels were selected. The geology of tunnel hosting rock masses is mainly composed of limestone, marly limestone and marl. By using of instruments installed every 50 meters along the tunnel, tunnel convergences were measured.

A total number of sixteen numerical models for each zone with the same geo-mechanical data stated in the above table were analysed using Phase2 software package. In these models, the distance between tunnels was changed and subsequently the shear strains in the pillar were calculated. In order to control numerical modelling accuracy, a comparison between model outputs and data gathered by using of instruments installed on tunnels perimeters, was made.

The resulting strains in the pillar under variable twin tunnels distances and also constant geological conditions were calculated.

The normal stress induced due to tunnel excavation has been calculated in the numerical model. When the stress magnitude becomes equal to the compressive strength of the rock mass, the respective shear strain is calculated and is selected as the allowable strain of the rock mass.

By reducing the distance between two tunnels, the resultant stress due to the interaction of two induced stress field in both tunnels will increase and therefore the strain amount in the pillar will increase as well. The applied stress will be equal to the strength of the pillar. Therefore, the pillar will reach its ultimate bearing stress level at this point and any more stress applied to the pillar will result in its collapse.

Considering the PRC graph drawn for the Pooneh twin tunnels, taking into consideration the corresponding strains of the pillar strength for each zone, the respective w/h ratio hase been obtained as well. In order to obtain the optimum distance, the weighted average of the w/h ratios based on the tunnel length has been calculated.

4. Conclusion

Based on results obtained from PRC analysis, it is obvious that by reaching the normal stress induced in rock mass due to excavation to the compressive strength of the rock mass, the resultant shear strain is in allowable range. This indicates the optimal distance between the twin tunnels.

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