University of Tabriz

*Journal of Civil and Environmental Engineering*
Volume 51 (2021), Issue 1 (Spring), 59-71

**EXTENDED ABSTRACT**

# Seismic Evaluation of Railroad Tunnels with Stone Masonry Lining Based on Pseudo-Static Method: The case study of 68 tunnel

Mohammad Reza Zareifard [a,*], Masoud Ranjbarnia [b]

[a] *Faculty of Civil Engineering, Higher Education Center, Estahban 7153234501, Iran*
[b] *Faculty of Civil Engineering, University of Tabriz, Tabriz 5166616471, Iran*

**Received:** 15 April 2018; **Accepted:** 15 July 2019

**Keywords:**
Tunnel, Stone masonry lining, Tubular KT-joint, Seismic evaluation, Pseudo-static method.

## 1. Introduction

Iran is one of the most seismically active areas in the world. Railway tunnels are an integral part of the infrastructure of modern society. Railway tunnels built in areas subject to earthquake activity must withstand both seismic and static loading. In this manner, some railroad tunnels need retrofitting. They have been designed without considering the seismic loading and can damage in future earthquakes. Thus, these tunnels should be evaluated, seismically. This paper, presents a summary seismic analysis and evaluation of railroad tunnels with stone masonry lining. 68 railroad tunnel is investigated, in this manner, as a case study.

## 2. Methodology

### *2.1. Ground motion parameters and design*

Firstly, the development of appropriate ground motion parameters, including peak accelerations and velocities, target response spectra, and ground motion time histories, and geomechanical parameters is briefly presented. The ground motion parameters are typically established at the ground surface. Tunnels, however, are generally constructed at some depth below the ground surface. For seismic evaluation of the tunnel structure, the ground motion parameters should be derived at the elevation of the tunnel. Because ground motions generally decrease with depth below the ground surface, these parameters generally have lower values than estimated for ground surface motions (e.g., Chang et al. 1986).

### *2.2. FE modeling*

For the considering tunnel, a numerical analysis was performed with a two-dimensional plane-strain finite element program, Phase2. Due to a blasting impact, a cylindrical blast-induced damaged zone has developed around the tunnel with different behavior parameters. In this study, both the damaged and undamaged rock masses are assumed to follow a Hoek-Brown brittle failure law with a non-associated flow rule, where the material's strength drops from peak to residual immediately after the yield condition is first reached. Using two-dimensional analysis, the tunnel is evaluated under static and seismic conditions.

### *2.3. Static loading*

It consists of three stages: a. initial elastic condition b. initial tunnel convergence c. installing the masonry lining and final convergence.

* Corresponding Author
*E-mail addresses:* zareefard@aut.ac.ir (Mohammad Reza Zareifard), m.ranjbarnia@tabrizu.ac.ir (Masoud Ranjbarnia).

### *2.4. Seismic loading*

Underground tunnel structures undergo three primary modes of deformation during seismic shaking: racking, axial and curvature deformations. The racking deformations, which are the main mode of deformations, are caused primarily by seismic waves propagating perpendicular to the tunnel longitudinal axis, causing deformations in the plane of the tunnel cross-section (Wang, 1993). Thus, the shear distortion of the ground is the most critical and predominant mode of seismic motions. It causes a tunnel to a rack (sideways motion). Analytical procedures by numerical methods are often required to arrive at a reasonable estimate of the free-field shear strain $\gamma_{free-field}$.EERA computer code is used to calculate $\gamma_{free-field}$ for one-dimensional ground for a system of infinite horizontal homogeneous layers which are subject to viscoelastic shear waves traveling vertically.

Here, the pseudo-static seismic deformation method is used for analysis of the tunnel under seismic loading, which consists of two theories: 1. Free-field racking deformation method and 2. Tunnel-ground interaction method. It has been proposed in the past that a tunnel structure be designed by assuming that the amount of racking imposed on the structure is equal to the free-field shear distortions of the surrounding medium. The racking stiffness of the structure is ignored with this assumption. The free-field deformation method serves as a simple and effective design tool when the seismically induced ground distortion is small, for example when the shaking intensity is low or the ground is very stiff. To more accurately quantify the racking response of tunnel structures a rational procedure accounting for the tunnel-ground interaction effect is considered in this paper. In pseudo-static seismic coefficient deformation method, the ground deformations are generated (induced) by seismic coefficients and distributed in the finite element domain that is being analyzed. The seismic coefficients were derived from a one-dimensional, free-field site response analysis.

## 3. Results

The tunnel is analyzed under static and seismic loadings. The results show; clearly that, the tunnel safely suffers the static loading; while it cannot suffer the seismic loading, as shown in Fig. 1.

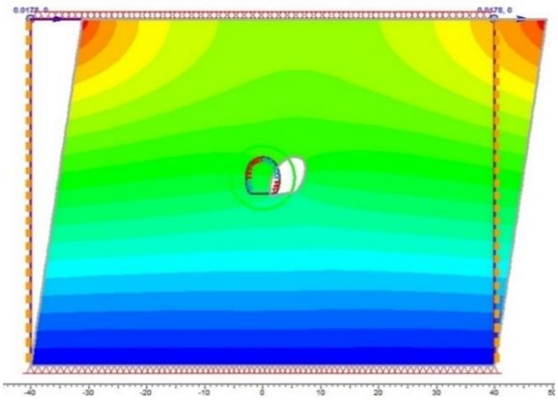

**Fig. 1.** Distribution of rock mass displacements and yielded lining elements

## 4. Conclusions

In this paper, a simplified procedure developed incorporating rock-structure interaction for evaluating masonry-lined tunnels is presented. Two-dimensional finite element models are used to analyze the cross-section of a tunnel under static and seismic loadings. The results show that, the structure may fail seismically and, if so, whether a seismic retrofit should be considered.

## 5. References

Chang CY, Power MS, Idriss IM, Somerville PG, Silva W, Chen PC, “Engineering characterization of ground motion task II: observational data on spatial variations of earthquake ground motion”, Report no. NUREGCR-3805, US Nuclear Regulatory Commission, 1986, 3.

Road, Housing and Urban Development Research center (BHRC), “Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard 2800)”, 2014, 4th Edition, PN S-253 (In Persian).

Wang JN, “Seismic Design of Tunnels: A State-of-the-Art Approach, Monograph”, Monograph 7. Parsons, Brinckerhoff, Quade and Douglas, Inc., New York, 1993.