Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 55(1) (2023) 39-42
DOI: 10.22060/ceej.2022.21540.7757

Evaluation of Effective Factors on Tunnel Instability Through Statistical Approach

M. Javadi*, F. Mohammadi, R. Rafiee

Faculty of Mining Engineering, Petroleum and Geophysics, Shahrood University of Technology, Shahrood, Iran.

ABSTRACT: In this paper, the role of effective factors on the instability of tunnels and underground excavations was explored through statistical analysis. To reach this goal, the effective factors (including 25 different factors) on the tunnel instability were recognized based on the deep literature survey and expert judgment. Then, a database of previous tunnel instabilities was established based on the type of tunnels and the main factor of instabilities. The effective factors were classified into six main groups and utilized for statistical analysis based on the relative frequency of tunnel instability. The results of this paper show that the geomechanical factors, design-investigation issues, and geological-geographic conditions of the site are the main three reasons for tunnel instability, where these main factors control more than 70% of civil-utility tunnels through all case studies. In addition, the design-investigation issues and geological-geographic conditions show the lowest and highest dependency on the tunnel utility, respectively. The "weak zones", "inadequate redesign during construction", and "the groundwater level and conditions" are the main three effective factors in tunnel instability, where the relative frequency of instability due to these factors reaches up to 40% for most of the case studies. Based on the main effective factors of instability, the freeway and highway tunnels show the highest consistency with all other utilities for tunnels in the statistical population. Therefore, freeway and highway tunnels can be considered as the most representative of overall utilities. The outcome of this paper can be applied to risk assessment of tunnel instabilities and technical management.

Review History:

Received: Jun, 30, 2022
Revised: Sep, 13, 2022
Accepted: Nov, 13, 2022
Available Online: Dec, 10, 2022

Keywords:

Tunnel Instability
Tunnel Utility Type
Instability Factor
Statistical Analysis.

1- Introduction

The statistical analysis of the instability of tunnels and underground spaces has been mainly focused on the special kind of problems or databases such as consequences on operation efficiency of under-pressure hydropower tunnels [1], collapse frequencies along time [2], risk management of tunnel collapse [3], and collapse risk assessing of mountain [4] and deep-buried tunnels of china [5]. In these studies, the reasons or effective factors for tunnel instability have not been considered in the analysis. On the other hand, the statistical role of instability effective factors has been indirectly applied in some previous studies [6, 7] without systematic classification. Although these studies reflect the state and necessity of statistical analysis of tunnel instability, few systematic analysis has been performed on the effective factors of instability by the establishment of a comprehensive database. In addition, a few statistical analysis of instability has been reported on the type of tunnel utilization. These issues contribute to the main goal of the present study.

In this paper, the statistical analysis of tunnel instability was performed by focusing on the establishment of a comprehensive database, effective factors of instability, and type of tunnel utilization. After the establishment of the database, different statistical analyses were performed mainly on the relative frequency of instability for different individual effective factors, main categories, and tunnel utilization types.

2- Data Collection for Statistical Analysis

This paper studies the statistical analysis of instabilities that occurred during tunnel construction by focusing on the main reason or main causes of instability. The tunnel instability effective factors were classified into six main categories including special conditions, geological and geographical conditions of the site, ground control and support system, investigation and design, geomechanical factors, and construction generic factors. Totally, 25 different factors were recognized as effective factors that were classified into the mentioned categories. After the reconnaissance and classification of effective factors on tunnel instability, data collection was performed to develop the database. The database contains 200 case studies from different countries around the world. For each case study, the main reason for instability, type of tunnel, and host country were recorded in the database under the supervision of tunneling experts.

*Corresponding author's email: mortezjavadi@gmail.com

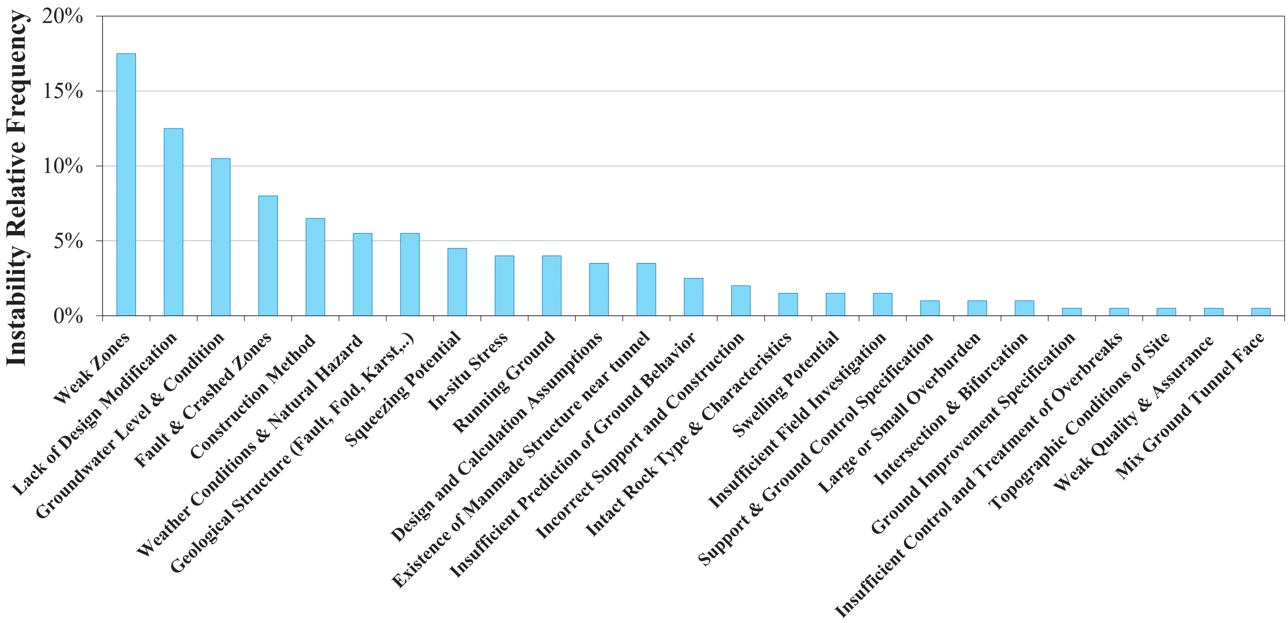

Fig. 1. The sorted distribution of relative frequency of instability for all individual factors.

3- Results

The relative frequency of main instability reasons was calculated for different utility types of tunnel. The results of this calculation show that the “geomechanical factors”, “investigation & design”, and “geological & geographical conditions” show the highest relative frequency of instability. These factors include about 73% of instabilities recorded for civil tunnels in the database. The analysis of results shows that the minimum and maximum standard deviation of the relative frequency of main instability reasons occurs for “investigation & design” and “geological & geographical conditions”, respectively. This means that the factor of “investigation & design” shows less dependency of instability to tunnel utility type and an average of about 23% of instabilities take place due to this reason. On the other hand, the “geological & geographical conditions” of the tunnel site show maximum instability dependency on the tunnel utility.

Each of the main instability groups is composed of several individual factors. The relative frequency of instability of these individual factors is calculated for all the case studies in the database and plotted in Figure 1, sorted according to the relative frequency. Figure 1 shows that the weak zones are the most popular reason for instability with a relative frequency of about 17.5%. The eight most popular reasons for tunnel instability are weak zones, lack of design modification during construction, groundwater level & condition, fault & crashed zones, construction method, weather conditions & natural hazard, geological structure (fault, fold, karst,..), and squeezing potential, respectively. These eight reasons (about 32% of all individual reasons) include about 70 to 80% of all instability cases. In other words, about 70% of instabilities occur due to only 30% of the factors, where this argument is equivalent to Pareto principle. Therefore, the reasonable safety improvement of tunnel stability is anticipated by the management of these most important factors.

4- Conclusion

The main goal of this paper is to investigate the effective factors of tunnel instability during construction based on the statistical analysis of case instabilities. First, about 25 instability-effective factors (or reasons) were identified and then classified into six main categories. These effective factors and classifications were used for the establishment of an instability database in addition to the type of tunnel utility types. After the establishment of the database, the effective factors on tunnel instability were statistically analyzed for different tunnel utility types and factor classification. In the data analysis, the relative frequency of instability was separately investigated for different tunnel utility types, the main group of reasons, and individual instability effective factors. Based on the statistical analysis performed in this study, the following conclusions were obtained:

The maximum average relative frequency of instability is observed for the main category of “geomechanical factors” in the statistical analysis of civil-utility tunnels. Moreover, the individual effective factor of “weak zones” shows the maximum relative frequency of instability.

The “geomechanical factors”, “investigation & design”, and “geological & geographical conditions” show the highest relative frequency of instability. These main factors include about 73% of instabilities recorded for civil tunnels in the database. Moreover, these main factors show the minimum and maximum standard deviation of the relative frequency of instability.

The “weak zones”, “inadequate redesign during construction”, and “the groundwater level and conditions” are the main three effective individual factors on tunnel instability, where the relative frequency of instability due to these factors reaches up to 40% for most of the case studies.

The statistical analysis of individual factors shows a fair corresponding between the results and Pareto principle, where eight individual factors (about 32% of all) include about 70 to 80% of all instability cases.

Based on the main effective factors of instability, the freeway and highway tunnels show the highest consistency with all other utilities for tunnels in the statistical population. Therefore, freeway and highway tunnels can be considered as the most representative of overall utilities.

References

[1] L.N. Lamas, Contributions to understanding the hydromechanical behaviour of pressure tunnels, PhD Thesis, Imperial College, London, (1993) 419.

[2] P. Spyridis, D. Proske, Revised comparison of tunnel collapse frequencies and tunnel failure probabilities, ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, 7(2) (2021) 04021004.

[3] Q. Qian, P. Lin, Safety risk management of underground engineering in China: Progress, challenges and strategies, Journal of Rock Mechanics and Geotechnical Engineering, 8(4) (2016) 423-442.

[4] G.-H. Zhang, Y.-Y. Jiao, L.-B. Chen, H. Wang, S.-C. Li, Analytical model for assessing collapse risk during mountain tunnel construction, Canadian Geotechnical Journal, 53(2) (2015) 326-342.

[5] G.-Z. Ou, Y.-Y. Jiao, G.-H. Zhang, J.-P. Zou, F. Tan, W.-S. Zhang, Collapse risk assessment of deep-buried tunnel during construction and its application, Tunnelling and Underground Space Technology, 115 (2021) 104019.

[6] R.L. Sousa, H.H. Einstein, Lessons from accidents during tunnel construction, Tunnelling and Underground Space Technology, 113 (2021) 103916.

[7] T. Seidenfuss, Collapses in tunnelling, Master Degree Foundation Engineering and Tunnelling. Stuttgart, Germani, 194 (2006).

HOW TO CITE THIS ARTICLE

M. Javadi, F. Mohammadi, R. Rafiee , Evaluation of Effective Factors on Tunnel Instability Through Statistical Approach, Amirkabir J. Civil Eng., 55(1) (2023) 39-42.

DOI: 10.22060/ceej.2022.21540.7757

This page intentionally left blank