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EFFECT OF CIRCULAR TUNNEL ON EXESTING BUILDINGS UNDER SEISMIC LOADING

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Abstract: The paper deals with analysis of the time history response of the soil profile surrounding tunnel during earthquakes. The analysis presented illustrates the behavior of buildings due to tunneling under seismic loading condition. Generally tunnels have a fairly high safety against earthquakes. However , at the earth surface the reaction to the earthquake action may lead to more complicated consequences. The proposed approach can also be used for estimation of dynamic load influence on development of differential settlement for nearby structure. A real tunnel model which is subjected to earthquake forces was considered and for the purpose of analysis modified numerical program MIDAS 2D was used.

Keywords: Tunnel excavation, superstructure, Earthquake, MIDAS 2D

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INTRODUCTION

One of the most important factors affecting the design of the structures is the impact of the seismic loadings on the design displacements. Where as, the influences of the near structures on the existing buildings, which sometimes can cause great changes in forces and displacements. Thus, the induced displacement in the adjacent buildings due to newly constructed underground tunnel will be investigated in this study. The behaviour of the super structures, such as buildings, bridges, under seismic conditions is highly affected by the underlying soil layer. So far, extensive studies have been carried out to know the impact of the earthquakes on underground and ground structures and it can be evaluated, whether the amount of variations in displacements are in the allowable ranges, and what measures are needed to save the structures in case of excessive displacement. Different shapes of tunnels are shown in figure1.

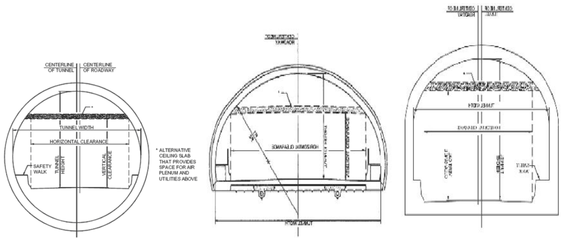


Figure 1: Circular, Horseshoe and Curvilinear (Oval) Tunnel (FHWA, 2005a)

Engineering Approach to Seismic Analysis and Design

Earthquake effects on underground structures can be grouped into two categories, a) ground shaking and, b) ground failure such as liquefaction, fault displacement, and slope instability. Ground shaking, refers to the deformation of the ground produced by seismic waves propagating through the earth's crust. The major factors influencing shaking damage include: i) the shape, dimensions and depth of the structure ii) the properties of the surrounding soil or rock iii) the properties of the structure and iv) the severity of the ground shaking, Seismic design of underground structures is unique in several ways. For most underground structures, the inertia of the surrounding soil is large relative to the inertia of the structure. Measurements of the seismic response of an immersed tube tunnel during several earthquakes show that the response of a tunnel is dominated by the surrounding ground response and not the inertial properties of the tunnel structure itself. The focus of underground seismic design, therefore, is on the free field deformation of the ground and its interaction with the structure. The emphasis on displacement is in stark contrast to the design of surface structures, which focuses on inertial effects of the structure itself. This led to the development of design methods such as the Seismic Deformation Method that explicitly considers the seismic deformation of the ground. Many researchers present a review on the seismic behavior and design of underground structures in soft ground with an emphasis on the development of the Seismic Deformation Method. The behavior of a tunnel is sometimes approximated to that of an elastic beam subject to deformations imposed by the surrounding ground.

1. Numerical Programme

The numerical program reported herein, that involves a real tunnel model which is subjected to earthquake forces are considered. A tunnel of 6 m diameter and overburden depth 17 m was considered. Which was embedded in the formation comprises four alternating hard rock, soft rock weather rock and top clay layers. The left and right structures are placed at a distance of 10 m and 15 m from the center of tunnel and the length of structures are 20m and 25m respectively. A typical cross section shows the information about strata, the alignment of tunnel and other related details is shown in Fig. 2.

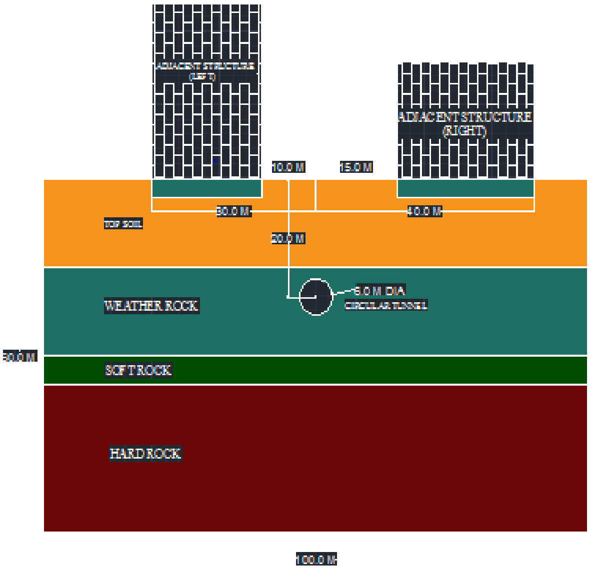


Figure 2: Ground Profile and The Positions of the Existing Structures and Tunnel in the Selected Model.

2.1 Material

The material properties of the formation and that of the tunnel lining are listed in Table 1 and Table 2 respectively.

Table 1: Material Properties of Ground Medium

Depth (m)	DryUnit Weight (kN/m)	Poisons Ratio (μ)	Elastic Modulus *E* (kN/m^2)	Angle of Friction Ø	Cohesion *C* (kN/m^2)
15	18	0.3	40000	33	28
15	21	0.3	200000	37	40
5	24	0.27	1350000	37	100
25	26	0.2	8900000	55	500

Table 2: Material Properties of Structural Medium.

Sr. No	Material Type	Modulus of Elasticity (kN/m^2)	Poisons Ratio (μ)	Unit Weight (kN/m^3)
1	Structure	20000000	0.2	25
2	Soft Shotcrete	5000000	0.3	24
3	Hard Shotcrete	15000000	0.3	24

2.2 Dynamic Analysis

A set of input acceleration time history had been seleced from data base records. The finite element software MIDAS GTS 2D has been used to perform two dimensional dynamic analysis.

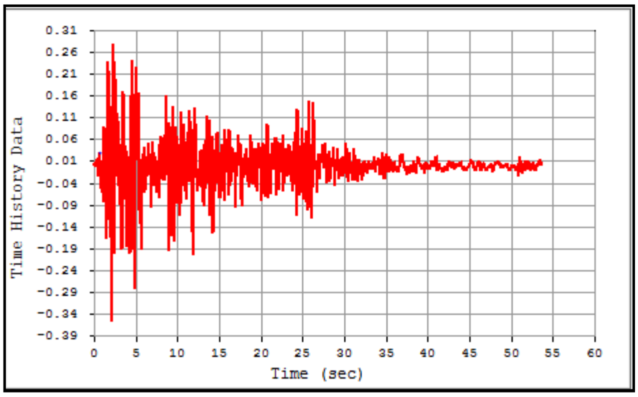


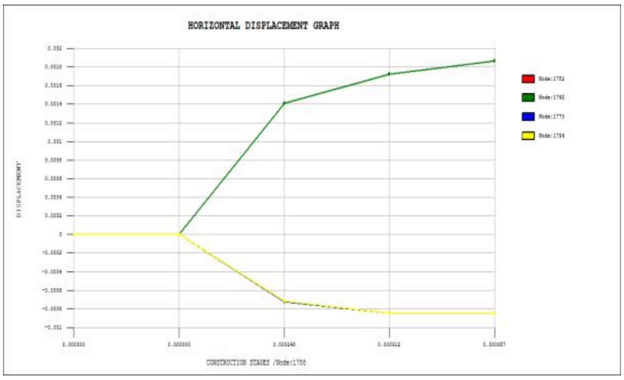
Figure 3: Time History Load Function of El Centro Site, 270 Deg Earthquqke.

2. Numerical Results and Discussion

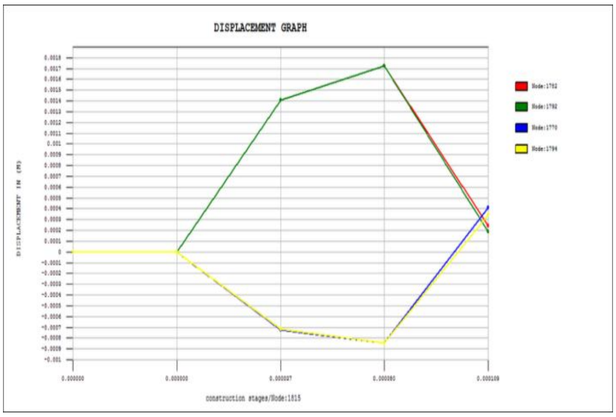
The numerical analysis presented hear was used to examine the effect of dynamic loads on the stability of nearby structures perticularly buildings, tunnels and especially due to earthquakes. Vertical and horizontal displacements were estimated to examine the behavior of structure under following cases, as mentioned in table.3

Table 3: Different Loading Cases.

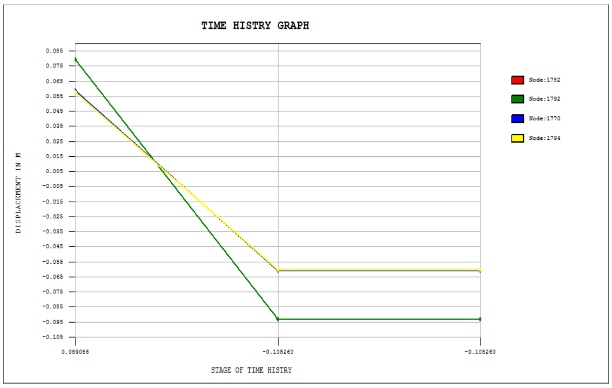
Case I	Self Load of Structure
Case II	Surcharge Load
Case III	El Centro Time History Loading.



i) Case I

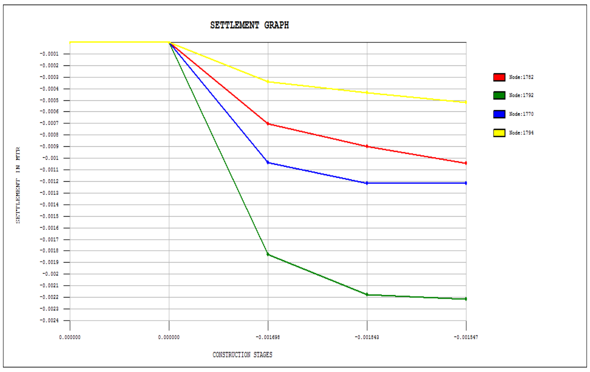


ii) Case II

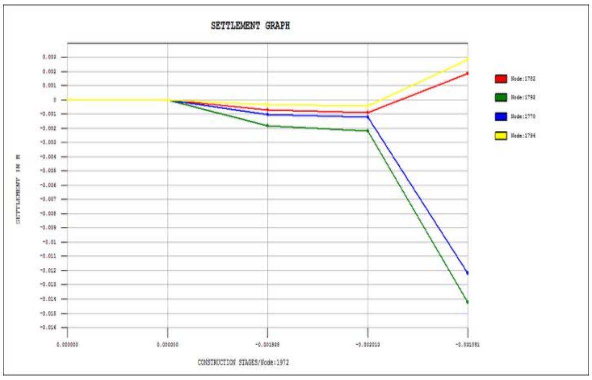


iii) Case III

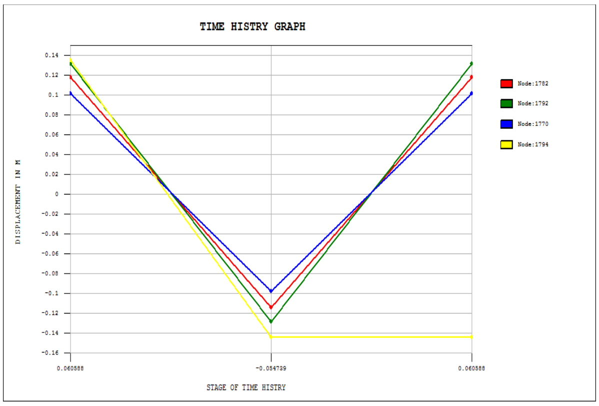
Figure 4: Horizontal Displacement of Structure for Different Cases.



i) Case I



ii) Case II



iii) Case III

Figure 5: Vertical Displacement of Structure For Different Cases.

The maximum vertical displacement of about -2.217 mm was obtained for case I at nearest point of structure from tunnel, where horizontal displacement was 1.865 mm . In case II maximum vertical displacement occurred was -14.248 mm and horizontal displacement was 0.407 mm . for case III maximum vertical and horizontal displacements were -144.172 mm and -93. 413 mm respectively. The details of results are present below in tabular format as shown in table .4

Table 4: Summary of Results Obtained From Analysis Cases.

i) Case I

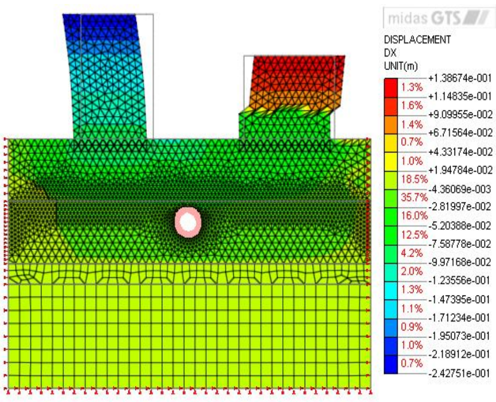
Division		Distance	Displacement (mm)	
Structural Effect Check	Adjacent Structure (Left)	10 M	Horizontal	1.865
			Vertical	-2.217
		30 M	Horizontal	1.865
			Vertical	-1.044
	Adjacent Structure (Right)	20 M	Horizontal	-0.852
			Vertical	-1.218
		40 M	Horizontal	-0.848
			Vertical	-0.518

ii) **Case II**

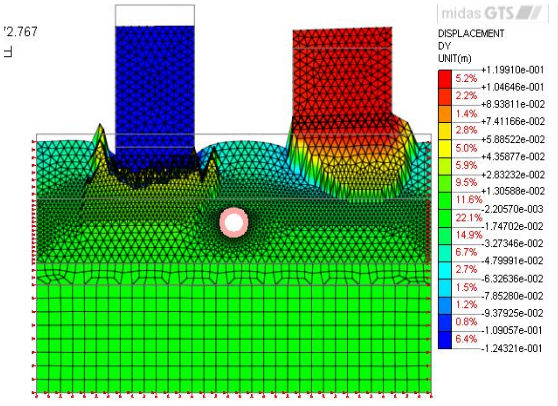
Division		Distance	Displacement (mm)	
Structural Effect Check	Adjacent Structure (Left)	10 M	Horizontal	0.190
			Vertical	-14.248
		30 M	Horizontal	0.243
			Vertical	1.849
	Adjacent Structure (Right)	20 M	Horizontal	0.407
			Vertical	-12.186
		40 M	Horizontal	0.345
			Vertical	2.843

iii) **Case III**

Division		Distance	Displacement (mm)	
Structural Effect Check	Adjacent Structure (Left)	10 M	Horizontal	-93.413
			Vertical	118.169
		30 M	Horizontal	-93.299
			Vertical	131.473
	Adjacent Structure (Right)	20 M	Horizontal	-61.102
			Vertical	101.253
		40 M	Horizontal	-60.335
			Vertical	-144.172



i) **Horizontal Displacement**



ii) Vertical Displacement

Figure 6: Horizontal And Vertical Displacement of Structure For Case III.

4. Concluding Remarks

It was observed that maximum displacement occurred at a point closer to tunnel excavation. Differential settlement occurred in case of vertical displacement. Also displacement was maximum in case of high rise building and less influence on low rise building. Under seismic loading condition tunnel survived but structure over which was damaged. It was found that at the upperearth surface the reaction to earthquake waves might lead to higher amplitudes of acceleration.

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