SEISMIC RESPONSE BY SPECTRAL ANALYSIS OF THE SYSTEM ROCK - UNDERGROUND CONSTRUCTION (TUNNEL)

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Abstract: Analysis of seismic response of structures buried by spectral analysis, is one of the most effective method for verifying the earthquake resistance of these buildings, with major impact for the population. Concrete railway tunnel, in this case study is located at an altitude of 1000 meters, is 128 m in length, earth coverage of 26.17 m. The cross section is horseshoe shaped, concrete and the soffit is molon protection. The present research uses a computer model consisting of two-dimensional finite element flat deformation state. Spectral analysis was used to design software SAP2000-V14.

Key words: underground construction, earthquakes, spectral analysis, tunnel, static load, its dynamic response.

1. Introduction

One of the most important activities related to underground construction safety, construction is to determine the behavior of seismic shock acceleration. This activity is coordinated Romania and P100-2006 according to norm established procedures and core values to be considered. You do not have spared no effort to achieve earthquake resistant civil engineering. In addition to reviewing the considerations static loads and their dynamic response, the calculation to seismic action was considered in two ways, as the spectrum of design and form of accelerograms. We also have to consider zoning the territory of Romania in terms of peak values of ground acceleration for earthquakes having IMR design (the average recurrence) 100 years (P100-2006) and the Romanian territory in terms of zoning period control (corner) Tc response spectrum (P100-2006). Tc = 1.0 sec and ag = 0.28 g. Behavior factor q was determined based on P100-2006 and on the structure regularity account. For the behavior factor q, it was considered the structure with only two walls, thus $\alpha 0/\alpha 1 = 1.0$ was chosen for studying tunnel value q = 3.

This paper emphasizes the results of behavior-environment tunnel system to seismic accelerations, so that they last only review findings static loading and its dynamic response of the tunnel. Diagrams were also reproduced the most significant.

2. The calculation model

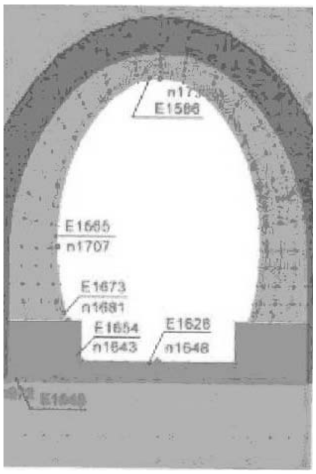
The calculation model consists of two-dimensional finite elements in a state of plane deformation (Mesta 1997, Fierbinteanu 1989)

The calculation has been considered an area of 26.17 m above and the rest around 5 tunnel diameters.

Generated by the model size (63x56m) ensures the elimination of the consequences of disturbances created by the cinematic shape.

Therefore the vertical sides of rigid links were placed horizontally and in vertical elastic links. At the bottom of the rigid link model were introduced in the vertical direction.

To increase the accuracy of the model has increased the number of vertical and horizontal elements resulting in 1866 nodes and 3613 degrees of freedom (equations).



Details: n = node
E = element

Tabel 1 Caracteristicile mecanice ale materialelor

Material	Modul de elasticitate (kN/m^2)	Coeficientul Poisson	Greutatea specifică (kN/m^3)
Pământ = Hidroizolația	$E_{static} = 3{,}03 \times 10^5$ $E_{dinamic} = 2{,}42 \times 10^5$	$\mu_{static} = 0{,}22$ $\mu_{dinamic} = 0{,}02$	20,50
Beton tunel B150	230×10^5	0,2	24,00
Moloane	230×10^5	0,2	24,00
Beton fundație B75	155×10^5	0,2	24,00

Vibration characteristics are determined by the modulus of elasticity (kN/m2), Poisson ratio and specific gravity down concrete tunnel (B150), moloane concrete foundation (B75).

3. Considerations on static loading

The values of any size coming from symmetrical loads are also symmetrical. It is considered the maximum vertical direction, amounting to 5.3 cm as a result of their weight and 0.02 cm the effect of 20% of the convoy. Horizontal displacement, the value is 0.73 cm (for weight) is 14% of vertical movement.

Unified efforts as both S11 and S22 in the direction of their maximum values in the tunnel elements. For its own weight load peaks are in different areas of the tunnel, while the convoy loaded with the maximum weight is in the slab.

1-1 are maximum efforts towards the different sections - the middle slab to load its own weight and the upper slab for convoy. However, the overall model, efforts are in the slab S11 for both types of loads. 1-1 maximum effort for the convoy is about 11% of maximum effort for 1-1 own weight.

Maximum efforts towards 2-2 are placed on the inside of the tunnel or the distance between walls is maximum or corner of the slab. Convoy intake is different in the two levels, namely 3% is almost to the distance between the walls is high and about 12% at the upper slab.

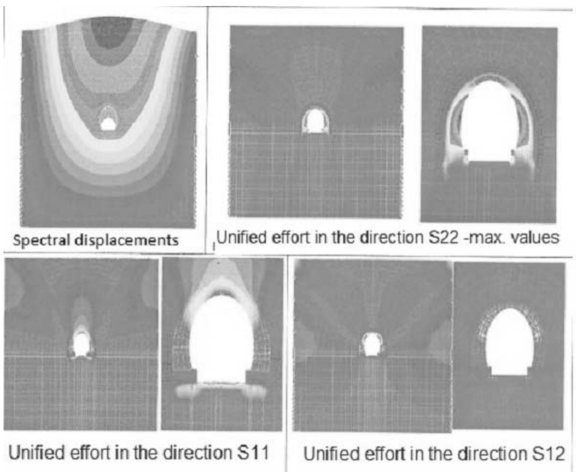


Fig.1 *Spectral response charts where it is placed on the vertical direction*

Table 2. *Values of mechanical assembly - spectral response / vertical spectrum.*

Mechanical size			Value	Position
Maximum Displacement (m)	Vertical direction		0,042	In the middle of the land surface model
	Horizontal direction		0,01	Land surface
Unified Effort kN/m^2	S11	Max	773,5	The tunnel - the middle slab
		Min	2,7	In several areas - Tunnel + Ground
	S22	Max	1452,3	The tunnel - the side walls
		Min	2,4	The lateral limits below ground tunnel
	S12	Max	727,2	The tunnel - the side walls
		Min	0,0	The tunnel at the bottom of the shaft

4. Comments on its dynamic response

Fundamental mode (T1 = 0.407 s) located between the structure with rigid behavior. Type vibration vector is vertical translation.

Module two (T2 = 0.326 s) is a horizontal vibration which causes the 84% modal mass. Its period 2 value is 20% lower than the value of the fundamental period, while the proportion of the modal mass is driven higher by 27%.

Module three (T3 = 0.282 s) is the amount of torsion and its period is 31% lower than the fundamental mode. It is considered that the movements of ambient rock system - tunnel are very orderly and a drive assembly.

5. Spectral response

The study seeks seismic response by spectral analysis. Spectrum is the spectrum of design used in normative P100-2006, according to seismic zone is located in the tunnel.

Given the dynamic sensitivity of the structure, the spectrum was considered in three cases of application, namely: 1) vertically, (2) horizontally and (3) to 45^0.

The figures below are maximum and minimum consistent efforts if the action spectrum for both the vertical direction across the field-structure and the structure. Mechanical values of the spectral response characteristic are summarized in the same manner in the following tables.

Table 3. *Sizes mechanical characteristic points - spectral response / Vertical spectrum*

Node position	Node number	Movement (m)	Unitary effort kN/m^2			
Land area - middle	1809	Vertical 0.042	S11	11.6	S22	248.8
Land surface (extreme points)	Left 1794	Vertical 0.01	S11	155.3	S22	46.5
	Right 1822		S11	211.3	S22	69.7
Tunnel - Key soffit	1739	Vertical 0.0266	S11	31.3	S22	500.2
Tunnel - walls to the maximum	Left 1707	Vertical 0.026	S11	22.8	S22	1377.7
	Right 1771		S11	23.5	S22	1377.0
Tunnel - vault birth (interior)	Left 1681	Vertical 0.0261	S11	112.1	S22	679.5
	Right 1684		S11	113.1	S22	680.9
Tunnel - mid-slab	1648	Vertical 0.0259	S11	728.5	S22	34.1
Tunnel – slab edge (corner)	Left 1643	Vertical 0.026	S11	205.0	S22	797.7
	Right 1653		S11	205.2	S22	802.4
Tunnel - extreme Foundation	Left 972	Vertical 0.026	S11	150.1	S22	623.1
	Right 990		S11	148.2	S22	483.4

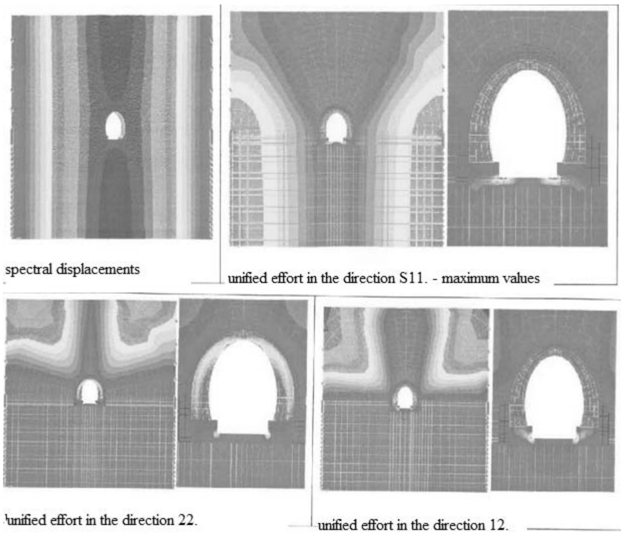


Fig. 2 *Spectral response graphs if the spectrum is inserted horizontally*

Table 4. *Values of mechanical assembly - spectral response / horizontal spectrum*

Mechanical size			Value	Position
Maximum Displacement (m)	Vertical direction		0.0003	land surface
	Horizontal direction		0.0086	land surface in the middle of the model
Unified Effort kN/m^2	S11	Max	192.3	slab over the tunnel
		Min	0.2	land surface in the middle of the model
	S22	Max	83.8	land surface - to the extreme field
		Min	0.0	
	S12	Max	66.0	land surface – Extreme field
		Min	0.0	

Table 5. *Mechanical sizes characteristic points - response spectral / horizontal spectrum*

Node position	Node number	Movement (m)	Unitary effort kN/m^2			
Land - means	1809	Horizontal 0.008	S11	0.3	S22	14.2
land surface (extreme points)	Left 1794	Horizontal 0.0 Vertical 0.001	S11	62.6	S22	59.5
	Right 1822		S11	73.3	S22	48.8
Key tunnel soffit	1739	Horizontal 0.0083	S11	5.76	S22	32.6
tunnel - the wall at maximum distance	Left 1707	Horizontal 0.0082	S11	1.0	S22	13.9
	Right 1771		S11	1.0	S22	13.9
tunnel - the birth of the vault (interior)	Left 1681	Horizontal 0.0083	S11	23.5	S22	11.5
	Right 1684		S11	23.7	S22	11.6
tunnel - the middle slab	1648	Horizontal 0.0083	S11	11.3	S22	2.3
tunnel - slab edge (corner)	Left 1643	Horizontal 0.0080	S11	126.9	S22	43.9
	Right 1653		S11	126.7	S22	44.3
tunnel - extreme Foundation	Left 972	Horizontal 0.0083	S11	40.1	S22	3.6
	Right 990		S11	40.1	S22	3.6

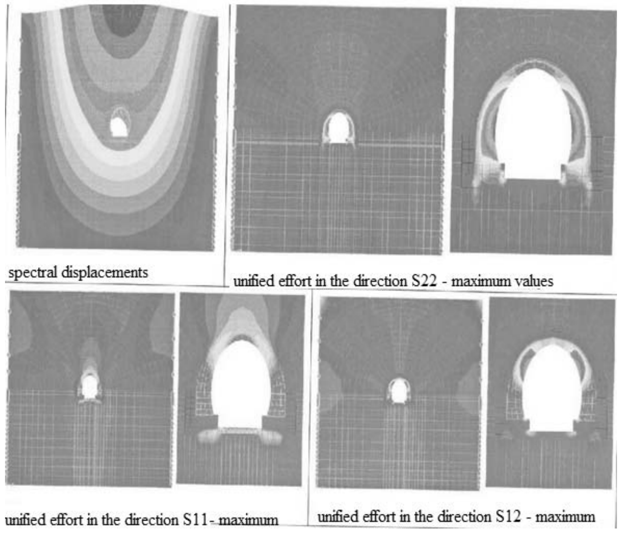


Fig. 3 *Spectral response graphs if the spectrum is introduced at 45^0*

Table 6. *Values of mechanical assembly - response spectral / spectrum at 45^0*

Mechanical size			Value	Position
Maximum Displacement (m)	Vertical direction		0.03	land surface in the middle of the model
	Horizontal direction		0.0084	land surface - extremities
Unified Effort kN/m^2	S11	Max	548.7	tunnel - mid-slab
		Min	2.0	in several areas of land
	S22	Max	1026.9	tunnel - the side walls
		Min	2.4	field lateral limits under tunnel
	S12	Max	514.3	tunnel - the side walls
		Min	0.0	field at the bottom of the shaft

Tabel 7. *Mechanical sizes characteristic points - response spectral / spectrum at 45^0*

Node position	Node number	Movement (m)	Unitary effort kN/m^2			
Land - means	1809	V 0.0298 H 0.062	S11	8.17	S22	176.2
land surface (extreme points)	Left 1794	V 0.0071	S11	118.4	S22	53.4
	Right 1822		S11	158.1	S22	58.9
Key tunnel soffit	1739	V 0.0188 H 0.0083	S11	22.1	S22	354.4
tunnel - the wall at maximum distance	Left 1707	V 0.0185	S11	39.7	S22	974.2
	Right 1771	H 0.0058	S11	42.7	S22	973.6
tunnel - the birth of the vault (interior)	Left 1681	V 0.0184	S11	81.1	S22	480.5
	Right 1684	H 0.0058	S11	81.8	S22	481.4
tunnel - the middle slab	1648	V 0.0183 H 0.0059	S11	512.3	S22	24.2
tunnel - slab edge (corner)	Left 1643	V 0.0184	S11	171.3	S22	567.0
	Right 1653	H 0.0058	S11	171.4	S22	566.7
tunnel - extreme Foundation	Left 972	V 0.0184	S11	110.2	S22	341.6
	Right 990	H 0.0083	S11	110.2	S22	341.8

Table 8. *Maximum and minimum values of mechanical quantities of spectral response for the three load cases*

Mechanical size			Vertical spectrum	Horizontal spectrum	Spectrum at 45^0
the maximum movement(m)	vertical direction		0.042	0.003	0.030
	horizontal direction		0.01	0.0088	0.0084
Unified effort kN/m^2	S11	Max	548.7	192.3 In tunnel slab corners	548.7
		Min	2.7	0.2	2.0
	S22	Max	1452.3 In tunnel lateral walls	83.8	1026.9 In tunnel lateral walls
		Min	2.4	0.0	2.4
	S12	Max	727.2	66.0	514.3
		Min	0.0	0.0	0.0

6. Conclusions on the response spectrum loading structure design

As expected design load spectrum in the vertical direction leads to the highest values of spectral response.

Maximum values are field trips to the top of it. Maximum values are consistent efforts in concrete structure on the side walls of the tunnel. And the slab is applied to values approaching the maximum.

Travel, spectral response spectral maximum vertical load is about 14 times higher than the maximum spectral response spectral horizontal loading.

Nodal displacements from 0.042 to 0.003 (m)

To work unit spectral response spectral maximum vertical load is about 7.5 times higher than the maximum spectral response spectral horizontal loading.

Efforts uniform spectral lines 1452.3 to 192.3 (kN/m2)

One can say that the response displacement spectral type is 2 times more sensitive than single response type effort.

The maximum spectral vertical - 4.2 cm - is under static displacement under its own weight - 5.3 cm - representing about 80% of it. The maximum spectral horizontal - 1.0 cm - is about 37% higher than static maximum horizontal displacement - 0.73 cm.

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