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Theoretical and numerical analyses of squeezing rock mass around a spherical opening considering the existence of a damaged zone

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ABSTRACT: If an underground opening is excavated using the drill and blast method, an excavation damaged zone (EDZ) will appear around the opening in which it's mechanical and creep properties can be very different from the initial rock mass. The existence of such a zone in squeezing rock masses can lead the time-dependent displacements to increase. Therefore, in this paper, a closed-formed analytical solution is proposed to determine the long-term performance of a spherical opening surrounded by an EDZ. To consider the time-dependent behavior, the viscoelastic Burgers model is assigned to the rock mass. After verifying the proposed method, a parametric study is performed and the influence of various factors such as the radii of the opening and EDZ, the shear modulus, and the viscosity of rock mass are investigated. It is found that if the EDZ radius is considered constant, the displacement of the cavity with 7 meters radius, immediately and after 10 years, is respectively 1.42 and 1.57 times greater than the case in which the cavity radius is 4.57 meters. On the other hand, if the cavity radius is equal to 4.57 meters, immediately and after 10 years, the displacement of the cavity wall in which the EDZ radius is 8 meters is respectively 50% and 70% greater than the case in which this radius is equal to 6 meters. When the radii of the cavity and the EDZ are constant, if the Kelvin viscosity in the EDZ and the initial rock mass becomes one-twentieth, the cavity displacement increases by 115% and 173% after 1 year, respectively. However, if 20 times of the initial Maxwell viscosity of the EDZ is used in the calculations, this displacement decreases by about 14%, after 50 years.

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1- Introduction

The stability of underground openings in squeezing rock masses is one of the challenging issues in the field of geotechnical engineering. These rocks mainly have low mechanical properties and are located at great depths, and show time-dependent behavior.Due to the excavation method, an excavation damaged zone (EDZ) can exist around these underground openings in which its long-term properties are different from the initial rock mass. Thus, the existence of such zones in squeezing rock masses can have a significant effect on the performance of these openings.In most of the previous researches, the distribution of stresses and displacements around the tunnel wall has been greatly investigated, using different assumptions [1-6], and less attention has been paid to the case of spherical cavities. However, the influence of the existence of EDZ around these underground openings on their time-dependent behavior has not been considered. Therefore, in this paper, a closed-form solution is proposed to determine the distribution of stresses and displacements in the rock mass with viscoelastic behavior around the spherical cavity, considering the existence of the damaged zone. After verifying the proposed method, a parametric study is performed and the effects of various factors on the results are investigated.

2- Analytical method

It is assumed that the inner radius of the cavity is R_0 and a pressure equal to $\sigma_{r(R_0)}$ acts on this boundary. Also, an EDZ with radius R_{alt} is created around this opening (Figure 1).

The main assumptions in this paper are:

Small strain assumption is adopted;

The shape of the cavity and the EDZ is spherical;

The rock mass is homogeneous and isotropic and its behavior is viscoelastic (considering the Burgers model);

The initial stress conditions are hydrostatic;

The radial stress in the sphere wall is constant;

Groundwater table does not exist;

Axisymmetric conditions exist;

Displacements toward the cavity and compressive stresses are positive.

Based on these assumptions, a closed-form solution is proposed to predict the long-term behaviors of tunnels.

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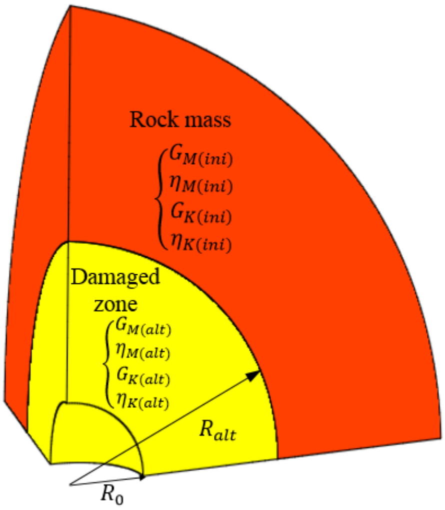


Fig. 1. EDZ around the spherical cavity

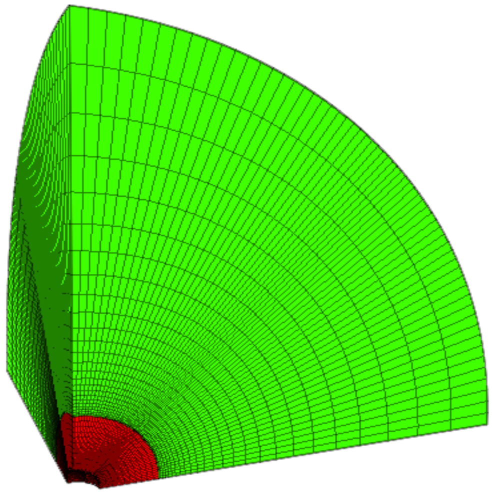


Fig. 2. The geometry of the model constructed in FLAC3D software

3- Numerical method

To compare the results of the proposed method with the numerical method, FLAC^{3D} software is used. The geometry of the model constructed in this software is shown in Figure 2.

4- Results and Discussion

Figure 3 depicts the influence of the cavity and EDZ radii on the cavity displacements. As seen, if the EDZ radius is considered constant, the displacement of the cavity with 7 meters radius, immediately and after 10 years, is respectively 1.42 and 1.57 times greater than the case in which the cavity radius is 4.57 meters. Besides, if the cavity radius is considered constant and is equal to 4.57 meters, immediately and after 10 years, the displacement of the spherical cavity wall in which the EDZ radius is 8 meters is respectively 50% and 70% greater than the case in which this radius is equal to 6 meters.

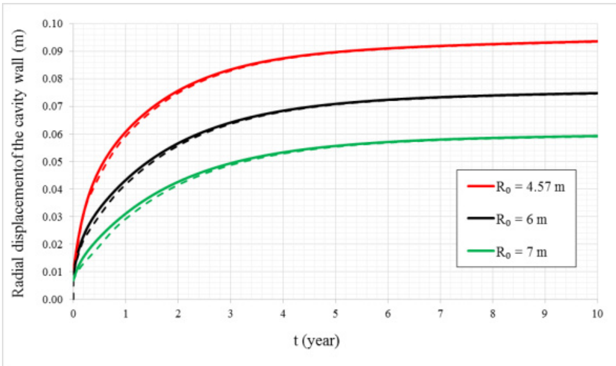
5- Conclusions

In this paper, a closed-formed analytical solution was proposed to determine the distribution of stresses and displacements of rock mass around a spherical cavity considering the existence of an EDZ. Based on the conducted parametric study, the following results were obtained:

When the radii of the spherical cavity and the EDZ are constant, if the Kelvin viscosity value in the EDZ and the initial rock masses becomes one-twentieth, the cavity wall displacement increases by 115% and 173% after 1 year, respectively.

When 20 times of the initial Maxwell viscosity of the EDZ is used in the calculations, the displacement of the cavity wall decreases by about 14%, after 50 years.

a)



b)

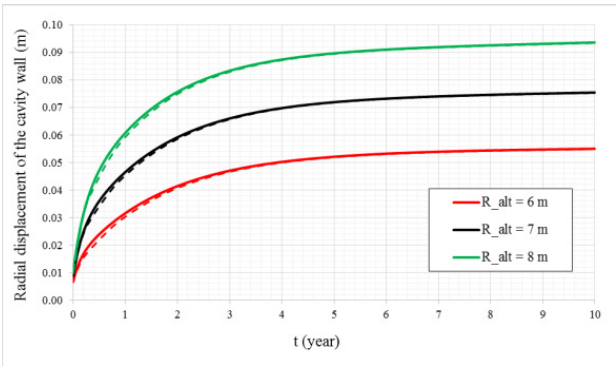


Fig. 3. The effect of a) the cavity radius, b) the EDZ radius on the displacement of the cavity (continuous and dashed lines represent the results of the proposed and numerical methods, respectively)

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