University College of Takestan

Available online at **http://UCTjournals.com**

UCT Journal of Research in Science, Engineering and Technology

UCT. J. Resea. Scien. Engineer.Techno. (UJRSET)

Volume 6 ,Issue 4

01-05 (2018)

ISSN 2382-977X

Investigation the Interaction of Tunnel Structure and Soil In Encountering Earthquake

Mehran Biglari Esfahani1, Mehdi Zamani2* , Arash Mohammadi Farsani2

1. MSc, Department of civil engineering, Faculty of basic sciences, Shahrekord branch, Islamic azad university, Shahrekord, iran
2. Ph.d , Department of civil engineering, Faculty of basic sciences, Shahrekord branch, Islamic azad university, Shahrekord, iran

Original Article:
Received 10 Nov. 2018 Accepted 02 Dec 2018 Published 30 Dec. 2018

ABSTRACT

Importance of subterranean structures in no secret to anyone and tunnels are one of the important factors indicating development of countries which are employed for various applications including transportation, water and waste water conveyance and also as a reservoir of various materials, urban subways and …. Established for water providing with the central salt desert, Golah water conveyance tunnel in the length of 10km has been bored employing the full section boring device and it cover is segmental.

Tunnel performance will continue perfectly provided that its coating segment can show strength and stability all during their life span and remain in the allowable modifications.

Tunnel structure is influenced by the forces resulting from creep and there is a crushed zone between the stony and coating regions. This model has been studied for the MDL and MCL danger levels and a time history analysis has been done to study the tunnel behavior.

Intended responses include maximum tunnel diameter in each zone and plastic strain of the concrete as well as damage parameter proportional to the plastic strain. Obtained results revealed that in the second and third zones structure segments with a thickness of 25cm have been modified beyond the maximum limit and fail and that this structure has suffered unrepeatable damage at the MDL danger level and that the highest damages were relevant to the third zone.

Keyword:
Golab Tunnel; Soil and tunnel interaction; Earthquake; Strain.

*** Corresponding author:** ***Mehdi Zamani***

Peer review under responsibility of **UCT Journal of Research in Science, Engineering and Technology**

1. Introduction

Subterranean structures are amongst the crucial structures in the present modern buildings. Tunnels are one of the most important subterranean structures enjoying very broad applications [1]. Amongst which applications, one can mention read and railroad tunnels and highway tunnels. Interaction between the tunnel structure and it surrounding soil environment has been always considered as one of the complex problems either in civil or in mine engineering arisen and being considered since ancient limes. Factor influencing seismic damages include:

1. Form, dimensions and depth of the structure 2. Earth stratification and type of earth 3. Structure specifications 4. Earthquake intensity 5. Procedure used to build the tunnel. These deformations occur due to the partial situation of the earth quake waves in proportion to the tunnel axis. In the even that waves move parallel to the tunnel axis, the cause pressure and tension stresses and it seismic waves cause small deformations in a direction perpendicular to the tunnel axis lead to flexural deformation on the tunnel axis.

Design of subterranean structures for stability against seismic forces is much different from designing of superficial or surface ones.

In this dissertation, tunnels with large spans executed through the boring or excavating and coating procedures have been studied and we have refrained to study the underground large gouges and/or water and waste water pipes.

Large – spam tunnels are structure the length which is much larger than the size of their spans.

Such structures can be grouped into three categories each having their distinct design profile and building procedure [1].

Response of subterranean structures to the ground deformation

In order to determine E_q we need to understand the translocation due to seismic waves in the ground and interaction of the subterranean structure with the ground [2]. In this section, the procedure used to estimate translocations and forces similar to the deformation modes (compressive, tensile, axial bending, indentation effect and becoming ellipsoid) mentioned at the beginning of this section.

Ellipsoid effect of the circular tunnel

Whenever the waves propagate perpendicular to the tunnel axis, ellipsoid deformation occurs. Therefore, designing should be performed for the ellipsoid cross section or in the transversal direction (mostly in the two – dimensional and flat conditions). Studied reveal that when ellipsoid form is produced due to propagation of transversal or oblique waves, propation of shear wave dominate earthquake forces resulting [4]

$$\frac{\Delta d}{d} = \pm\frac{\gamma_{\max}}{2}$$

Numerical analysis

Numerical analysis might be used for estimating shear deflection of the free field, especially if the site enjoys a variable structure. There are several acceptable computer programs for analysis such as programs of Lyons [5] and Folce [6] wave propagation. Majority of program patterns model geological structure as horizontal layers and have been derived from the theory of unidimensional wave propagation.

The Ground Dynamic Pressure

Dynamic pressure of ground on the cut and coating tunnel structure creates a complex shape of distribution of shear and vertical stresses along the external surface of the tunnel.

Precise determination of external forces requires strong dynamic analysis of soil-structure.

Withman in 1990 suggested a new theory on dynamic pressure of the ground. In the dynamic pressure of the ground it is supposed that majority of the seismic forces are created by the inertia of the surrounding soils. Another procedure for determining the increased lateral pressure is the Okabe-monobe method, suggested in 1970 by seed, H.B. & Whitman and the civil Engineering Association of Japan in 1970 [7].

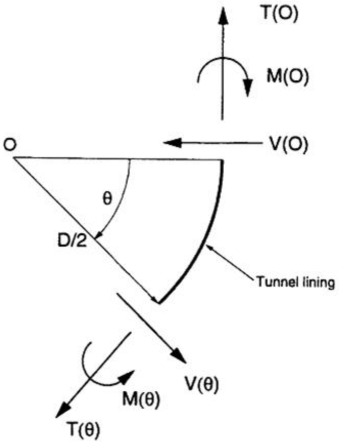


Figure1. Conventional signs for force components in the circular coating [3]

Data collection

Required data are as follows;

* Tectonic and seismic tectonic data

* Analysis of the seismic danger and determination of the required designing parameters

* Geotechnical and structural data of the Golab tunnel

Following gathering information, the below mentioned stages were followed up.

Modeling, analysis and extraction of the required information

* Selection of the finite components software

* Determination of data required for modeling

* Analysis and data retrieval

* Comparison of obtained results with each other and conclusion

Analysis of the seismic danger

At this level of studies the most intended parameter is the strong movement of ground in controlling the structure designing against the earthquake danger, and maximum acceleration values for the horizontal and vertical components. Based on the performed studies, and in accordance with ICOLD recommendations, results relevant to the probability procedure were used for introducing levels of the DBL and MDL seismic planning and results of the determination method were employed to introduce the MCL seismic designing level.

Background of the suggested values for the various seismic designing levels in various party of the tunnel are presented in the following table3s.

Values for background acceleration for strong movement of the ground in the 100-year useful life for various levels of the seismic designing at the tunnel inlet [4]

Design Levels	Maximum Ground (earth) acceleration			
	Vertical Acceleration (g)		Horizontal Acceleration (g)	
	cor	uncor	cor	uncor
DBL	16.0	14.0	0.23	0.20
MDL	0.22	19.0	0.32	0.29
MCL	0.31	0.26	0.47	0.38

Background values of the strong ground (earth) movement during the useful 100-year life for various seismic designing in the middle section of the tunnel [4]

Design Levels	Maximum Ground (earth) acceleration			
	Vertical Acceleration (g)		Horizontal Acceleration (g)	
	cor	uncor	cor	uncor
DBL	17.0	14.0	0.22	0.20
MDL	0.23	0.21	0.32	0.28
MCL	0.28	0.24	0.43	0.34

Modeling stages in the Abaqus software

Creating a PART which can be either unidimensional or three-dimensional. Selected dimensions for tunnel modeling in the soil mass is 60×60 (m^2). Inside this square a circular tunnel with a diameter of 4.2m is established. Concrete coating as well has been designed to be like a ring (in the two-dimensional case). Dimensions of the tunnel depth should be such selected that exceed one fourth of the length of the shear wave. Length of the shear wave is computed from the below –mentioned relation:

In the above relation, H stands for the tunnel surcharge (overload) relevant to the depth of structure which is equal to 30m (depth at the created model)

Therefore, the minimum pattern dimensions should be 30×30m as well. Regarding the 60×60m^2 size, this point has been also considered and transversal dimension of the tunnel is more than one fourth of the length of its shear wave.

Designed section enjoy reinforcement. The amount of employed reinforcement has been ignored in the static and dynamic analyses. The cause of this abandonment is that the amount of the reinforcement employed in the sections is not at a level that can be considered as reinforced concrete [10].

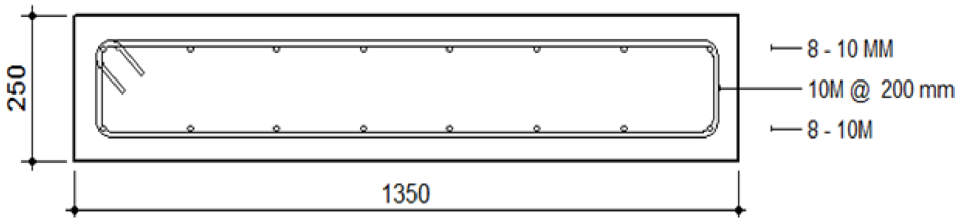


Figure2. Transverse section of the tunnel coating

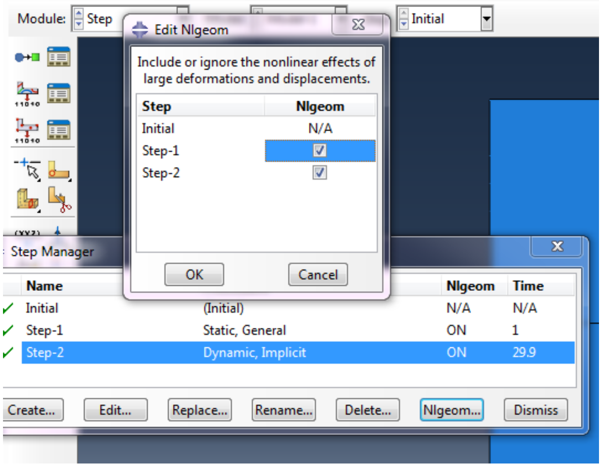
Reinforcements present in the tunnel section are as show in the above diagram. Eight reinforcements (wires) with a diameter of 10mm exist above and at the bottom of the section such that the ratio of the tensile reinforcement (wire) to the total section is equal to 2.9×10^{-3} which is less than the minimum tensile reinforcement of the under bending sections;

Therefore, this section is not the section of a reinforcement concrete.

Analysis stages

In this stage, type of the intended analysis should be selected. For static loads such as load weight static general method and further to analysis the dynamic implicit has been determined.

As shown in the diagram, in the dynamic analysis the N1 geom choice has been activated so that large non linear deformations characteristics of the analysis are also considered.



Include or ignore the nonlinear effects of large deformations and displacements.

Step	Nlgeom
Initial	N/A
Step-1	☑
Step-2	☑

	Name		Nlgeom	Time
✓	Initial	(Initial)	N/A	N/A
✓	Step-1	Static, General	ON	1
✓	Step-2	Dynamic, Implicit	ON	29.9

Figure3. Considering nonlinear effects of the large deformations (Abaqus software)

The time of earthquake occurrence is also specified in this stage. The temporal steps and their intervals can be determined too. Each temporal step is a fraction of the total time and also the number of these steps indicate the number of analysis steps.

MDL level

One of the crucial parameter used for studying the circular tunnel is changes of the tunnel diameter which has been employed for analyzing the temporal history and was considered in section four. In case we consider the tunnel coating as a concrete stab, maximum stab deformation in the middle of the tunnel can be L/240 in which relation L is equal to the slab span length which in a tunnel with a circular section can be considered to be equal to a half of the tunnel's circumference which is equal to 14.52m

Therefore, the maximum tunnel deformation diameter can be twice 6.05cm i.e. 1.12 cm. because the deflection established in the tunnel is equal to half of the tunnel diameter deformation [6].

As such, the obtained diameter changes should be compared with the 1.12 cm. If the above said value exceeds this value, it can be concluded that the deformation is not with the allowable zone and changes should be performed in the tunnel section so that sufficient stability for the tunnel is obtained [8].

Damage parameters intended to study the level of damages inflicted to the tunnel is also one of the useful parameters. In section four estimation of the maximum damage inflicted to the tunnel coating has been considered. Therefore, using this parameter it can be concluded that the more damage inflicted to the tunnel coating elements, occurrence of crazing due to pressure and cracks due to tension can be expected.

Maximum plastic strain PEEQ reveals plastic strain at the tunnel section. Maximum plastic strain value in compression for concrete is 0.0035.

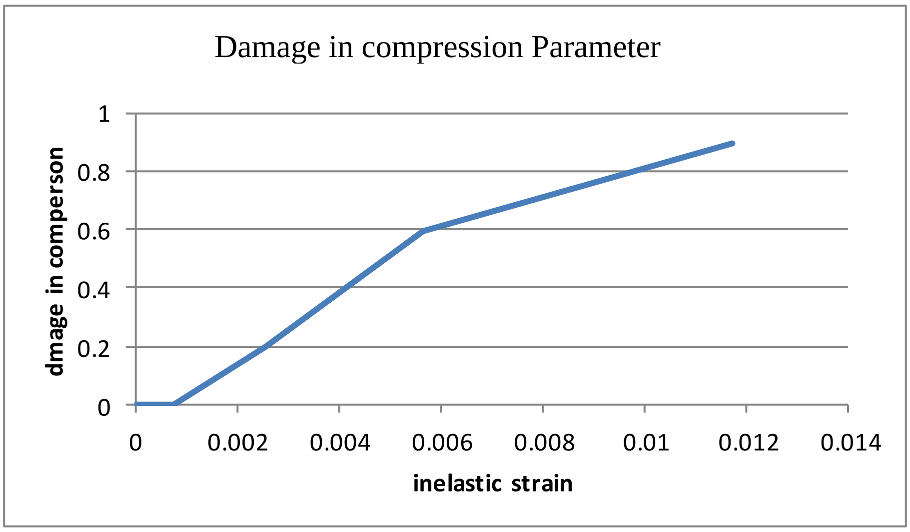


Diagram1. Relation of compression plastic strain with the compression damage parameter

General Conclusion

In the three first, second and third zones at MDL and MCL danger level responses were not identical and along with increased tunnel surcharge (overload) and changed nature of the stones has been added to a long-term force due to the phenomenon of stones creep around the tunnel.

The designed section has not been appropriate for any of the zones. Deformations and the compression damage parameter revealed that the section has suffered beyond expectation deterioration and irreparable at MDL level and at MCL level has caused tunnel instability.

Therefore it can clearly said that this section has not been a proper one.

Study of various thicknesses for the tunnel at presumptive 30, 35 and 40 sections can be appropriate choices however, the section 40 is not economical therefore section 35 is suggested.

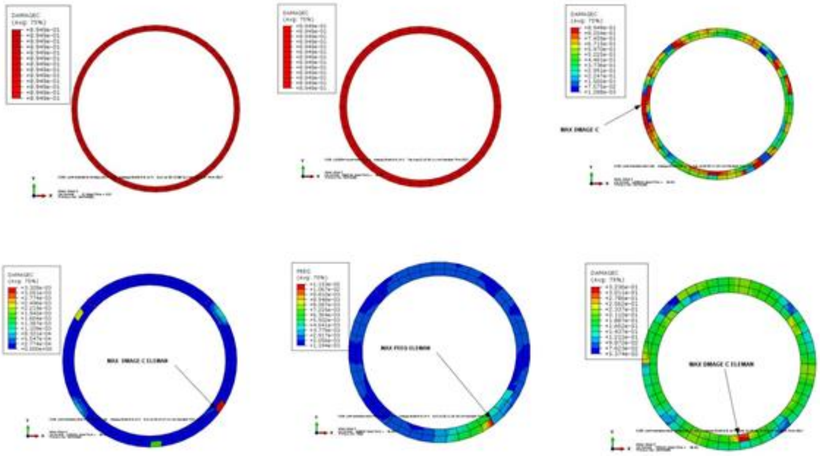


Figure4. Damage at different thicknesses (Abacus software) - As it can be seen, damage parameter decreases along with increased thickness [9].

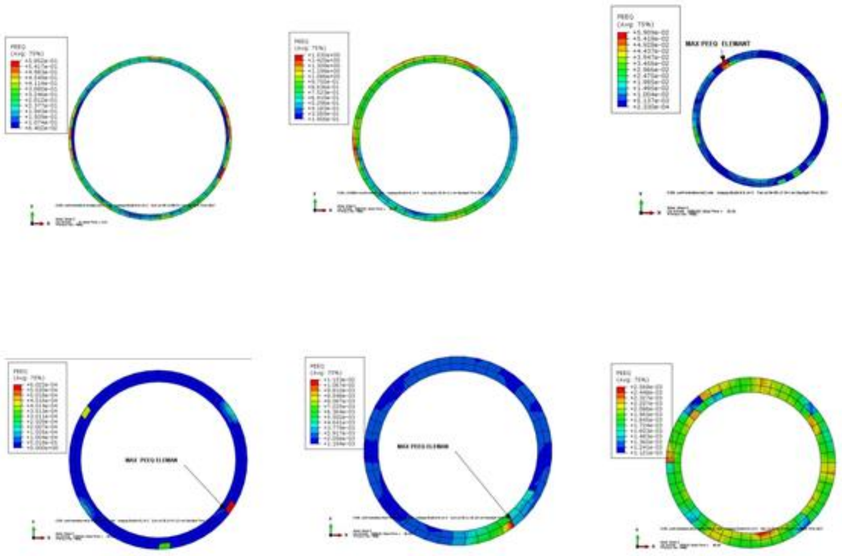


Figure5. Plastic strain at various thicknesses (Abacus software)-As it can be seen, along with increased plastic strain thickness in the concrete, compression is decreased.

Reference:

[1] Y. M. Hashash, Tunnelling and Underground Space Technology16, pp. 247- 293, 2001.

[2] in Seismic Design of Tunnels, vol. 7, New York, Brinckerhoff, 1993.

[3] G. S. Owen, Earthquake engineering of large underground structures, Federal Highway Administration and National Science Foundation., 1981.

[4] Regional water of Isfahan province, "Golab water transfer tunnel studies", Ministry of Energy, Isfahan, 2011.

[5] J. U. T. T. C. S. H. Lysmer, "FLUSH: A computer program for approximate 3-D analysis of soil interaction problems. structure," Earthquake Engineering Research Center, 1975.

[6] J. U. T. T. C. S. H. Lysmer, "FLUSH: A computer program for approximate 3-D analysis of soil interaction problems. structure," Earthquake Engineering Research Center, 1975.

[7] R. Whitman, "Seismic design and behavior of gravity retaining walls," Design and Performance of Earth Retaining Structures., vol. 25, pp. 817-842, 1990.

[8] H. W. R. Seed, "Design of earth retaining structures for dynamic loads," in Proceedings of the ASCE Specialty Conference on Lateral Stresses in the Ground and Design of Earth Retaining Structures, 1970.

[9] Japanese Society of Civil Engineers, Specifications for Earthquake Resistant Design of Submerged Tunnels., Tokyo: Japanese Society of Civil Engineers, 1975.

[10] I. C. G. Inc., FLAC 3D version 3.3:Fast Legrangian Analysis of Continua.