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# ANALYSIS OF UNDERGROUND ROAD TUNNEL SUBJECTED TO SEISMIC FORCE

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## ABSTRACT

*Road tunnels are very practical alternatives to cross physical obstructions or traverse through physical barriers such as mountains or snow bound areas. Analysis of underground road tunnel subjected to seismic force is present in this paper. Providing the strength, stability and ductility are major purposes of seismic analysis. Seismic force bring one of the major natural hazards, it becomes at most important to analyses structure against it. To study the change in critical zone and forces in presence and absence of seismic forces, initially tunnel is analyses for normal forces, later on same tunnel is analyzed for normal and seismic forces both. The presence of lateral load reflects major changes in stress value, moments and displacement. This study will impress there of structure, broader the understanding the design concepts in structural domain and performance when subjected to natural hazard like seismic force. Seismic coefficient method is used for the analysis of tunnel for seismic forces.*

***Keywords: - Loads, Breaking Force, Design Of Tunnel, Geometric Specification, Seismic Coefficient.***

## I INTRODUCTION

Road tunnels are very practical alternatives to cross physical obstructions or traverse through physical barriers such as mountains or snow bound areas. In cases of road passing through hilly terrain, a tunnel can shorten the length of road to be travelled thereby reducing hazardous emissions. Reduction in length of road to be constructed avoids many a scars highway engineers are forced to put on beautiful hill faces definition, are sustainable features. Most tunnel structures were designed and built, however, without regard to seismic effects. In the past, seismic design of tunnel structures has received considerably less attention than that of surface structures, perhaps because of the conception about the safety of most underground structures cited above. Yet one certainly would not want to run away from a well-designed building into a buried tunnel when seismic events occur if that tunnel had been built with no seismic considerations. as tunnel is very important way communication so it is necessary to analyses structure with considering the effect of seismic force to achieved the safety of human life. If the underground structure are not analysed for seismic loading then it may lead to loss of life and destruction of structure. For achieved the seismic stability and resistivity analysis and design of structure by considering the effect of seismic forces is necessary.

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### 1.1 Need of analysis

Most tunnel structures were designed and built, however, without regard to seismic effects. In the past, seismic design of tunnel structures has received considerably less attention than that of surface structures, perhaps because of the conception about the safety of most underground structures cited above. Yet one certainly would not want to run away from a well-designed building into a buried tunnel when seismic events occur if that tunnel had been built with no seismic considerations. As tunnel is very important way communication so it is necessary to analyses structure with considering the effect of seismic force to achieved the safety of human life. If the underground structure is not analyses for seismic loading then it may lead to loss of life and destruction of structure. For achieved the seismic stability and resistivity analysis and design of structure by considering the effect of seismic forces is necessary.

### 1.2 Research methodology

- Basically the geological, geotechnical, hydrological data, Soil structure interaction and geometry of structure etc. studied in brief.
- Loads are considered for analysis of the structure by referring the IRC 6-2000.
  a) Self Weight structure b) Earth load on top slab c) Horizontal pressure of earth d) Live surcharge
  e) Water pressure f) the live load for design of bottom slab 70R (T) breaking force &self-weight of wearing course of bitumen is taken.
- The complete analysis of RCC box tunnel is carried out manually for the various load combinations as per relevant I.S. Codes.
- Firstly the Magnitude of seismic forces are calculated for tunnel subjected to ground condition and different loading combinations given by IS 1893 and then complete normal analysis & seismic analysis is carried out computationally using STADD-PRO.
- For the analysis work, seismic coefficient method is chosen.
- Soil structure interaction is considered.

## 1.3 Loads on Tunnel

The Various types of load such as self-weight, Earth pressure, water pressure, uplift pressure, Vehicular live load, overlying pressure and seismic force are taken for analysis of underground structure. The above loads are taken from IRC 6-2000. Self-weight, Earth Pressure Water Pressure Uplift Pressure Live load overlying pressure Temperature stresses Seismic force.

### Loading Criteria

For Tunnel Structure:-

$$U=D+L+E1+E2$$

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Where

U = required structural strength capacity

D = effects due to dead loads of structural components

L = effects due to live loads

E1 = effects due to vertical loads of earth.

E2 = effects due to horizontal loads of earth.

In normal design of a tunnel, only gravity loads are considered for design. For the load combination given above, the design moments and shear forces are calculated. For calculation of design moments, Moment distribution method was adopted. After getting all the design moments and shear forces, actual design is carried out as per the relevant I.S. code method.

## 1.4 Seismic Design Approach

### 1.4.1 Loading Criteria

**Maximum Design Earthquake (MDE)** The performance goals of the MDE (i.e. Public safety), the recommended seismic loading combinations using the load factor design method are as follows

### 1.4.2 Tunnel Structures

- **U = D + L + E1+ E2 +EQ**

Where

U = required structural strength capacity, D = effects due to dead loads of structural components.

L = effects due to live loads. E1 = effects due to vertical loads of earth.

E2 = effects due to horizontal loads of earth. EQ = effects due to design earthquake (MDE).

## 1.5 Seismic Coefficient Method (Analysis method)

The seismic coefficient method is used for the analysis of tunnel.

The seismic force to be resisted by tunnel component shall be considered as follows

**F = Ah W**

Where

F = Horizontal seismic force to be resisted

W = Weight of mass under consideration ignoring reduction due to buoyancy or uplift

Ah = Design horizontal seismic coefficient as

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Horizontal Seismic Coefficient Ah- The design horizontal seismic coefficient, Ah shall be determined from following expression IS Used for calculation the design horizontal seismic coefficient.

Ah = (Sa/g x Z/2 x I/R )

Provided that for any structure with T< 0.1 sec, the value of Ah will not be taken less than Z/2 whatever be the value of I/R

Where,

Z = Zone factor

I = Importance factor  Refer Table No 2 Of IS 1893 Part *III*

R = Response reduction factor Refer Table No 3 IS 1893 Part III

Sa/g = Average Acceleration coefficient for rock or soil sites

**Table No 1 -Zone factor (IS 1893-2002)**

| Seismic Zone | II | III | IV | V |
|---|---|---|---|---|
| Seismic Intensity | Low | Moderate | Severe | Very Severe |
| Zone Factor(Z) | 0.10 | 0.16 | 0.24 | 0.36 |

**Table 2 Material densities**

| Material | Dry density KN/$m^3$ | Safe bearing capacity kN/$m^2$ |
|---|---|---|
| Water | 9.81 | --- |
| Murum | 18 | 200 |
| Backfill | 18 | 200 |

**Table No 3 -Average Acceleration coefficient for rock or soil sites(IS 1893-2002)**

| Type of soil | Avg. Acceleration Coefficient | Coefficient Value |
|---|---|---|
| For Rocky or hard soil sites. | Sa/g | 1+15T, 0.00<T<0.10 |
| | | 2.50, 0.10 < T < 0.40 |
| | | 1.00/T 0.40 < T <4.00 |
| For Medium Soil Sites | Sa/g | 1+15T, 0.00<T<0.10 |
| | | 2.50, 0.10 < T < 0.56 |
| | | 1.36/T 0.55 < T <4.00 |
| For Soft Soil Sites | Sa/g | 1+15T, 0.00<T<0.10 |
| | | 2.50, 0.10 < T < 0.67 |
| | | 1.67/T 0.67 < T <4.00 |

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### 1.6 Load combinations

When earthquake forces are combined with other forces such as dead load and live load, the load factor for plastic design of steel structures and partial safety factors for limit state design of reinforces concrete structures and pre-stressed concrete structures shall be considered. Load factors may be used as in IRC/IRS codes with the provision that when earthquake load (EL) and dead load (DL) are combined, load factor shall be minimum 1.5; and when seismic load is combined with all other loads, load factor shall be minimum 1.2. Partial safety factors for limit state design of reinforced concrete and pre-stressed concrete structures In the limit state design of reinforced and pre-stressed concrete structures, the following load combinations shall be accounted for

1) 1.5( DL+IL)

2) 1.2( DL+IL+EL)

3)1.2( DL+IL-EL)

4) 1.5( DL+EL)

5)1.5( DL-EL)

6) 0.9DL+1.5EL

7)0.9DL-1.5EL

#### 1.6.1 Indian Standard Codes used for Design

- I.S. 456-2000 ( Limit state design of RCC structure)
- I.S.1893-2002(Part-I)
- I.S.1893 Part-III (Criteria for Earthquake Resistant Design of Structures: Part 3 Bridges and Retaining Walls)
- IRC-78-2000(Standard specification and code of practice for road bridges)
- IRC-6-2000(Standard specification and code of practice for road bridges)
- IRC-21-2000((Standard specification and code of practice for road bridges)Cement Concrete plain and reinforced
- IS-11105-2004(Design and construction of tunnel plug)
- IRC SP 99-2013 Manual of specification and standard for expressway
- IRC SP 19-2001 Manual For Road project
- BD 78/99 -Design Of Road Tunnel

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## 1.7 Seismic Design vs. Conventional Design

The purpose of seismic design, like any civil engineering design, is to give the structure the capacity to withstand the loads or displacements/deformations applied to it. The philosophy employed in seismic design is different, however, from standard structural engineering practice because:

• Seismic loads cannot be calculated accurately. Seismic loads are derived with a high degree of uncertainty, unlike dead loads, live loads, or other effects such as temperature changes. Any specified seismic effect has a risk (probability of exceedance) associated with it.

• Seismic motions are transient and reversing (i.e., cyclic). The frequency or rate of these cyclic actions is generally very high, ranging from less than one Hz to greater than ten Hz.

• Seismic loads are superimposed on other permanent or frequently occurring loads. Although seismic effects are transient and temporary, seismic design has to consider the seismic effects given the presence of other sustained loads. Conventional design procedure under permanent and frequently occurring loads calls for the structure to remain undamaged (i.e., more or less within elastic range). Because of the differences discussed above, however, proper seismic design criteria should consider the nature and importance of the structure, cost implications, and risk assessment associated with such factors as public safety, loss of function or service, and other indirect losses.

### 1.7.1 Surface Structures vs. Underground Structures

For underground structures such as tunnels, the seismic design approach differs from that of the surface structures (e.g., bridges and buildings).

### 1.7.2 Surface Structures

In the seismic design practice for bridges, the loads caused by an extreme event (earthquake) in a seismically active region are often several times more severe than the loads arising from other causes. To design a bridge to remain elastic and undamaged for such infrequent loads is uneconomical and sometimes not possible Therefore, it is clearly not practical to use the same design approach to earthquakes as issued for other types of loads. The seismic design philosophy developed for bridges Surface structures is not only directly subjected to the excitations of the ground, but also experience amplification of the shaking motions depending on their own vibratory characteristics. If the predominant vibratory frequency of the structures is similar to the natural frequency of the ground motions, the structures are excited by resonant effect.

### 1.7.3 Underground Structures

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In contrast, underground structures are constrained by the surrounding medium (soil or rock).It is unlikely that they could move to any significant extent independently of the medium or be subjected to vibration amplification. Compared to surface structures, which are generally unsupported above their foundations, the underground structures can be considered to display significantly greater degrees of redundancy thanks to the support from the ground. These are the main factors contributing to the better earthquake performance data for underground structures than their aboveground counterparts.

### 1.7.4 Computational Analysis

Case-I Analysis of underground road tunnel subjected to seismic force is carried out by using STADD PRO Software.

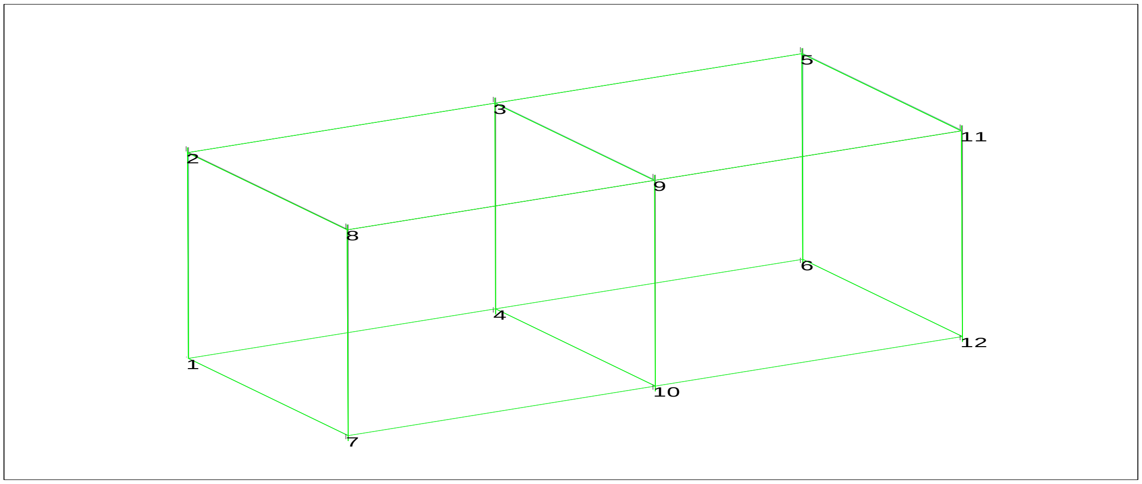


**Fig. 1 Proposed Various Nodes of the Structure**

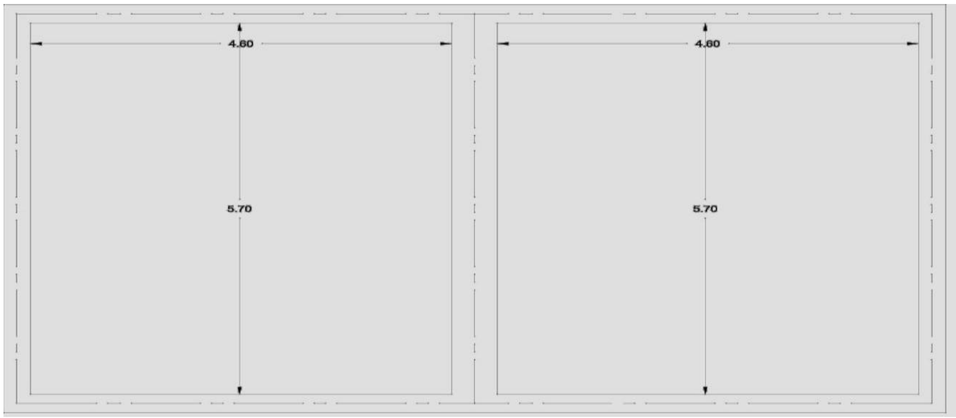


**Fig 2 Proposed geometry of tunnel structure**

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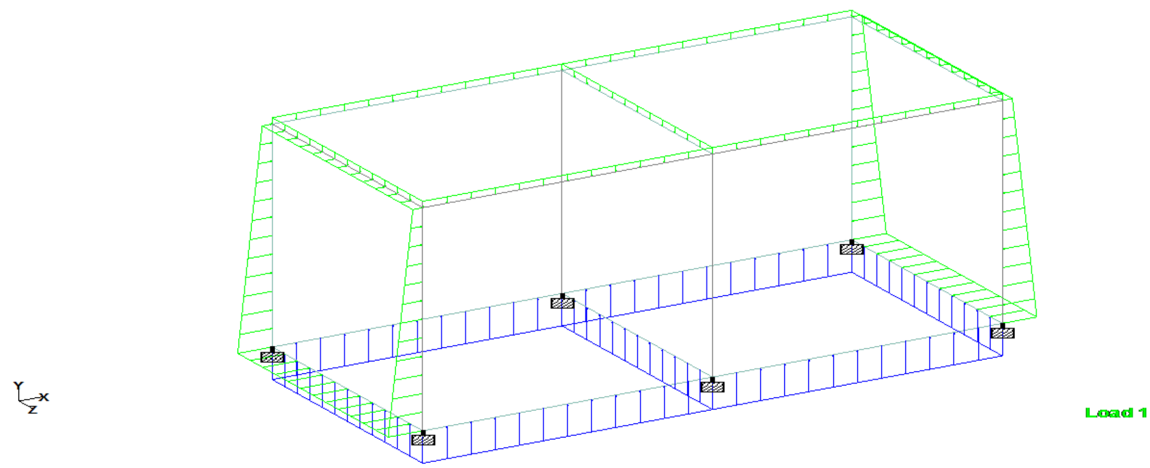


**Fig 3 Load distribution on Structure**

## II CONCLUSION

From the study done over here in this paper work for analysis of tunnel subjected to various forces, it can be seen that when the tunnel is analyzed for seismic loads and combinations which includes surcharge, self-weight earth pressure, vehicular load, uplift pressure, active soil pressure, seismic force the forces and stresses are majorly developed in top plate as compared to any other component of tunnel. The development of high reaction values can be justified by provision of raft or inverted slab base. The present paper presented a broad overview of the concepts, methodology, immediate applications, loads combination, seismic design philosophy for tunnel and the behavior of underground structure subjected to seismic forces. Further when the study and analysis is done for consideration of seismic forces in lateral direction that is in both horizontal directions.

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