

A Comparative Study of Seismic Analysis of a Horse Shoe Tunnel for Different Types of Soil

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ABSTRACT: The main issue of this thesis is to study the influence of different ground soils in structural behaviour of deep and long tunnel in highly seismic prone hilly area. Tunnels in hilly area are very necessary structures to create transport facilities as like plenty area. It makes possible to establish transportation networks such as highway, railway or subway in very steep terrain and highly landscape prone hills. That's why it has become as an integral part of transportation in hilly areas. But designing and construction of it becomes very challenging when there is present variation of soil formations along the proposed tunnel line. To investigate this problem and to find out some solutions of it a tunnel model of 25 meter length of horse shoe shape which is most commonly used for tunnel cross section, was considered in this thesis. Afterwards, it was analysed for different types of soil like as hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil with the help of MIDAS GTS software. Data of these soils were collected from N. F. Railway, Silchar in the Bhairabi –Aizawl section. Finally the displacements, axial forces, shear forces and bending moments of the cross section of this tunnel model for every type of soil were analysed and compared to each other. In this way this study permits to assess the influence of different types of ground soil in the tunnel behaviour.

KEYWORDS: Horse shoe shape tunnel, Railway, Different types soil, Hilly area.

I. INTRODUCTION

In the present thesis, a horse shoe tunnel has been thoroughly investigated based on the soil on the soil properties supplied by N. F. Railway, Silchar in the Bhairabi –Aizawl section. In the present work, the tunnel has been analysis for different types of soil. It has been observed that various stress properties vary abruptly with the variation of soil properties. In the present case, Tunnel is located in a highly seismic zone where there is a probability of occurring high magnitude earthquake ($M_w > 8.0$) in future. Tunnel is a very important engineering structure where special attentions are required for the analysis and design purpose in an earthquake prone area. It is better to consider the site specific ground motion time history in the analysis of Tunnel based on the surrounding seismic source potentials.

Earthquake is random in nature and it is not possible to predict the specific location and time of future earthquake. So, engineering structures should be design such that it can sustain the all sorts of dynamic forces that may be arises from a probable earthquake in a region.

II. RELATED WORK (LITERATURE SURVEY)

In the analysis and design of tunnels, lot of work appears to have been done such as : Villy a. Kontogianniet al., [2003] examined details of Earthquakes and Seismic Faulting: Effects on Tunnels. They have presented that tunnel excavated in tectonically inactive areas such as NW Europe are not vulnerable to seismic faults and shaking. But for tunnel in tectonically active areas earthquake and faulting represent important cause of failure, both during construction and their operating.

Christoph Butscher [2012] have done Steady-state groundwater inflow into a circular tunnel. He has presented that inflows are higher for lined tunnels with a drainage layer than for unlined tunnels, if the head in the drainage layer corresponds to the level of the tunnel center or invert. If the head in the drainage layer corresponds to the level of the

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tunnel crown, inflows are higher for unlined tunnels. He has further suggests that for unlined tunnels, inflows are higher at the invert than at the crown. For lined tunnels with a drainage layer, the reverse is true. Differences between inflows at the crown and invert decrease with increasing depth of the tunnel under the groundwater table.

A.Giannakon, et al.,[2005] worked on the Seismic Behaviour Of Tunnels In Soft Soil: Parametric Numerical Study And Investigation On The Causes Of Failure Of The Bolu Tunnel (Düzce,turkey, 1999).They have presented the dynamic response of circular tunnels .

Yiming Sun et al., [2008] have done Seismic Analyses of the Bay Tunnel. They have represented ground degradation during seismic ground motion is reasonable for dynamic analysis.

ElefterijaZlatanović[2008] has done comprehensive work on influence of earthquakes on the stress and strain state of the shallow tunnel structures in saturated soil of low bearing capacity. He has presented the deformations of tunnel structure under the influence of earthquake and seismic impact on shallow laid tunnel by the analysis of longitudinal and transversal loads.

III. IMPORTANCE OF TUNNEL IN THE NORTH EASTERN REGION OF INDIA

The Northeast region, a part of Eastern Himalayas, consists of Northeast Hills like Patkai-naga hills and Lushai hills and the Brahmaputra and the Barak Valley Plains.

In Indian sub-continent's, Northeast region of India has some of the last remaining rain forests which supports diverse flora and fauna and several crop species. Mighty Brahmaputra-Barak river systems and their tributaries covered this region. Altitude varies in this from almost sea-level to over 7,000 meters above MSL and average rainfall in this region occurs around 10,000 millimetres and above. High seismic activity and landslides also occurs in this part of India. The entire area is densely forested mainly consisting of Sandstones.

The following priority Eco regions has identified by WWF in North-East India:

- The Eastern Himalayan Broadleaved Forests
- The Eastern Himalayan Sub-alpine Coniferous Forests
- Brahmaputra Valley Semi Evergreen Forests
- India–Myanmar Pine Forests

North East India is a part of Indo-Burma 'hotspot'. The hotspot is the world's second largest. more than 60% area of the North Eastern states have under forest cover, In India out of 1500 endangered floral species, 800 are reported from North East India according to the Indian Red data book published by the Botanical Survey of India. In the North Eastern region six important vegetation types of India are found out of nine.

Considering all these importance of the land surface of this region and hazardous situations like landslides due to heavy rainfall or due to an earthquake,

- It will be better to construct tunnel for connecting different places rather than open road or railway. Tunnelling will not disturb the forest environment and also the distance between places will be reduced drastically as tunnel will proceed straight through the hills.
- Tunnelling will reduce traffic on cities with subway station and decrease the loss of all important working hour.
- Tunnelling can also resolve water requirement with bringing water from rivers.
- Moreover tunnel is highly needed to change the economic status of region providing extra working time to the recipients of this area.
- As tunnelling will change the transportation system of this region & it will welcome many investors who are already attracted to this region's petroleum and natural gas reserve.
- In general tunnelling will change the life style of this corner of the world without effecting its huge natural environment and using its resources properly whole country can improve a lot.

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IV. SELECTION OF HORSE SHOE TUNNEL

It is very popular form of tunnels. It has semi-circular roof together with arched sides and curved invert. The cement concrete lined horse shoe cross section offers a good resistance to external ground pressure. The shape is most popular for traffic tunnels such as highways or railways.

Horse shoe tunnel provided better resistance, compared to the stress developed at the bottom of the tunnel due to concave distribution, thus reducing the floor heaving of the tunnel.

It may be generally started, that dimensioning of tunnel section must be effected either against the overburden weight (geostatic pressure) or against loosening pressure (i.e. the weight of loosened zone called also protective or trompeter's zone).

The most important potential loads acting on the underground structure are earth or rock pressure and water pressure. In all countries of the world this shape very commonly is used for constructing highways and railways tunnels. The floor of the tunnel is flat enough to give working space to the contractor.

Considering the advantages and disadvantages of each cross-section, their construction ease, rock load supporting capacity, Horse shoe- Shaped cross-section is proposed for Bhairabi-Aizwal section of N.F. railway. The cross-section is adopted based on the railway standards for electrified sections. Diameter and height of the tunnel are 7.426m and 7.3m.

The proposed cross section of the tunnel is as follows

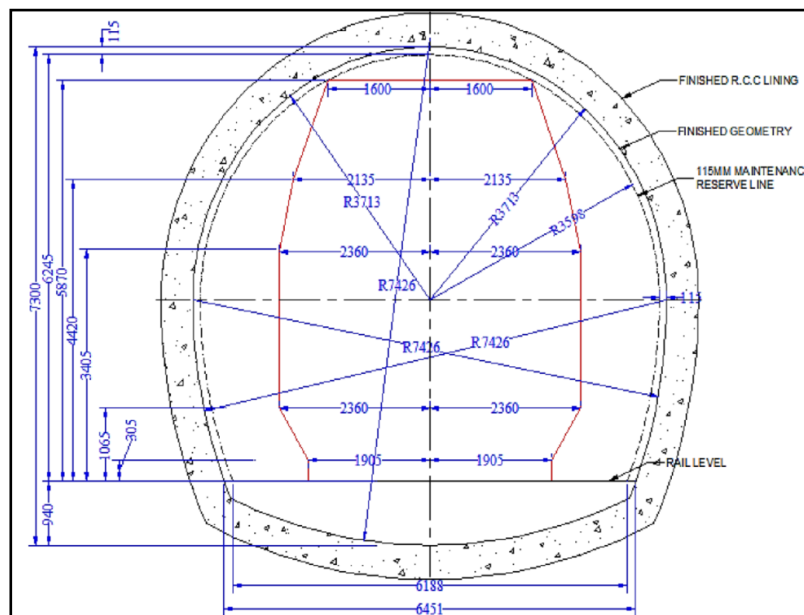


Fig.1. Proposed Horse-Shoe shaped cross section for Railway Tunnel

V. RESULTS

We have analysed the Horse Shoe tunnel section. The horse shoe tunnel has been analysed for six different types of soil condition such as hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil using MIDAS GTS software. Crown is the most critical zone of tunnel. So, for each type of soil displacement, axial force, shear force and bending moment have been estimated at crown nodes. Figure 2, 3, 4, 5,6 and 7 shows the displacement, axial force, shear force and bending moment in crown nodes.

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Fig.2 compares the displacement in x direction for different types of soil at crown nodes which is located at the top part of the tunnel. Here displacements at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 0.00103276m, 0.001104112m, 0.001539522m, 0.002070663m, 0.002534998m and 0.002662m respectively.

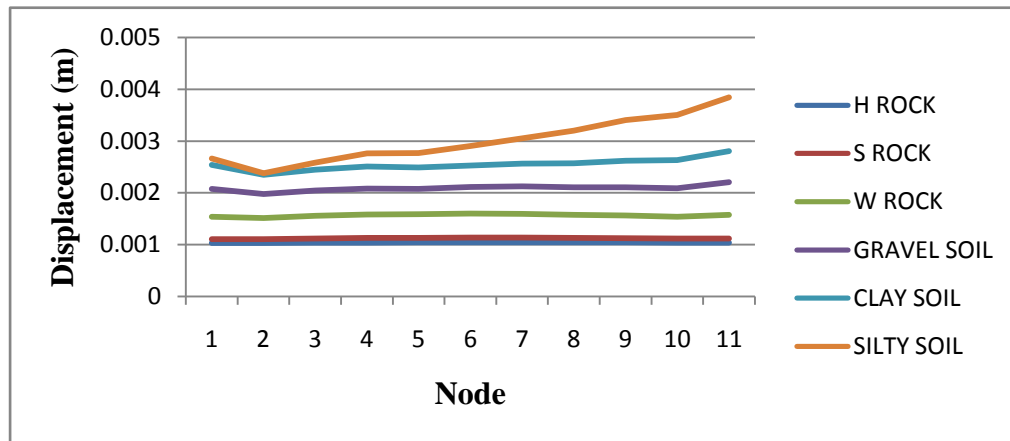


Fig.2. Displacement at crown in x direction

After that displacement for hard rock, soft rock, weathered rock, gravel soil and clay soil are constant up to node no.11. But displacement for silty soil is going to increase up to node no. 11 in positive direction. Value of displacement at node no.11 is 0.00384246m. So, maximum displacement throughout the tunnel is occurring at node no. 11 for silty soil.

Fig.3 also compares of displacements in x direction for different types of soil at crown nodes which are located at the top part of the tunnel. Here axial forces at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 72.12326kN/m, 244.45859kN/m, 941.13719kN/m, 1592.8147kN/m, 1826.09597kN/m and 2068.99498kN/m respectively.

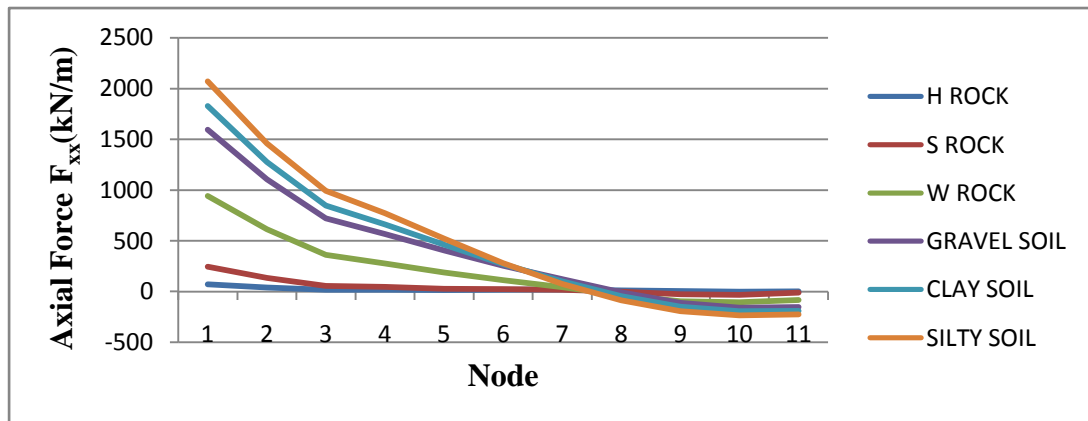


Fig.3. Axial Force at crown in x direction

After that axial F_{xx} are going to decrease up to node no. 7. Again axial force starts to slightly increasing up to node no. 11 in negative direction. So, maximum axial force throughout the tunnel is occurring at node no. 1 for silty soil.

Fig.4 compares the axial force F_{yy} for different types of soil at crown nodes which are located at the top part of the tunnel. Here axial forces at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are -44.44111kN/m, -129.3838kN/m, -55.46kN/m, 197.6538kN/m, 307.8416kN/m and 493.7677kN/m respectively.

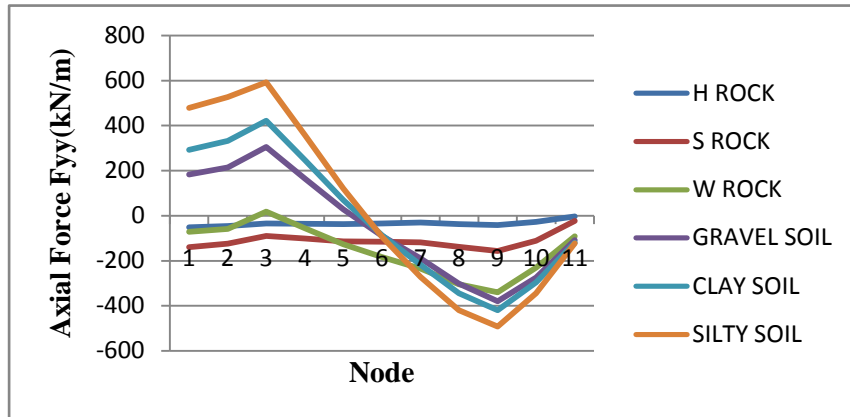


Fig.4. Axial Force at crown in y direction

After that axial force for hard rock and soft rock are almost constant up to node no.11. But the axial force for weathered rock is continuously increased up to node no. 9 in negative direction. For weathered rock, the value of shear force at node no. 9 is -333.5839kN/m. After that this value is decrease up to node no 11 in negative direction. But shear force for weathered rock, gravel soil, clay soil and silty soil are going to increases in positive direction up to node no.3. Values at node 3 are 315.5770kN/m, 432.3719kN/m and 602.4664kN/m in above mentioned sequence. After that these values are decreases up to node no.6 in positive direction. Then these values are again going to increase up to node no.9 in negative direction. After that these values are going to decrease up to node no. 11 in negative direction. So, maximum axial force throughout the tunnel is occurring at node no. 3 for silty soil.

Fig.5 compares the shear force F_{xx} for different types of soil at crown nodes which are located at the top part of the tunnel. Here shear forces at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 45.57356kN/m, 139.76602kN/m, 395.40977kN/m, 574.58576kN/m, 658.69859kN/m and 757.43861kN/m respectively.

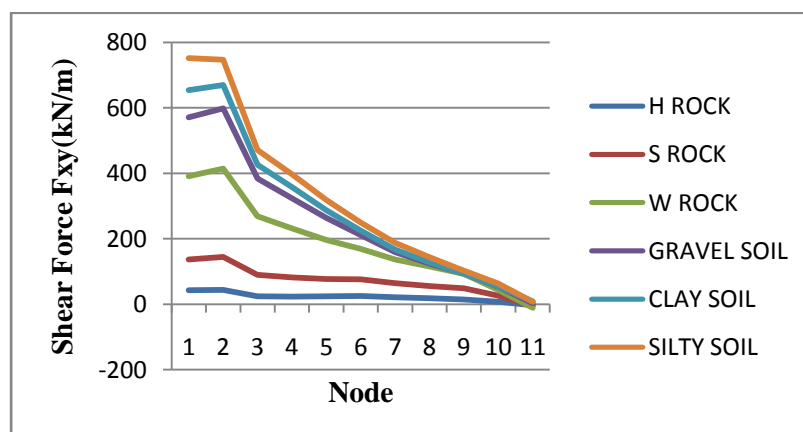


Fig.5. Shear Force at crown in xy Plane

After that shear forces are constant up to node no. 2. Again the displacements are decreasing continuously up to node no. 11. So, maximum shear force throughout the tunnel is occurring at node no. 1 for silty soil.

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Fig.6 compares the moment M_{xx} for different types of soil at crown nodes which are located at the top part of the tunnel. Here moments at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 0.280764kNm/m, -0.563641kNm/m, 2.254405kNm/m, 9.15693kNm/m, 3.084kNm/m and -41.16286kNm/m respectively. After that moment for hard rock, soft rock, weathered rock, gravel soil and clay soil are almost constant up to node no.11. But moment for silty soil is increase up to node no. 3 in negative direction.

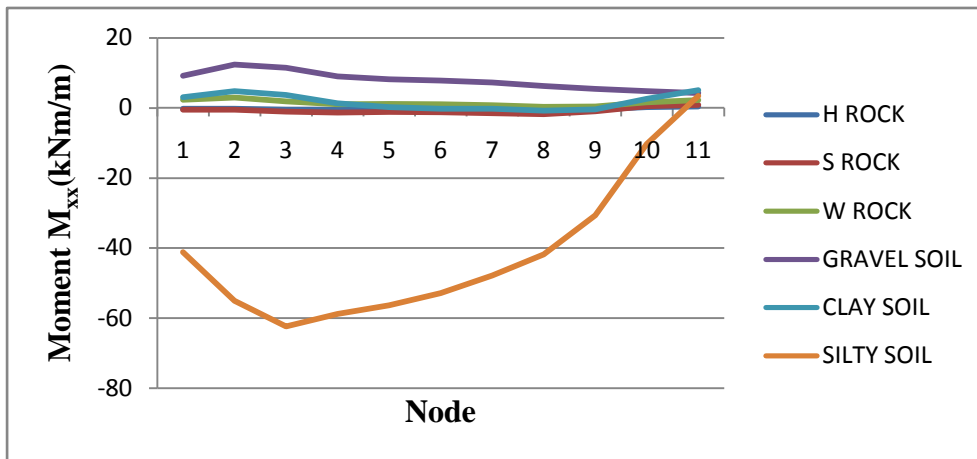


Fig.6. Moment at crown in x direction

After that this value is again going decrease up to node no. 11. So, maximum moment throughout the tunnel is occurring at node no. 3 for silty soil.

Fig.7 presented a graph between moment M_{yy} and node no. The graph is drawn for six types of soil such as hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil when response spectrum load towards x direction.

This graph compares the moment M_{yy} for different types of soil at crown nodes which are located at the top part of the tunnel. Here moments at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 2.795476kNm/m, 6.986834kNm/m, 27.71109kNm/m, 59.90099kNm/m, 44.01267kNm/m and -91.1488kNm/m respectively. After that moment for hard rock and soft rock are almost constant up to node no.11.

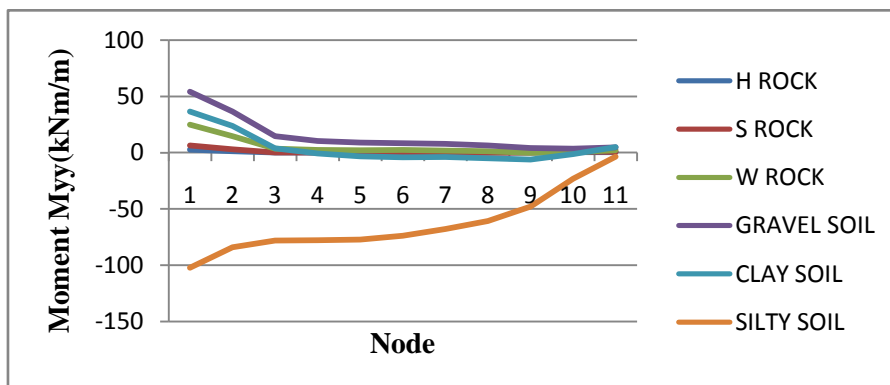


Fig.7. Moment at crown nodes in y direction

But moment for weathered rock, gravel soil and clay soil are going to decrease up to node no 3 in positive direction. Then these values are constant up to node no. 11. But for silty soil the value of moment is gradually decrease up to node no.11. So, maximum moment throughout the tunnel is occurring at node no. 1 for silty soil.

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V. CONCLUSIONS

Author of this paper analyse the horse shoe tunnel in different types of soil and compare the values of displacement, shear force and bending moment at crown, left side and right side nodes of the tunnel. It is observed that: - Based on the results of the research, the following conclusions can be drawn:

1. In general, hard rock is more suitable for in horse shoe shape tunnel, where achieve economic design by decreasing in quantities of concrete and reinforcement, because the displacement, shear force and bending moment of hard rock is less than other types of soil.
2. The horse shoe shape of tunnels is more suited for traffic purpose than other shape of tunnels.
3. The horse shoe shape of tunnel in silty soil more affected, because the displacement, shear force and bending moment of silty soil is greater than other types of soil.
4. Final (inner) lining is not considered in the analysis, but adds extra structural safety. However, in the case, site investigation showed that inner lining carries a considerable amount of load. Hence, to improve the results the contribution of the inner lining is to be taken into consideration in the analysis.
5. Inlongitudinal direction, steady state conditions are to be achieved at a certain distance behind the tunnel face. This distance varies and it depends upon the K_0 value. As the K_0 value an increase, the distance is reduces and as the K_0 value reduces, the distance rises.
6. The results of 3D analyses are in good, in general, with the site data. However, the predictive capability of the 3D model can be increased by further calibrating the model. To give an example, the ground behaviour can be represented by different material models other than Mohr Coulomb model to improve the accuracy of the results. Analyses with considering the water table may add improvement to the design from the long term point of view.

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