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The effect of height in vaulted tunnels on the stability parameters

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Abstract— **This paper presents the effect of height of vaulted tunnels on the stability parameters such as surface settlement, displacement and yielded elements around tunnels. This effect has been investigated in tunnels with different upper arches. Numerical analysis is done by a 2D finite element program with software Phase2, whereby vaulted tunnels are modeled with different upper arches and with widths of 4, 6, 8 and 10 meters and the heights of 3, 5 and 7 meters. The results of the evaluations show that by decreasing the height of tunnels, the stability parameters have improved for all the radius of tunnel arch. Furthermore, variations of the surface settlement, displacement and yielded elements around tunnels has reduced when width of tunnel become larger from radius of tunnel arch.**

Index Terms— **Height of tunnel; Arch radius; Vaulted tunnels; Stability parameters**

I. INTRODUCTION

Tunnels excavate in various rock masses and ground conditions with different modes of behaviour. The way the rock masses surrounding a tunnel behave is very important. The behaviour of ground largely depends on the shape and size of underground excavation. The ground behaviour can be assessed via ground conditions with various project features. The fitness of different rock engineering tools upon ground behaviour have presented by [1].

The ratio of rock mass strength to the in situ stress value specifies that these deformations induce stability problems in the tunnel. Therefore, deformation process takes place immediately upon excavation of the tunnel face. The basic input parameters for a safe tunnel design are tunnel size and characteristic of the rock masses surrounding the tunnels. During excavation, the numerical models allow the rapid choice, installation and control of the best solutions, after empirical adjustments for different situations [2]. In order to describe the deformation in tunnels, multiple numerical methods have been developed [3] , [4].

Due to excavation of tunnel in weak rocks, the surface settlement of ground could be occurred. The displacements at the surface of ground and the displacement distributions around tunnels varying in the plastic zone according to the method used. In this matter, the theories are investigated by [5] and [6]. Yielding in around of tunnels when occurs that tangential stresses overcome to rocks strength so the yielded elements have important role in analysis of the stability of underground constructions which designed and implemented in rock. The size and shape of tunnels have an important role in number of yielded points in around tunnels. Select the appropriate shape for tunnels can reduce the number of yielded elements and increase the stability of tunnels.

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This paper attempts to evaluate the effect of height of vaulted tunnels on the stability parameters such as surface settlement, displacement and yielded elements around tunnels excavated in shale rocks.

II. GEOMECHANICAL PROPERTIES OF THE ROCK MASSES

In this study, the geomechanical parameters of the shale rock masses are obtained by using Roclab software [7]. These parameters are obtained based on the Hoek-Brown failure criterion and it is presented in Fig. 1.

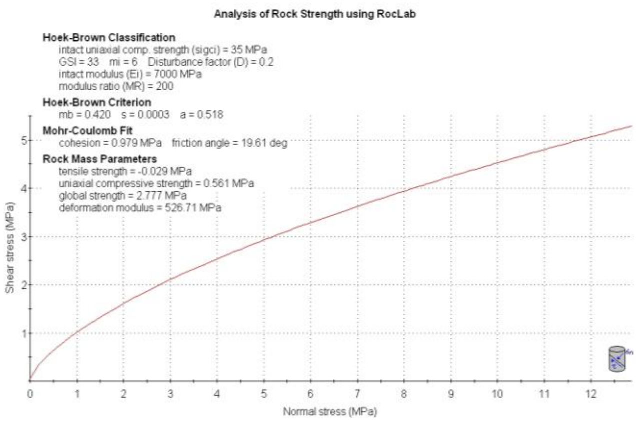

Fig.1. The geomechanical parameters of shale rock masses

III. NUMERICAL ANALYSIS OF THE UPPER ARCH TUNNELS

The tunnels modeling are done using a two-dimensional hybrid element model, called Phase2 Finite Element Program [8]. The geomechanical properties for these analyses are extracted from Fig. 1. The generalized Hoek and Brown failure criterion is used to identify elements undergoing yielding and the displacements of the rock masses in the tunnel surrounding.

To simulate the excavation of tunnels in the shale rock masses, a finite element models is generated with different upper arches for vaulted tunnels with widths of 4, 6, 8 and 10 meters and the height of 3, 5 and 7 meters (for example Fig. 2). The outer model boundary is set at distances of 7 times the tunnel radius and six-nodded triangular elements are used in the finite element mesh.

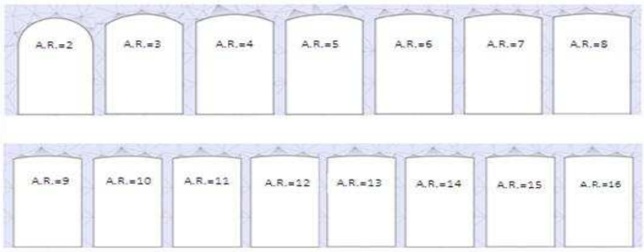

Fig. 2. The modeling of vaulted tunnels with width of 4 meters, height of 7 meters and different arch radius (A.R. is arch radius of tunnel to meter)

By run of models, the values of displacement in the roof of tunnel, the surface settlement of ground and the number of yielded elements is determined for each tunnel (for example Fig. 3) and the obtained results are shown in Figs. 4 to 6.

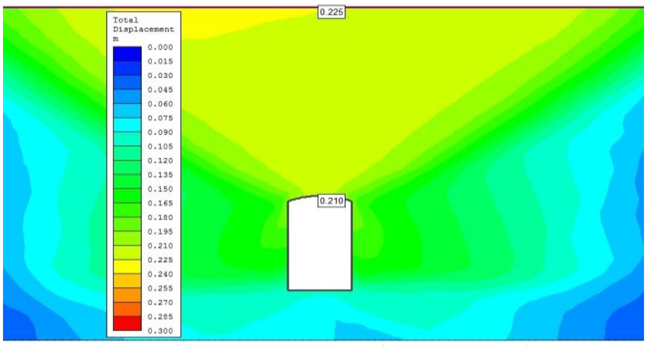

Fig. 3. The values of displacement and surface settlement of ground in a vaulted tunnel with arch radius of 5meters and height of 7 meters

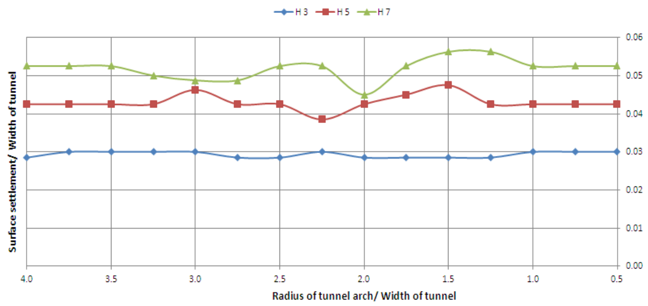

Fig. 4. The normalized diagram shows ratios surface settlement of ground for different radius of tunnel arch and heights of 3, 5 and 7 meters

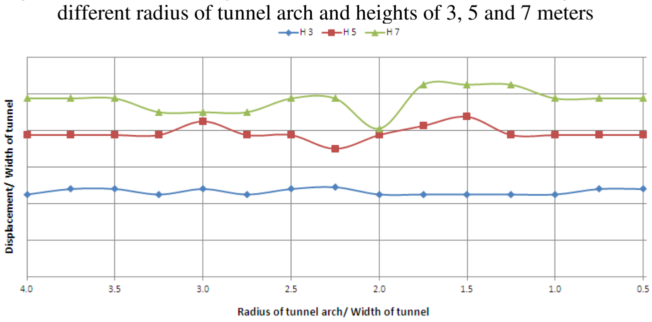

Fig. 5. The normalized diagram shows ratios displacement of tunnel roof for different radius of tunnel arch and heights of 3, 5 and 7 meters

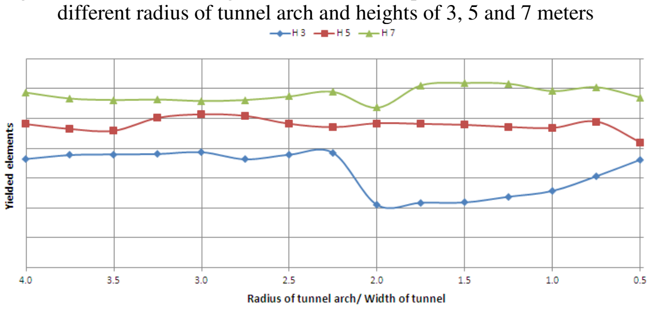

Fig. 6. The normalized diagram shows number of yielded points around tunnels for different radius of tunnel arch and heights of 3, 5 and 7 meters

As the above diagrams show, by increasing the height of tunnels, the stability parameters have been worse and the effect of radius of tunnel arch is more prominent, so that the optimal arch radius is twice the width of tunnel. The diagram in Fig. 4 shows that by decreasing height of tunnels, fluctuations surface settlement of ground has reduced and the effect of radius of tunnel arch in the surface settlement has decreased. The diagram in Fig. 5 shows that fluctuations of displacement in the tunnels roof has increased considerably and in height of 7, the minimum of displacement is obtained for ratio of radius tunnel arch to width of tunnel equal to 2. The diagram in Fig. 6 shows that the minimum fluctuations of yielded points is related to height of 5 meters and also, the minimum of yielded elements around tunnels is obtained for ratio of radius tunnel arch to width of tunnel equal to 2.

Results of this analysis show when using the optimal arch radius, the stability parameters become more optimal nearly 22 percent and variations of them has reduced when width of tunnel become larger from radius of tunnel arch.

IV. Conclusions

This study provides an estimation of the effect of the height of vaulted tunnels and could be used for modeling of these tunnels. The following conclusions could be noted:

– By decreasing the height of tunnels, the stability parameters have improved for all the radius of tunnel arch.

– Variations of the surface settlement, displacement and yielded elements around tunnels reduce when width of tunnel become larger from radius of tunnel arch.

– In vaulted tunnels, when width of tunnel is larger of height of tunnel, the variations of stability parameters become negligible.

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