Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 7; April-June, 2015 pp. 611-615
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http://www.krishisanskriti.org/jceet.html

Seismic Hazard Response of Bhairabi-Sairang Tunnel Due to the Effect of Faulting

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Abstract—*In this study, structural response of Bhairabi-Sairang Tunnel due to presence of seismic faults has been thoroughly examined. There may be several active faults located in and around the project. Faults are the key seismic sources from where earthquakes are originated. The magnitude of earthquake will depend on the length of the fault. A long fault more than 200 km can produce earthquake of magnitude (M_w) more than 8.0 and smaller length less than 10 km will produce small magnitude earthquake. Now-a-days it is very much essential to identify the distance and length of a fault from the project site. Based on this, in the present paper, a case study of the Bhairabi Sairang Tunnel of 1.73 Km length located in the North Eastern Region of India has been selected to calculate the seismic hazard from the surrounding effect of faults. A comparative study of seismic hazard at the tunnel site has been made based on the location of faults with the seismic hazard obtained from the Indian Standards code of Practice.*

Keywords*: Faults, Seismic hazard, Soil factor*

1. INTRODUCTION

Seismic hazard at Bhairabi –sairang site is calculated from the existing seismotonic set up of the region. In the present paper, seismic hazard contributed from all seismic source potential at the bhairabi sairang tunnel has been thoroughly investigated. Bhairabi- Sairang tunnel has been sourrended by nearly 70 active faults . This faults has great effect on the tunnel during earthquake. Deterministic seismic hazard analysis has been carried out for the tunnel and the tunnel has been analysed..

2. SEISMIC STATUS OF THE TUNNEL

The tunnel is situated in Aizawl and laying in 23.75^0 N latitude 92.70^0 E longitude The city aizawl falls on the north eastern part of India which is highly seismic zone which has faced many high magnitude earthquake and there is probability of occurring earthquake magnitude larger than M_w $_=$8 in near future. North East of India has faced many devastating Earthquake in past. The Assam earthquake of 1897 occurred on June 12 in Assam and had an estimated moment magnitude of 8.1. The earthquake occurred on the South-South-West-dipping fault, named Oldham fault that forms the northern edge of the Shillong Plateau within the Indian Plate. There was a minimum displacement on the main fault of 11 m (36 ft), although up to 16 m (52 ft) has been calculated, one of the greatest for any measured earthquake. The Assam earthquake of August 15, 1950, which had a magnitude of 8.6 on the Richter scale, was centered near Rima in the Tibet region of China, but the Brahmaputra Valley in the northeastern Indian state of Assam experienced the most extensive damage. The earthquake that struck Cachar, Assam on 10th January 1869 was of magnitude 7.5 caused heavy damage in the region. The impact of the shock was felt over 6,50,000 square kilometers.

The tunnel is located in Surma valley region. It is observed from the seismotonic map in the fig .1 that the tunnel is sourrended by several active faults. All the faults are capable of producing earthquake lower to higher magnitude . Mat faults lies very near to the tunel . Sylhet fault, Dauki fault, Kopilli fault, Dhubri fault are the nearby devastating faults that may largly effect tunnel. Recent recordings of earthquake events clearly demonstrate that Kopilli fault is highly active at present. The Jammu or Dhubri fault has been the source for 1931 (M_w=7.1) Dhubri earthquake. Movement along the Dhubri fault generated the 1897 great Assam earthquake.

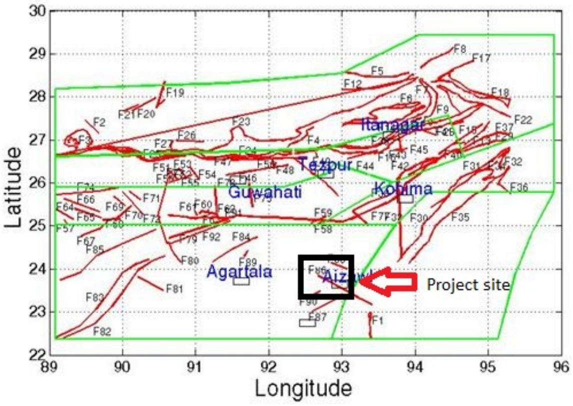

Fig. 1: Seismotonic map of North-East of India

3. ANALYSIS MODEL

The Bhairabi sairang tunnel is a horse shoe shaped tunnel . The finished diameter of the tunnel is 6.940 m and the height of the tunnel is 7.4520 m. The width of the tunnel at the base is 6.451.Outer area of the Tunnel 63.15m^2. Finished area of the Tunnel 45.73 m^2 .Concrete lining thickness provided 0.50 m. Unit weight of concrete 25 KN/m^3. The detailed dimension of the tunnel is as shown in Fig. 2.

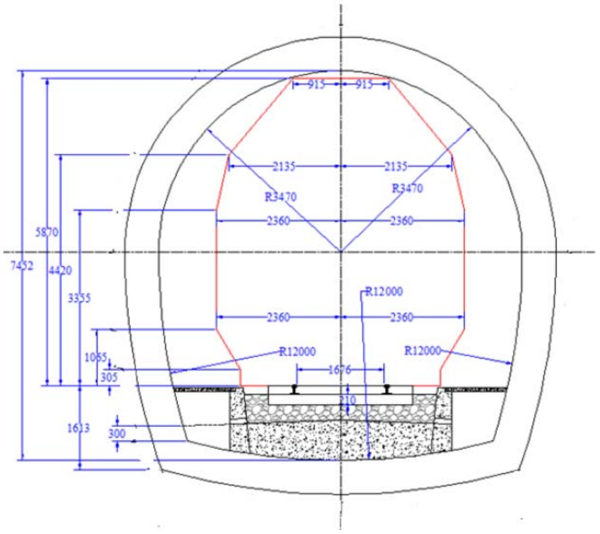

Fig. 2: Bhairabi sairang tunnel cross-section

Material Properties : Soil properties were collected from northeast zone of the N.F. Railway department. Here we have taken the soil parameter of these soil sample from the site of tunnel Bhairabi- Sairang section.

Table 1: Soil Parameter

Soil Parameter	symbol	unit	value
Young modulus	E	KN/m2	120x10^3
Poisson's ratio	µ		0.3
Unit weight	ϒ	KN/m3	20.4
Saturated unit weight	ϒsat	KN/m3	25
Cohesion	C	KN/m2	50
Friction angle	ф	degree	30

Table 2: Material Properties

Name	E(KN/m2)	µ	Unit weight(KN/m2)
Concrete	2.17E+07	0.17	24
Steel	2.00E+08	0.3	78

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4. AUTHOR NAME(S) AND AFFILIATION(S)

Site specific seismic hazard evaluation studies require estimation of strong ground motion from probable Earthquakes. The estimation of peak ground acceleration in terms of magnitude, source-to-site distance, tectonic environment and source type using attenuation relationships has been a major research topic in seismic hazard estimation studies. Such relationships are developed in past for various regions and comprehensive reviews have been published for such relationships Boore and Joyner (1982), Campbell (1985), Joyner and Boore (1988), Abrahamson and Letihiser (1989), Fukushima and Tanaka (1990), etc. Here for our project work peak ground acceleration at bed level are obtained using ground motion attenuation relation proposed by T. Rahman et al. 2008 for the North Eastern Himalayan and its surrounding region of India

$$\mathrm{InYbr} = C1 + C2(Mw-6) + C3(Mw-6)(Mw-6) - \mathrm{InR} - C4R + \mathrm{In}(ebr) \quad (1)$$

Where , M, R represents the PGA/SA value on the bedrock level in 'g', moment magnitude (Mw) and the hypocentral distance respectively .Peak ground acceleration at bed rock level for different time period is calculated using the formula (1) for corresponding period.

When seismic waves passes from the bed rocks to the surface through overlying soil at the faults, it may get amplified or de-amplified. Spectral acceleration co-efficient (Sa/g) at surface level are obtained using soil amplification factor. The variation of spectral acceleration at surface level vs time period is shown in Table1.

Table 3: Spectral Acceleration at Surface Level for Corresponding Time Period

Time period (Sec)	Peak Ground Acceleration at bed level	Soil coefficient	Spectral Acceleration (Sa/g) at surface level
0	1.218	1.5	1.827
0.01	1.2157	1.45	1.762765
0.015	1.4262	1.37	1.953894
0.02	1.9591	1.34	2.625194
0.03	3.4424	1.3	4.47512
0.04	3.6401	1.28	4.659328
0.05	3.3146	1.27	4.209542
0.06	3.0151	1.25	3.768875
0.075	2.6668	1.23	3.280164
0.09	2.398	1.22	2.92556
0.1	2.2532	0.91	2.050412
0.15	1.767	0.83	1.46661
0.2	1.4832	0.72	1.067904

0.3	1.1587	0.64	0.741568
0.4	0.9721	0.51	0.495771
0.5	0.8492	0.4	0.33968
0.6	0.7592	0.35	0.26572
0.7	0.6925	0.3	0.20775
0.75	0.6625	0.3	0.19875
0.8	0.6381	0.3	0.19143
0.9	0.595	0.3	0.1785
1	0.5573	0.3	0.16719
1.2	0.4973	0.3	0.14919
1.5	0.4279	0.3	0.12837
2	0.348	0.3	0.1044
2.5	0.3089	0.3	0.09267
3	0.2506	0.3	0.07518
4	0.1934	0.3	0.05802

The maximum and minimum value of PSA are 4.659g and 0.05801g at the time period of 0 .04 second and 4.0 second.

5. SECOND AND FOLLOWING PAGES

The tunnel has been analysed for first 50 metre construction stages. It has been analysed for the response spectrum analysis when excitation is in x direction for 5% damping using both IS code 1893 :2002 method and the responses obtained due to seismic faults around the tunnel site. Crown and bottom nodes are the most critical zones of tunnel. The model of the tunnel has been divided into 5 parts (5 node) at 10 metre interval. At each 10 metre interval at crown displacement, shear force and bending moment due to IS code method and responses due to faults around the tunnel are calculated and compared graphically

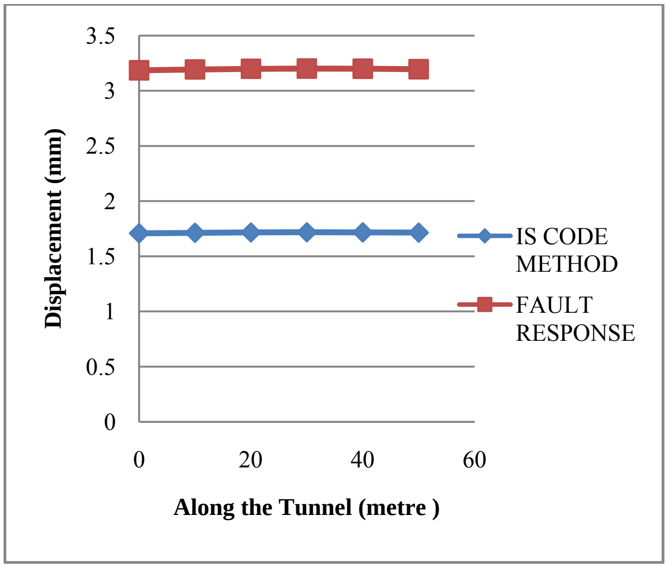

Fig. 3: Displacement at crown in x direction for response spectrum analysis at 10 metre interval

The displacement at crown in x direction obtained due to response spectrum analysis when excitation is in x direction is shown in fig 3. At 10 metre interval displacement is calculated .Displacement is more in case of faults response than IS code method .

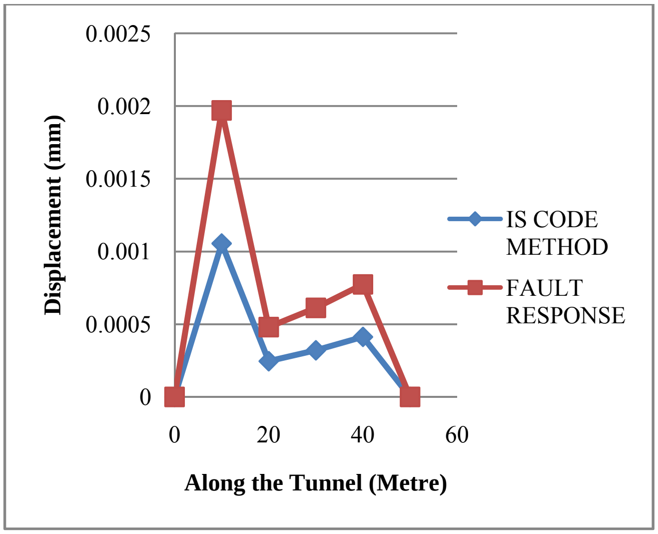

Fig. 4: Displacement at crown in y direction for response spectrum analysis at 10 metre interval

The displacement at crown in y direction obtained due to response spectrum analysis when excitation is in x direction is shown in fig 4. The units is in milli metre . Displacement is more in case of faults response than IS code method.

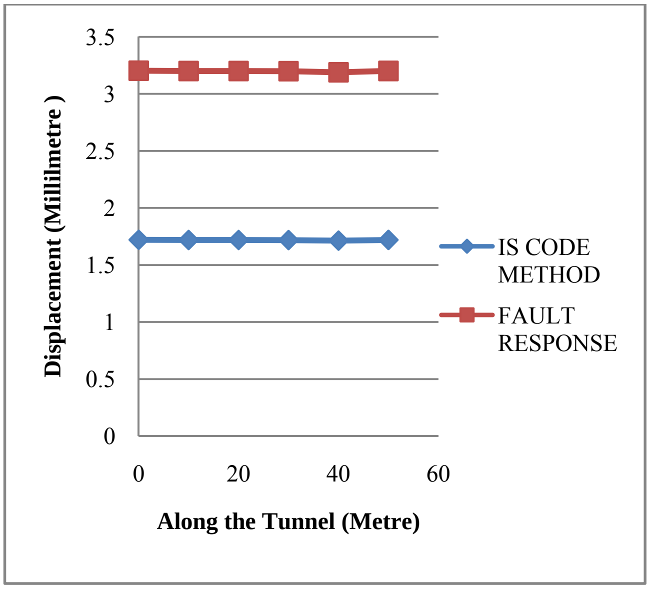

Fig. 5: Displacement at crown in z direction for response spectrum analysis at 10 metre interval

The displacement at crown in z direction obtained due to response spectrum analysis when excitation is in x direction is shown in fig 5. The units is in milli metre Displacement is more in case of faults response than IS code method.

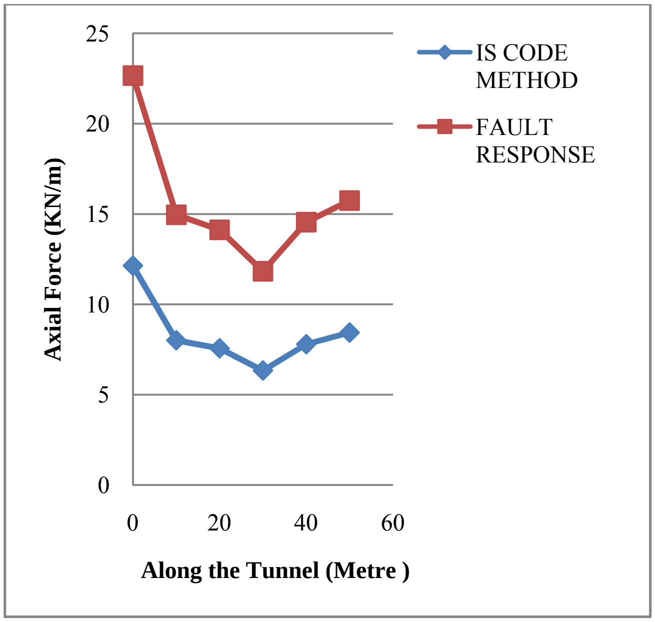

Fig. 6: Axial force at crown in x direction for response spectrum analysis at 10 metre interval

The axial force at crown in x direction obtained due to response spectrum analysis when excitation is in x direction is shown in fig 6. The unit is in KN/m. Axial force is more in case of faults response than IS code method.

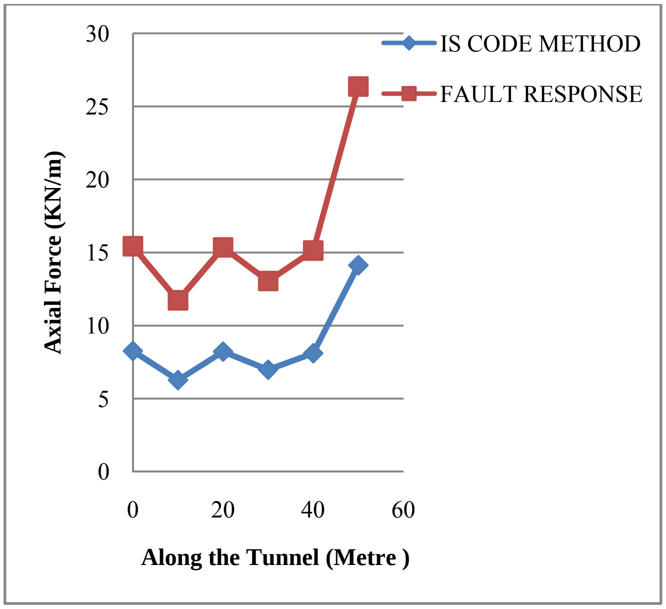

Fig. 7: Axial force at crown in y direction for response spectrum analysis at 10 metre interval

The axial force at crown in y direction obtained due to response spectrum analysis when excitation is in x direction is shown in fig 7. The unit is in KN/m. Axial force is more in case of faults response than IS code method

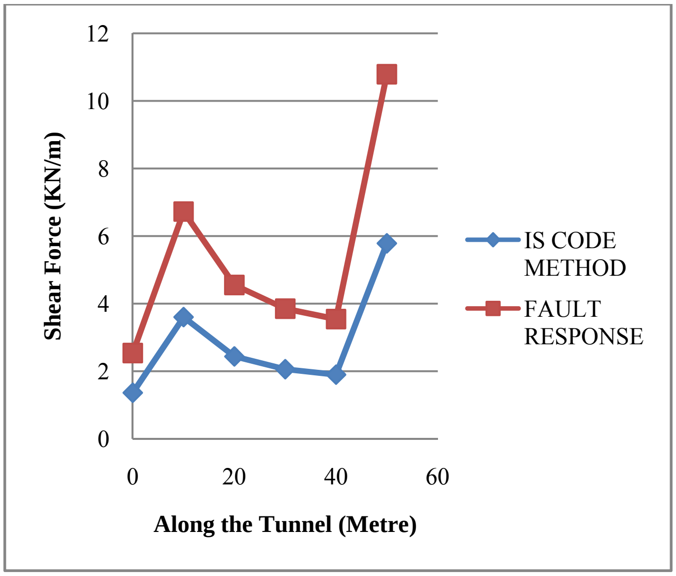

Fig. 8: Shear force at crown in xy plan for response spectrum analysis at 10 metre interval

The shear force at crown in xy plan obtained due to response spectrum analysis when excitation is in x direction is shown in fig 8. The unit is in KN/m. Shear force is more in case of faults response than IS code method

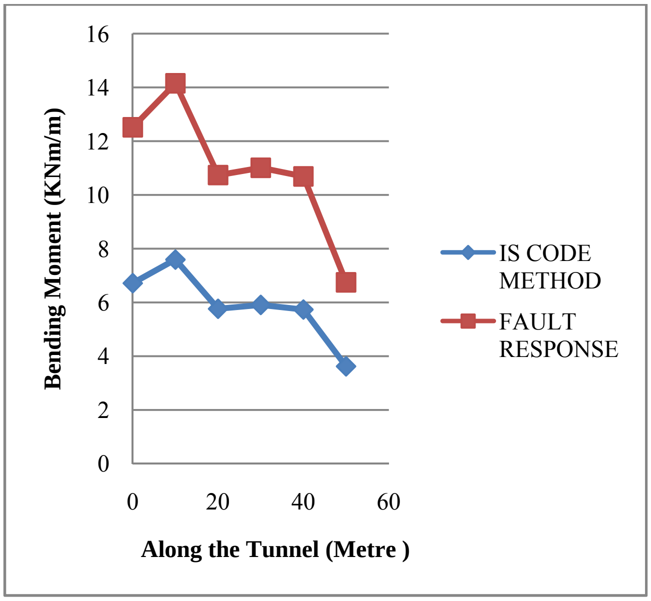

Fig. 9: Bending Moment at crown in x direction for response spectrum analysis at 10 metre interval

The bending moment at crown in x direction obtained due to response spectrum analysis when excitation is in x direction is shown in fig 9. The unit is in KNm/m. Bending moment is more in case of faults response than IS code method

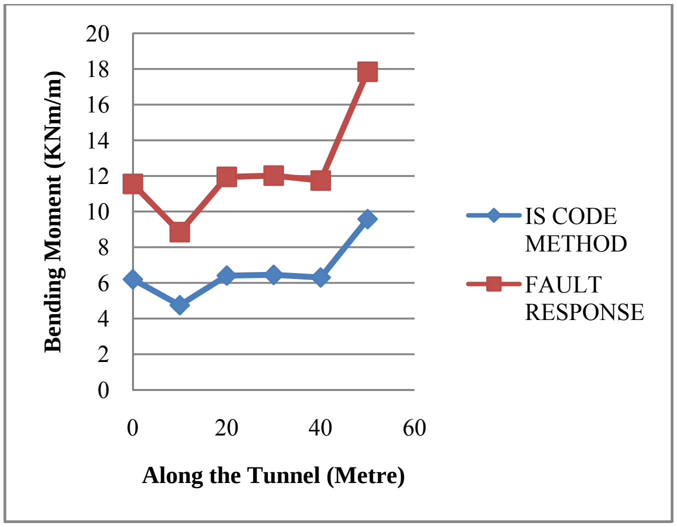

Fig. 10: Bending Moment at crown in y direction for response spectrum analysis at 10 metre interval

The bending moment at crown in y direction obtained due to response spectrum analysis when excitation is in x direction is shown in fig 10. The unit is in KNm/m. Bending moment is more in case of faults response than IS code method

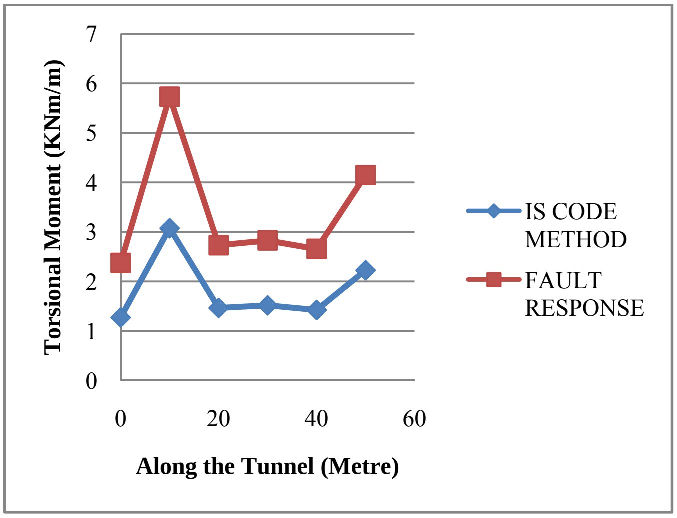

Fig. 11: Torsional Moment at crown in xy plan for response spectrum analysis at 10 metre interval

6. CONCLUSION

The IS code has adopted a uniform response spectra for all regions across India. The maximum value of response spectra given by IS code for highly seismic zone is 2.5g where as in our calculation we have got 4.659g which is in stark contrast with those given by IS code. As a result the displacement , shear force , bending moment due to the faults is more than IS codal method

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