Vol. 13, No. 36, Fall 2023, Pages 61-78

Journal of Analytical and Numerical Methods in Mining Engineering

Journal home page: http://anm.yazd.ac.ir/

Research article

The effect of two-dimensional and three-dimensional modeling on the seismic response of tunnels in the jointed rock mass by pseudo-static analysis

Mina Hashemi[1], Mohammad Hajiazizi[1*]

1- Dept. of Civil Engineering, Technical and Engineering Faculty, Razi University, Kermanshah, Iran

(Received: *June 2022* , Accepted: *February 2023*)

DOI: *10.22034/ANM.2023.18536.1557*

Keywords

Tunnel
Jointed Rock Mass
2D analysis
3D analysis
Seismic analysis

English Extended Abstract

Summary

Note that the relative stability of these structures against seismic loads is not a reason for this insignificance. Today, most seismic analyses are performed with the help of two-dimensional numerical methods due to their convenience. However, in some projects, three-dimensional tunnel analysis, especially in jointed rocks, to select a more accurate support system can be a crucial step in successfully and optimally implementing tunneling projects and rock mass stabilization around the tunnel. Of course, in some other cases, the two-dimensional analysis is sufficient. Therefore, in this study, two-dimensional and three-dimensional analyses of tunnels in the seismic state have been compared. First, the jointless rock mass is modeled in static and seismic states. Then, step by step, the displacement around the tunnel in two-dimensional and three-dimensional states is weakened by weakening the rock mass. The results show that in strong and joint-less rock masses, there is no significant difference in the results of two-dimensional and three-dimensional analysis, which is the case for both static and seismic analysis, and most of the results of two-dimensional modeling. More than. However, as the rock mass becomes weaker, the difference in displacements in two-dimensional and three-dimensional states becomes noticeable, especially in seismic analysis.

Introduction

So far, many numerical studies have been performed by various researchers in tunnel stability analysis in seamless and jointed rock masses, which are generally accorded to the facilities and skills of the researcher or with the help of two-dimensional software. It is done in three dimensions. Nevertheless, this study studies the effect of two-dimensional and three-dimensional modeling in static and seismic analysis in strong and jointed rock masses. We find that performing stability analysis with the help of two-dimensional software in any environment is not responsive. Choosing a maintenance system based on this type of analysis can sometimes be very conservative and cost the project dearly. In all rock masses, three-dimensional modeling is unnecessary due to its complexity and time-consuming, and two-dimensional modeling is sufficient. This study uses FLAC, finite difference software, in two-dimensional and three-dimensional mode, the stability analysis in static mode for hard rock mass and then creating a single joint to weaken the rock mass, step by step. The effect of discontinuities in two-dimensional and three-dimensional states is investigated. In the next section, seismic analysis is repeated for the mentioned conditions. Each analysis compares the displacement around the tunnel in two-dimensional and three-dimensional states. The final section presents a case study

*Corresponding author: E-mail: *mhazizi@razi.ac.ir*

Vol. 13, No. 36, Fall 2023, Pages 61-78

Journal of Analytical and Numerical Methods in Mining Engineering

Journal home page: http://anm.yazd.ac.ir/

to confirm the results.

Methodology and Approaches

This research uses FLAC 2D finite difference software for two-dimensional modeling and FLAC 3D for three-dimensional analysis.

Figure 1 shows both software's boundary conditions, calculation ranges, and tunnel cross-sections. To ensure that the boundaries do not affect the behavior of rock mass drilling, the dimensions of the created model should be slightly larger than the dimensions proposed by Rodriguez (15). The model height is assumed to be (H + 4D), the model length (H + 3D), and the model width (half of the model) is 3H, where H is the depth of the center of the tunnel and D is the diameter of the tunnel.

Therefore, in the three-dimensional model, the constructed model's width, length, and height equal to 80, 50, and 80 meters, respectively. In contrast, in the two-dimensional model, the strain model is flat. It should be noted that the load on the built model is calculated manually and applied to the upper boundaries of the model by applying a wide surface load. Also, the model's floor is fixed in the vertical direction, and the lateral borders are in the direction perpendicular to the surface. The horseshoe tunnel's geometry in the model's center is 9 meters high and 14 meters wide.

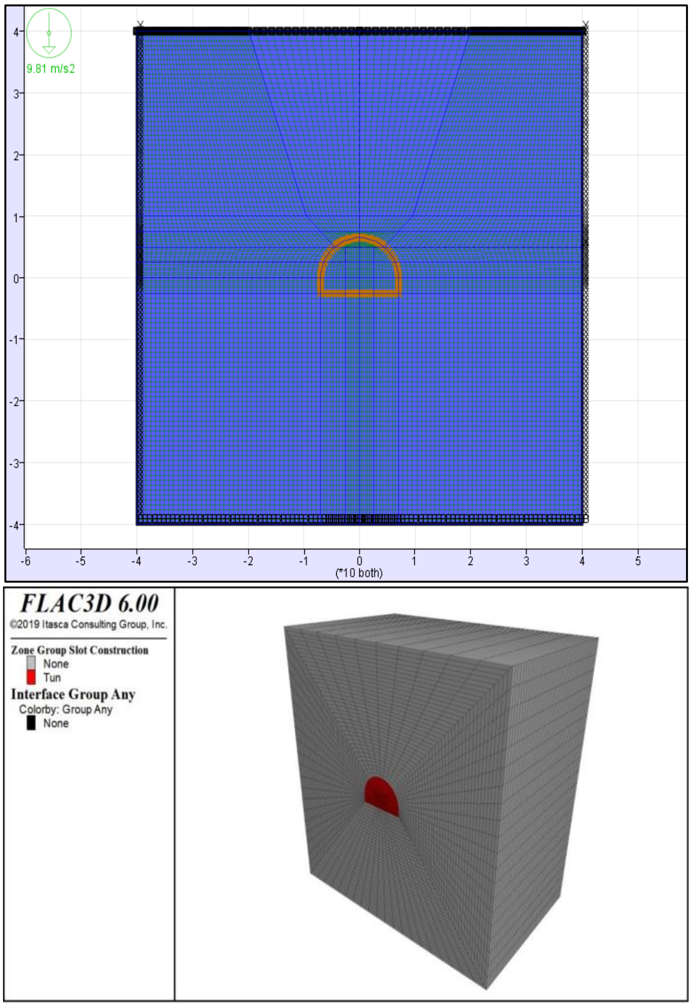

Fig. 1. Computational model: a) Two-dimensional model b) Three-dimensional model.

Vol. 13, No. 36, Fall 2023, Pages 61-78

Journal of Analytical and Numerical Methods in Mining Engineering

Journal home page: http://anm.yazd.ac.ir/

First, we model the tunnel in two and three dimensions when the rock mass is intact. In the subsequent modeling, to weaken the rock mass, the tunnel with a single joint is considered. To investigate the effect of joints in 2D and 3D modeling, the number of joints is increased, and the trend of displacement changes around the tunnel is investigated. Therefore, modeling is performed when the rock mass has two horizontal joints, three horizontal joints, and six horizontal joints, and the results are presented in two-dimensional and three-dimensional modes. The same analysis was performed for the seismic state.

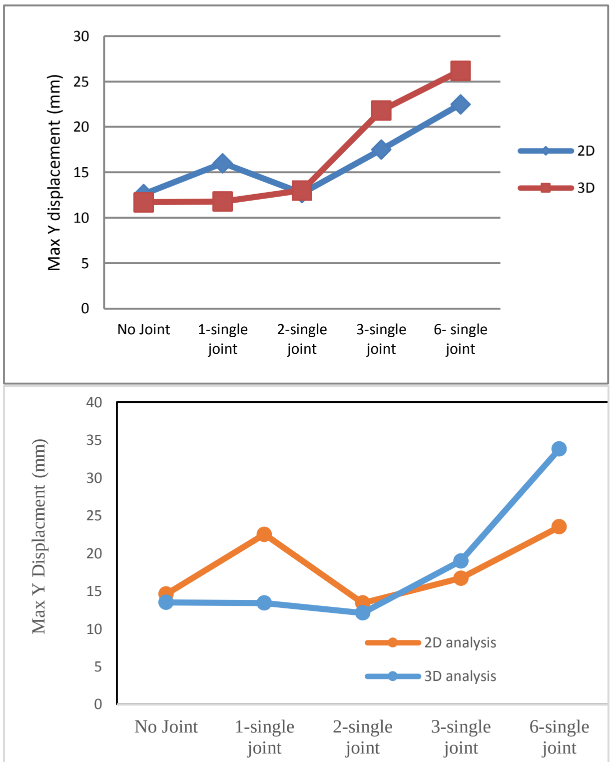

Fig. 2. Maximum normal displacement of the tunnel roof in the state of static analysis (Top) and seismic analysis (Down).

Results and Conclusions

A summary of the results is given below on a case-by-case basis:

1- As long as there is no joint in the rock mass or it is so-called seamless, or with one joint, the displacement in the two-dimensional state is more than three-dimensional because the tunnel front in the three-dimensional state, which has high resistance, prevents change. The place becomes more of a rock mass that does not exist in the two-dimensional state of this front .
2- As the number of single joints (three joints and above) increases in the rock mass (so-called weakening of the rock mass), the displacement around the tunnel increases, which is more intense for the three-dimensional state than for the two-dimensional state.
3- In this study, it was observed that the direction of the joint in the model does not significantly affect different loading cases in stiff and weak rock masses .
4- In seismic analysis, the difference in displacement around the tunnel in two-dimensional and three-dimensional states is more significant than in static analysis .
5- Applying seismic load does not significantly affect the displacement values in good rock masses .
6- In strong and non-jointed or low-jointed rock masses in seismic analysis, the results of the two-dimensional analysis are more conservative .

*Corresponding author: E-mail: mhazizi@razi.ac.ir

Journal of Analytical and Numerical Methods in Mining Engineering

Journal home page: http://anm.yazd.ac.ir/

7- Due to the three-dimensional nature of the joints, three-dimensional analysis is more accurate in weak and jointed rock masses .
8- In weak rock masses in seismic analysis, three-dimensional modeling is suggested due to the three-dimensional nature of the seismic load.

References

[1] Dowding, C. H., & Rozen, A. (1978). ''Damage to rock tunnels from earthquake shaking''. Journal Geotech Engineering Division, ASCE,GT2, 175–191.

[2] Adyan, O¨ ., Ohata, Y., Genis, M., Tokashiki, N., & Ohkubo, K. (2010). ''Response and stability of underground structures in rock mass during earthquakes''.Rock Mechanics Rock Engineering, 43, 857–875.

[3] Liu,J., Song,Y.,.Zhao, Y,.(2021) ''Numerical Modeling on Dynamic Characteristics of Jointed Rock Masses Subjected to Repetitive Impact Loading'', Shock and Vibration, Article ID 5274602, 13 pages.

[4] N Nikadat , Alireza Yarahmadi Bafgh, Estimating Joint Normal and Shear Stiffness Coefficient Using Statistical Methods, Journal of Analytical and Numerical Methods in Mining Engineering (ANM), Volume 3, Issue 6 - Serial Number 6 December 2013, Pages 93-103.

[5] Yu, H., Chen,G., (2021), " Pseudo-static simplified analytical solution for seismic response of deep tunnels with arbitrary cross-section shapes", Computers and Geotechnics 137-104306.

[6] Duan. Y, Zhao. M, Huang. J, Li.H & Du. X, (2021), " Analytical Solution for Circular Tunnel under Obliquely Incident P Waves considering Different Contact Conditions", Shock and Vibration ,Article ID 1946184,23 pages.

[7] Cui. Z, Sheng.Q, Zhang.G.m, Liu.H, (2021), "A modified rock mass classification considering seismic effects in the basic quality (BQ) system", Bulletin of Engineering Geology and the Environment 80:2249–2260.

[8] Jia,P & Tang C.A. (2008). "Numerical study on failure mechanism of tunnel in jointed rock mass", Tunnelling and Underground Space Technology,23, 500–507.

[9] Ahola, M. P., Hsuing, S. M., & Kana, D. D. (1996). ''Experimental study on dynamic behavior of rock joints. Coupled 4hermos-hydro-mechanical process of fractured media'', Developments in Geotechnical Engineering, 79, 467–506.

[10] Hajiazizi, Mohammad, Khatami, Razie Sadat, (2013), "Seismic analysis of the rock mass classification in the Q-system", International Journal of Rock Mechanics and Mining Sciences. Pages 123-130.

[11] Malavika Varma, V.B. Maji, A. Boominathan, (2019)," Numerical modeling of a tunnel in jointed rocks subjected to seismic loading", Underground Space 4 , 133–146.

[12] Hajiazizi, M., & Hashemi, M. (2017). "Predicting three-dimensional displacement around the tunnel and its impact on the value of Q-system". International Journal of Mining and Geo-Engineering ,51(2), 133-138.