Study on the behavior of Wise tunnel under static and seismic loading

Ali sanaeirad, Reza ebrazi

Abstract— Wise highway network is one of the most important routes along the east-west highway in Tehran considered the westernmost point of the easternmost point of access enables regional and local. This highway in the eastern part of Tehran highway in the western part of the mission and the highway is wise. Wise in the tunnel area along Highway 22 between Highway Tehran Iran war to the intersection of automobiles, part of the highway from Forest Park Cheetgar passes, tunnel consists of two round trip with three lines on each side of the crossing. Given the importance of this tunnel aware of the function of these structures is important in times of crisis. From the dangers that threaten these structures earthquake-up can be named. Earthquake near the tunnel may cause a lot of damage. In recent years, the development and frequency of seismic damage underground structures, seismic analysis and design of underground structures has been more and more attention. Especially in large-Osaka Kobe earthquake in 1995, some subway stations and tunnels were severe injury, the first about the damage caused by the earthquake is the modern amenities underground. After this, the scientists examined the underground seismic and thereby causes damage theory based analysis and design methods to be carried out. Extraordinary efforts to advance the underground seismic studies, the important instructions provided in the field of earthquake engineering. So study the effect of an earthquake on the tunnels is required. In this study, using the software PLAXIS the effect of an earthquake on a specific section of the tunnel has been wise. This means that performance wise tunnel earthquake was examined.

Index Terms—tunnel, underground structures, earthquake, highway

1 Introduction

In studying the effects of earthquakes on underground structures, several studies have been done that then referred to some of them. ASCE damage caused by the earthquake in the Los Angeles area in 1971 describes Sanfrnandv. JSCE the performance of several structures, including underground tunnels during vibration in Japan describes the dip tube. Duke and Leeds, Stevens, Dowding and Rozen, Owen and Scholl, Sharma and Judd, Power and others, Kaneshiro and others, all brief Historical cases of damage to underground utilities have to offer. Owen and Scholl Dowding and Rozen's efforts to date to have 127. Sharma and Judd a large database of seismic damage to underground structures using 192 historic spread. Power and others with about 217 historical, further revision carried out.

The following general observations can be made about the seismic performance of underground structures:

1. underground structures towards structures that are built on the surface, the earthquake losses are less.

2. The depth of the tunnel is, the failure rate compared with the shallow tunnels, no less. This naturally can be improved material properties by increasing the burden of overhead and disappears with de-linked seismic waves with depth.

3. underground structures built of soil in the underground structures of resistant rocks, failure will increase.

4. tunnels and tunnels in which a coating is injected relative to the overall stabilization of the tunnels without cover in the rock around the tunnel Aymntrnd.bh and improve contacts with media coverage by injection is effective in reducing losses.

5. tunnels under symmetric load which improves the interaction between the coating and the surrounding environment becomes more stable against earthquake. Thick coating may lead to a surge caused by the earthquake coverage.

6. Damage caused during an earthquake can be based on parameters such as maximum acceleration and speed the epicenter of the earthquake magnitude and distance are linked. Crashes occur mainly to higher magnitude 7 occurred.

7. The duration of strong ground motion during earthquakes is of considerable importance. Because it may cause the failure of large displacement.

8. The high-frequency movements may cause the falling rocks and concrete blocks on the page will be weakened. This type of frequencies that are to be removed rapidly, usually at a little distance from the earthquake source are created.

9. Depending on the angle of approach to the tunnel seismic waves, these waves can be strengthened. Of course, if the wavelength is between one and four times the diameter of the tunnel.

10. If an earthquake caused rock slopes or soil instability, the devastation caused by the tunnel entrance that could be significant.

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2 Seismic Studies of the Underground

The following is a summary of several historical underground seismic performance is provided.

2.1 Bay Area Transit System (Bart) San Francisco

BART system one of the first underground facility was designed with seismic load considerations [Kuesel; 1969]. Lumapryta during the earthquake of 1989, the facility was not damaged BART system. In fact, after the earthquake in operation is that this is primarily because the system is under stringent seismic design considerations was designed.

2.2 Hungarian Alameda, Oakland

Alameda channels of immersed tube tunnels that connect the island of Alameda to Oakland in the San Francisco Bay Area is the first tunnel of its kind in 1927 and 1963 were built without seismic design considerations.
During the earthquake Lvmapryta, ventilation buildings experienced several structural cracks. As well as water seeps into the tunnels was found to be limited. As the loose sediments of the tunnel at the entrance to the tunnel Alameda liquefaction occurred, the maximum horizontal acceleration was measured in the area between 0.1g and 0.25g limited [EERI; 1990]. Also due to the liquefaction potential of dams, tunnels, prone float [Schmidt and Hashash; 1998].

2.3 Metro Los Angeles

Los Angeles subway was built in several phases. During part of the Northridge earthquake (1994) was used. After the earthquake of concrete cover tunnels remained intact and damage. While the pipelines, bridges and buildings were damaged, the earthquake did not damage any subway system. The maximum horizontal acceleration of 0.1g and 0.25g measured in the area between the vertical ground acceleration were typically limited to two-thirds [EERI; 1995].

3 Introducing the Tunnel Wise and Specification Requirements

Wise highway network is one of the most important routes along the east-west highway in Tehran is westernmost elderly from urban areas to regional and local mills easternmost them access makes possible. Wise Wise tunnel on Highway 22 in the area of Tehran between Iran Azadegan Highway to the intersection of the vehicle, that part of it stems from Forest Park Cheetgar pass. Figure (1) and (3) respectively status indicator and an important loss plan Wise tunnel. The highway tunnel traffic wise sage of Forest Park area Cheetgar to reduce environmental effects is the plan. The tunnel has a length of 890 meters and the northern route is the southern route with a length of 960 m. North and South is the tunnel has the following technical specifications.
Number of lines three lines and three lines go Back
During the ramp North 470 South and 500 m
Design speed of 80 km per hour
Longitudinal gradient: 3.0 to 5.1 percent
The final section of the tunnel and cover it in the form (4-5) is shown.

Figure 1- Location tunnel Wise

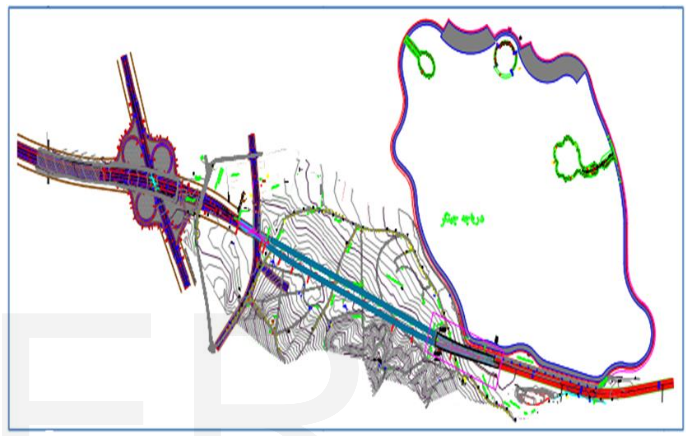


Figure 2- sage tunnel plan

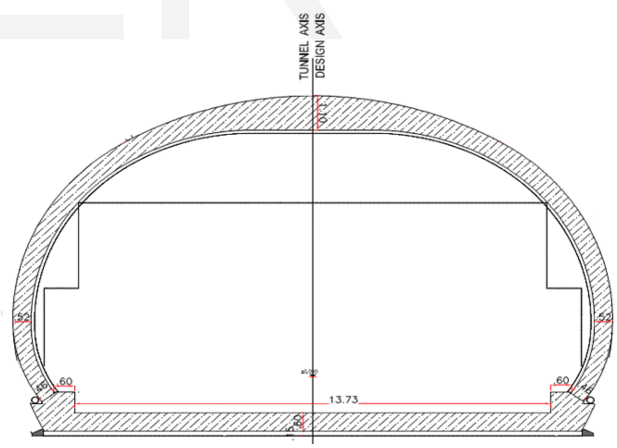


Figure 3- channel geometry and final cover tunnel Wise

4 Geotechnical Properties

Tunnel crossing point of two different levels is the ground. Formation type C, which has overhead one 5.4 m (entrances range) and their type A, which has a 13 m is the overhead. Structure interaction analysis with a height of 4.5 meters (input range) and C are parameters for the model with a height of 13 meters of overburden their parameters A in the calculations is considered. Given the diversity of overburden from 4.5 to 13.5 m, a maximum of 13.5 meters of overburden have been considered in the design.

5 Parameters permanent cover tunnel

Cover tunnel has a concrete point is that the details in the table (1) is given. Also, due to the effect of cracking in the concrete sections, the coefficient of 0.5 in the formula of the modulus of elasticity of concrete is considered.

$$E_C = 15100 \times \sqrt{f'_c} = 15100 \times \sqrt{350} = 282495.13\ kg/cm^2 \quad (1)$$

$$EI=E((bh^3)/12)\times 0.5 \quad (2)$$

$$EA=Ebh \quad (3)$$

Table 1- details the structural concrete slab

Concrete class	*Density (T/m³)*	*Elast. Modulus (kg/cm²)*	*Strength (kg/cm2)*
C35	2.5	280000	350

5.1 Geometry Model

15 node triangular elements for modeling land cover and soil behavior modeling is based on hardening. The linear elastic-plastic model complete with the following parameters:

γ: unit weight
E: modulus of deformation
υ: Poisson's ratio unloading
φ: angle of internal friction of soil
c: adhesion
$E_{re / un}$: module unloading / reloading
n: the impact of stress on the difficulty level

Soil-structure interaction analysis due to drilling problems and the implementation of the initial and final tunnel structure, combined with modeling of soil mass and initial and final retaining structures using finite element software PLAXIS numerical methods and modeling of excavation done by multi-stage is. Restrict horizontal model and the lower horizontal border, horizontal and vertical shift is considered closed. Finite element node network with 15 nodes and triangular elements are made automatically. The placement of elements smaller tunnels closer to model the nonlinear behavior of soil mass and stress concentrations in the range is used. Initial and final cover tunnel using elements beam linear elastic behavior using the interface elements are connected to soil mass, is modeled. Figure (4) and network computer model used to perform finite element analysis is displayed.

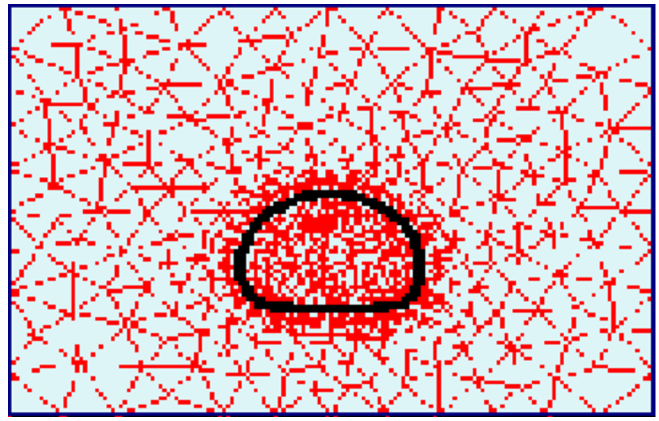


Figure 4- finite element computer model of the tunnel and network use

6 Loading

6.1 Static loading

Figures (5) and (6) soil-structure interaction models in the software PLAXIS show.

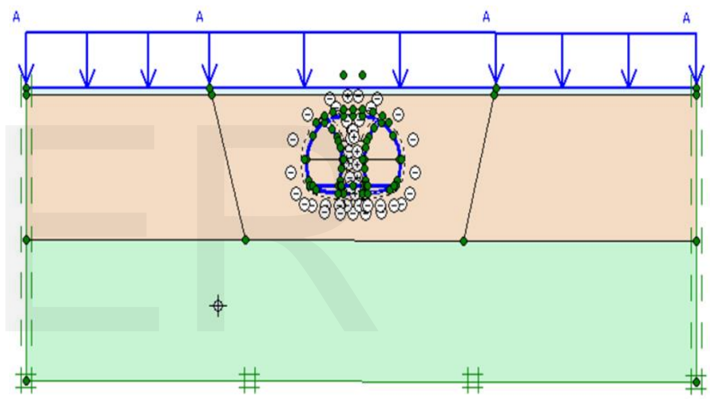


Figure 5- overhead geometry of the model with 4.5 m

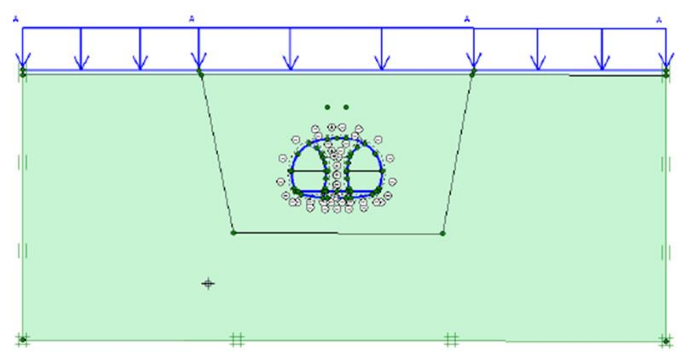


Figure 6- overhead model geometry with 13.5 m

6.2 Seismic loading

Quasi-static analysis is used to calculate the seismic forces. The parameters used were chosen based on the project specific risk analysis report. the level of risk in the form of (7) and (8) are listed for the project site response spectra.

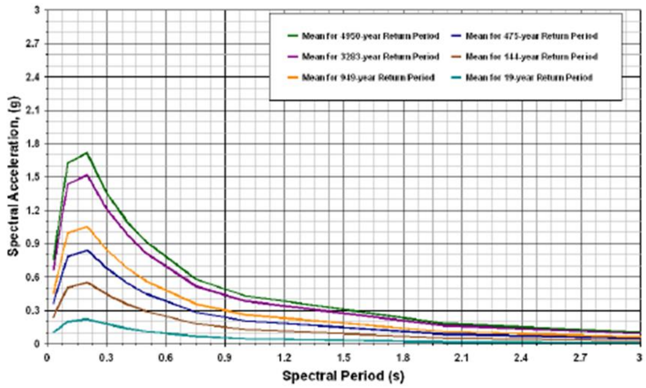


Figure 7- for horizontal acceleration whole site

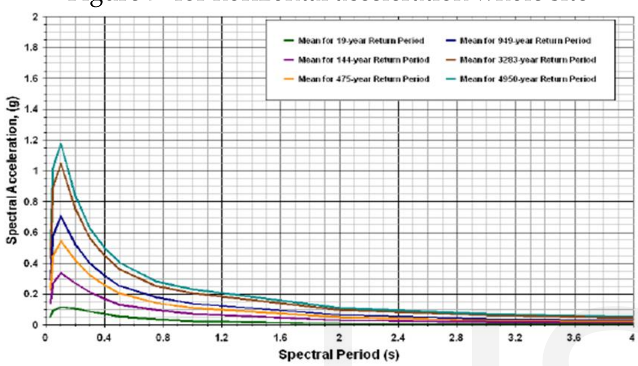


Figure 8- for vertical acceleration whole site

Quasi-static analysis is performed based on Hashash. The method used is the maximum ground speed. The maximum speed of the site is estimated based on the response spectra that are listed below.

$$S_V = S_a/\omega \quad (4)$$

$$S_V = 0.8\ m/\sec \quad MDE$$
$$S_V = 0.27\ m/\sec \quad ODE$$

Free shear strain field is estimated using the relationship Hashash. However, the levels of shear strain rate must be corrected during an earthquake. After calculating shear strain, the shear stress is calculated and the model is released. The computational process is modified as follows:

1-Calculated assuming maximum shear strain shear wave velocity (Hashash 2001)

$$\gamma_{ff} = \frac{V_s}{C_s} = \frac{0.8}{450} = 1.77 \times 10^{-3} \quad MDE \quad (5)$$

$$\gamma_{ff} = \frac{V_S}{C_S} = \frac{0.27}{450} = 0.6 \times 10^{-3} \quad ODE \quad (6)$$

2-Modified shear modulus and shear wave velocity based on strain rate

$$G_m = \rho C_S^2 \quad (7)$$

$$\rho = \frac{\gamma_{soil}}{g} = \frac{20}{9.81} = 2.04 \quad (8)$$

$$G_m = 2.04 \times 450^2 = 4.13 \times 10^5\ kN/m^2 \quad (9)$$

$$G_0 = 0.21 G_m = 0.21 \times 4.13 \times 10^5 = 8.67 \times 10^4 \frac{kN}{m^2} \quad MDE \quad (10)$$

$$G_0 = 0.4 G_m = 0.21 \times 4.13 \times 10^5 = 1.65 \times 10^5 \frac{kN}{m^2} \quad ODE \quad (11)$$

$$C_S = \sqrt{0.21} \times 450 = 206 \quad MDE \quad (12)$$

$$C_S = \sqrt{0.4} \times 450 = 285 \quad ODE \quad (13)$$

3-Shear strain is calculated according to the new parameters

$$\gamma_{ff} = \frac{V_s}{C_s} = \frac{0.8}{206} = 3.88 \times 10^{-3} \quad MDE \quad (14)$$

$$\gamma_{ff} = \frac{V_s}{C_s} = \frac{0.8}{285} = 0.95 \times 10^{-3} \quad ODE \quad (15)$$

$$\tau = (3.88 \times 10^{-3}) \times (8.67 \times 10^4) = 336\ kN/m^2 \quad MDE \quad (16)$$

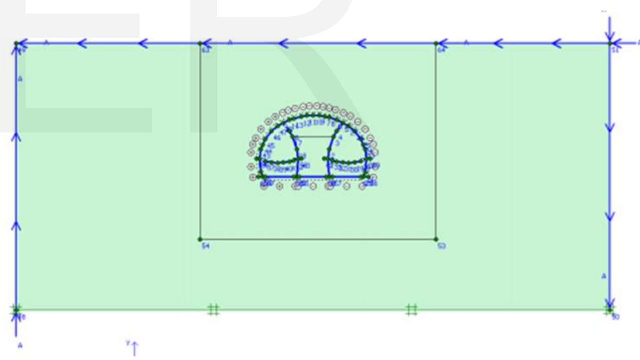
$$\tau = (0.95 \times 10^{-3}) \times (1.65 \times 10^5) = 157 \frac{kN}{m^2} \quad ODE \quad (17)$$

4-To analyze the behavior of elastic shear stress obtained on split coefficient.

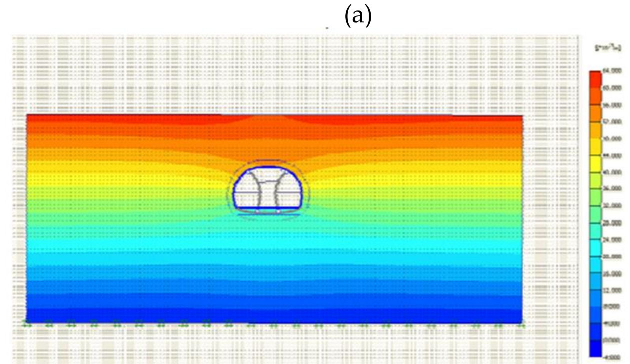
$$\tau = \frac{336}{3.5} = 96\ kN/m^2 \quad MDE \quad (18)$$

$$\tau = \frac{157}{1} = 157\ kN/m^2 \quad ODE \quad (19)$$

Figure (9) How to apply shear stress to soil-structure interaction model shows.



(a)



(b)

Figure 9- dynamic analysis model geometry and contour deformation Horizontal

interaction soil-structure model, tunnel structures multiplier shift to shift the open field close to the MDE 1.7 is obtained. This shows the stiffness ratio between the soil and soil-structure interaction model of the structure calculations (Fig. 9 (b)).

7 Conclusion

the results of the closed-form analytical solutions for the axial force and bending moment in the circular tunnel cover folding under excitation of seismic deformation due to slip under the terms of the interface, as well as comparing the distribution of axial force and moment the analytical solutions are given below:

1) The study covers Poisson coefficient, the maximum axial force created in the cover coating is not sensitive to Poisson's ratio Poisson's ratio also increases coverage bending moment generated in the coating increases.

2)Due to axial force can be justified by the behavior of the membrane lining the tunnel with increasing radius bending moment generated in reduced coverage. Due to the reduction of the maximum bending moment, bending rigidity lower coating that makes the cover of the membrane behavior. That is a significant moment in the coverage is not created.

3) review of parameters tunnel coating thickness, axial force by increasing the thickness of the coating in two ways Bobet Wang and slope slightly increased. However, in Penzien maximum axial force with steep increases. In all analyzes by increasing the coating thickness increases rapidly cover tunnel created in the bending moment. The maximum bending moment may be increased due to an increase in the flexural rigidity justifies covering the third power of thickness.

4) In the above analysis of the different parameters, the maximum axial force Penzien method compared to other methods reasonably be lower than the result. Wang also bending moment method than other methods result.

5) An analysis of the Wise tunnel was used for seismic analysis, the relationship between Wu & Penzien, respectively. As in Figure shown, the maximum values obtained from the analysis is very different relations, Wu & Penzien.

6) According to the model analysis can be concluded that the results of the seismic analysis of the results of this relationship MDE ratio under earthquake ODE, are more accurate.

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