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A Comparative Study of a D Shaped Tunnel for Different Types of Soil

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Abstract—*In this paper, we have analyzed a D Shaped tunnel for different type of soil profile. We have estimated various structural parameters for each type of soil profile. In this study, we have considered six types of soil profiles. There are wide variation of Bending moment, Shear forces, Axial force and displacement along the cross section of tunnel. For each type of soil profile we have calculated all the structural parameters at the crown, left and right periphery of D shape tunnel. We have made a comparison of the structural parameters at the crown and the side periphery of the tunnel. It gives us clear idea how the size of a d shape tunnel will be vary due to the variation of the soil parameter. This work will be vary much useful for the tunnel engineer to select the suitable dimension of a D shaped tunnel for a given sample of soil profile.*

Keywords: *D Shaped of tunnel, comparative study, structural parameter, Displacement, Axial force, Bending moment.*

1. INTRODUCTION

The construction and use of tunnels can be considered as one of the most important features of civilization in developed nations. It became one of the necessities of life .Tunnel is an underground passage through a mountain, beneath a city or under a waterway or tunnels are enclosed roadways, railways, waterways etc. with vehicle, trains, ships etc. access that is restricted to portals regardless of type of structure or method of construction. Tunnels are structures that require special design consideration that may include lightning, ventilation, fire protection systems and emergency egress capacity, as documented in design standards. So the study of the soil-structure interaction is very important, because one of its important problems which face many tunnels especially in case of week or soft clay soil around the tunnels.There are many methods used for the analysis of underground structures with the finite element method remained the most capable and versatile method of analysis of tunnels in different soil. A numerical model is presented as a plane strain problem taking into consideration the soil-structure-interaction .Mohr-Coulomb is used to model the nonlinearity of soil. The MC model is an elastroplasticmodel, which is defined using E and ν for elasticity, c and φ for plasticity, andψ for dilatancy. The material of the lining was chosen as a reinforcement concrete. The effect of the change of soils using different values of the modulus of elasticity (Es) and the Poisson ratio (ν) in the tunnels internal forces and displacement and soil stresses of a D-shape tunnel was studied. After analyzing the tunnel for 6-different types of soil it is observed that various stress properties vary abruptly with the variation of soil properties. In this study, a D-shape tunnel has been investigated based on the soil properties supplied by N.f. Railway, silchar in the Bhairabi-Aizawl section. Underground structures are subjected to the deformation through the interaction between the ground and the structures. We have performed static as analysis by taking into account the vertical pressure, lateral pressure and bottom pressure and obtained the corresponding results of displacement, axial force, shear force and bending moment.

2. NUMERICAL MODELLING

The geotechnical design parameters for analyses were derived from field and laboratory test results, and based on experience on local and similar ground conditions. The parameters used in the static and dynamic design and analyses are presented in Table 2.1 and table 2.2.

Table 2.1

Properties	Hard Rock	Soft Rock	Weathered Rock
E	6.00E+06	2.00E+06	3.50E+05
v	0.2	0.25	0.3
Y	26	25	23
Ysat	26	25	23
c	200	120	35
Φ	25	20	34

Table 2.2

Properties	Gravel Soil	Clay Soil	Silty Soil
E	1.20E+05	7.50E+04	4.50E+04
v	0.3	0.3	0.35
Y	19	18	17
Ysat	20	20	19
c	35	30	20
Φ	35	30	25

Table 2.3: Lining Material

Properties	Concrete	Steel
E	2.17E+07	2.00E+08
v	0.17	0.3
Y	24	78

Where-

E-Modulus of Elasticity in kN/m^2

v-Poisson's Ratio

Y-Weight Density in kN/m^3

Y_{sat}-Saturated Weight Density in kN/m^3

c-Cohesion Value in kN/m^2

Φ-Angle of Internal Friction

The segmental tunnel lining design was carried out using 3D finite element (FE) program MIDAS GTS NX to obtain the stresses on the tunnel lining. Mohr Coulomb model was adopted and the soil material type is taken to be drained. The tunnel linings are modelled with hinges to simulate the joints between the Twenty segments. The analysis consists of various parametric studies to determine the most critical case with respect to 6 different types of soil, presence of surcharge, K0 value, lining thickness, and the depth of tunnel. The maximum bending moment and its corresponding axial force, shear force and displacement values are calculated from the MIDAS results.The tunnel has a width 8.66 m and height 8.84 m, and it is analyzed for a tunnel overburden of 40 m.

3. RESULTS

Critical zones of tunnel are crown, left and right side nodes. The numerical analysis for displacement, shear force, axial force and bending moment of D-shape tunnel is calculated from different types of soil on crown, left and right side nodes shown in the fig1.These values are taken in particular interval of 1m in longitudinal direction.

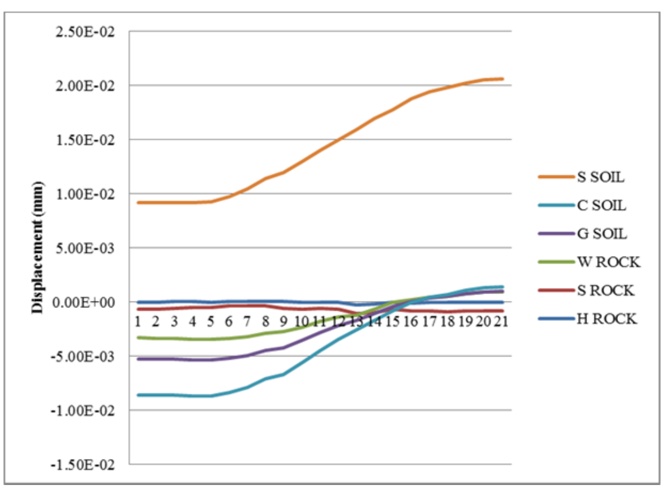

Fig. 3.1: Displacement at crown nodes in x direction

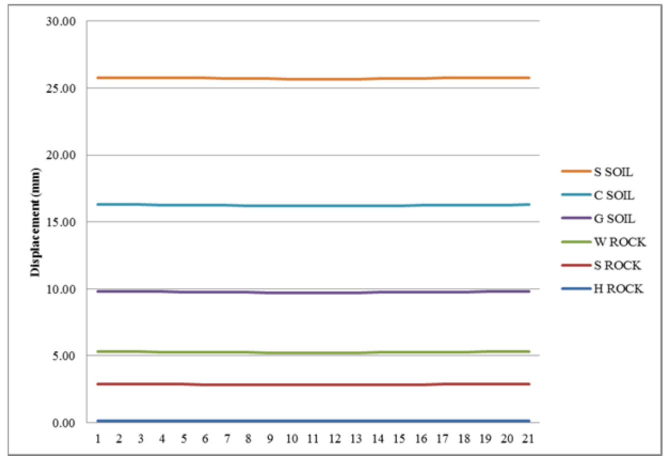

Fig. 3.2: Displacement at left side nodes in x direction

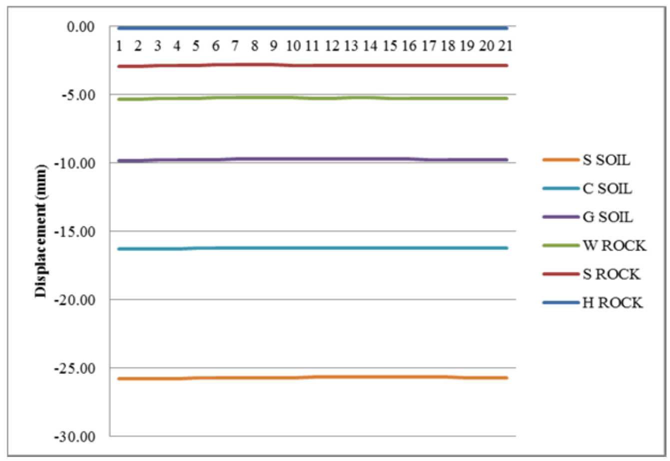

Fig. 3.3: Displacement at Right side nodes in x direction

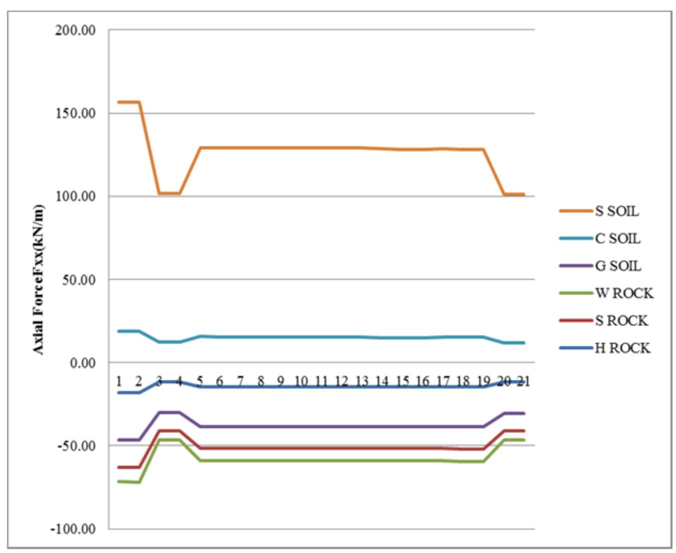

Fig. 3.4: Axial Force Fxx at crown

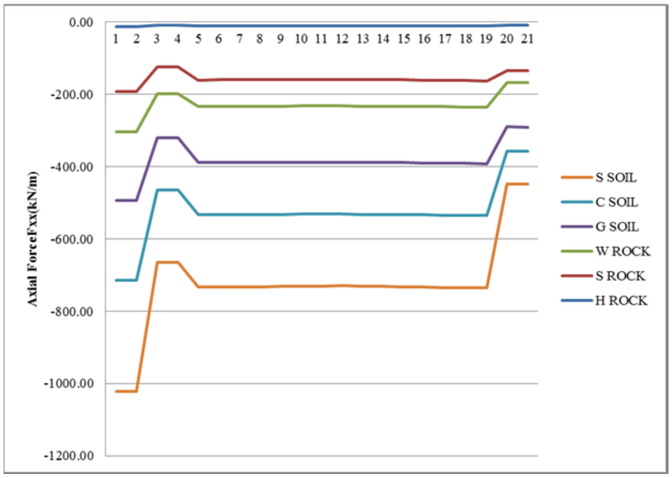

Fig. 3.5: Axial Force Fxx at left side nodes

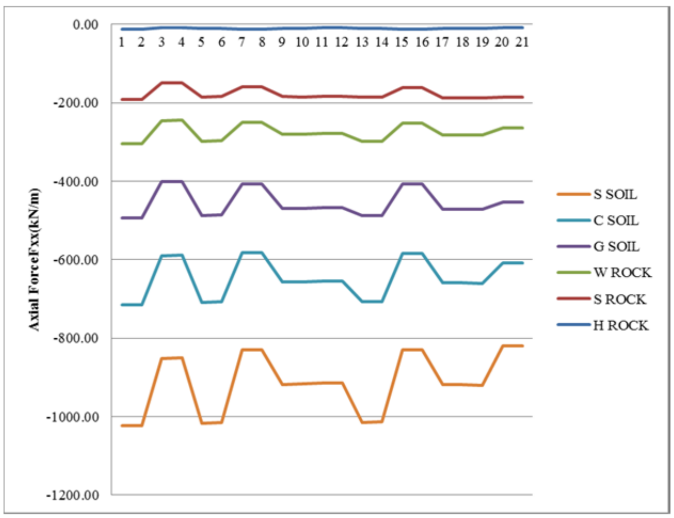

Fig. 3.6: Axial Force Fxx at right side

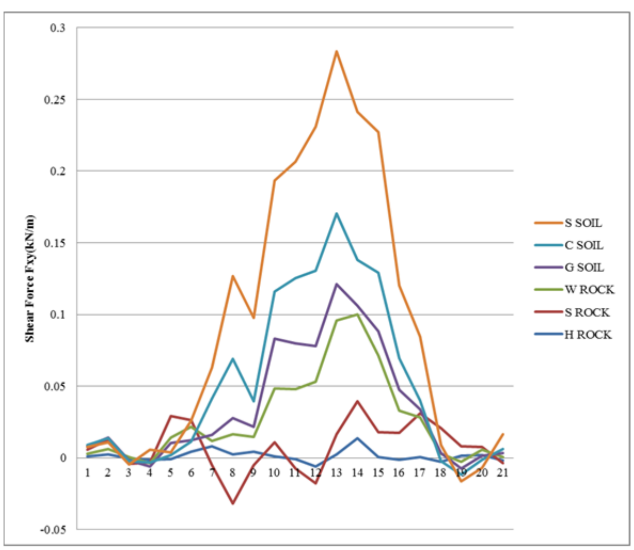

Fig. 3.7: Shear ForceFxyat crown

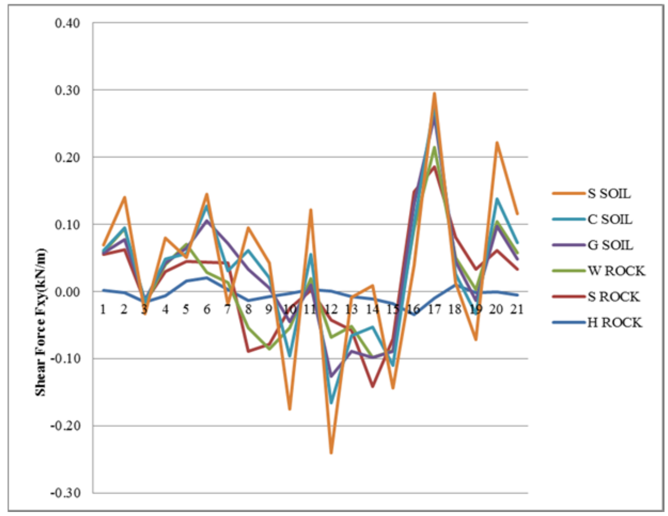

Fig. 3.8: Shear ForceFxyatleft side nodes

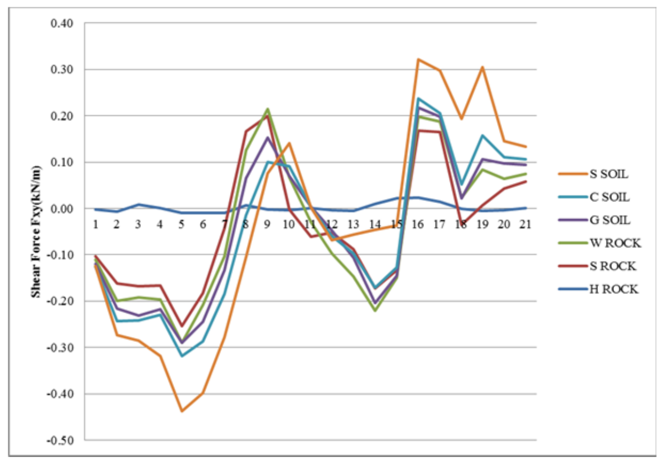

Fig. 3.9: Axial Force Fxyatright side nodes

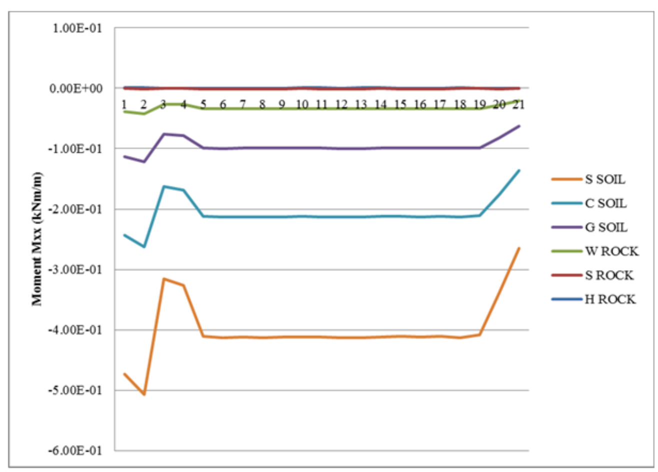

Fig. 3.10: Moment Mxxat crown

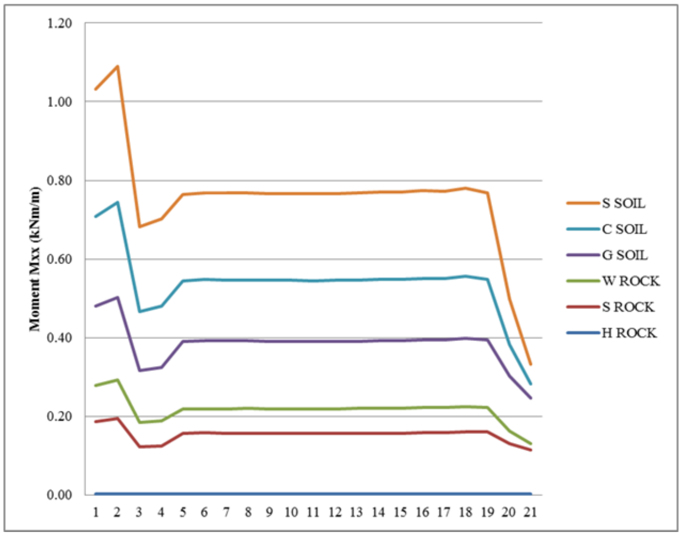

Fig. 3.11: Moment Mxxat left side nodes

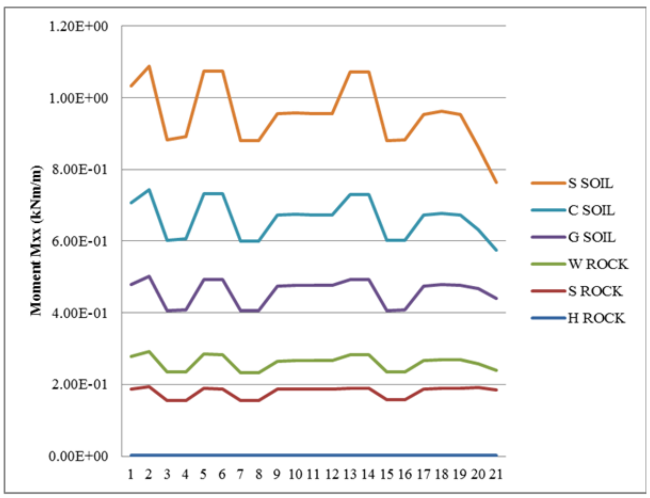

Fig. 3.12: Moment Mxxat right side nodes

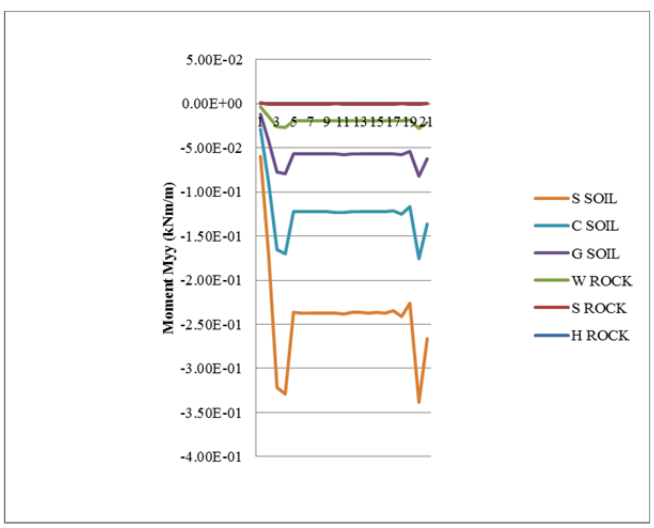

Fig. 3.13: Moment Myyat crown

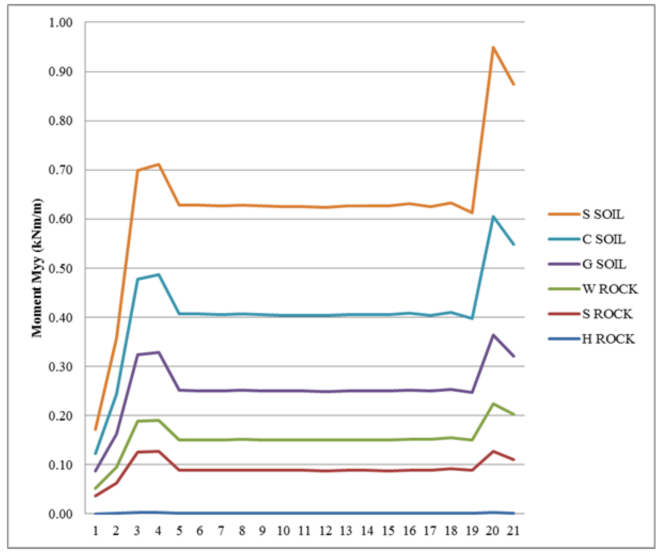

Fig. 3.14: Moment Myyat left side

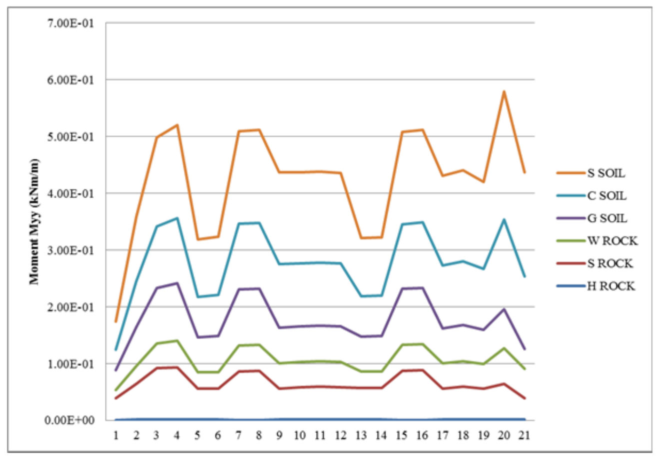

Fig. 3.15: Moment Myyat right side

4. DISCUSSION

After analyzing the D- shape tunnel we have calculated displacement in x direction , axial force F_{xx} , shear force F_{xy} and Bendng Moments M_{xx} , M_{yy} , for six different types of soil such as hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil using MIDAS GTS NX software. Graphs have been plotted between displacement vs node no,shear force vs node no and bending moment vs node no.

The numerical analysis of displacement of D-shape tunnel is calculated for six different types of soil on crown, left and right side nodes shown in the fig1.These values are taken in particular interval of 1m in longitudinal direction.

(Fig. 3.1)Here displacements at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 1.87E-07 mm, -7.00E-04 mm,-2.62E-03 mm, -1.97E-03 mm, -3.32E-03 mm and 1.78E-02 mm respectively. The graph evident that for hard rock and silty soil displacement value decreases continuously for consecutive nodes and got its maximum displacement as -2.38E-04 mm at node 13, and 1.93E-02 mm at node 21, whereas for soft rock, weathered rock, gravel soil and clay soil displacement values are increasing continuously and got the maximum negative displacement as -8.09E-04 mm at node 18, -2.99E-03 mm at node 5, -1.97E-03 mm at node 1 and -3.36E-03 mm at node 4 respectively. As can be seen from the graph (Fig3.2), the displacement values for all six type of soils are increasing continuously and got the maximum positive displacement as 0.13mm at node 2, 2.77 mm at node 21, 2.405 mm at node 16, 4.501 mm at node 5, 6.49 mm at node 4 and 9.49 mm at node 4 in earlier mentioned sequence. After reaching to their corresponding maximum values the displacement tend to decrease upto the last node. Fig. 3.3 presents graph between displacement and node nos. This graph compares the displacement in x direction for six different types of soil at right periphery of the tunnel. Here displacements at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are -0.130041 mm, -2.771580 mm,-2.405920 mm, -4.505750 mm, -6.498470 mm and -9.504310 mm respectively. After that the displacement values goes on increasing and got the maximum negative displacement as -0.13 mm at node 2, -2.77mm at node 1, -2.407 mm at node 4, -4.506 mm at node 4, -6.49 mm at node 4 and -9.51 mm at node 5 in earlier mentioned sequence. As you can see from this figure(Fig. 3.4), the displacement values are nearly same as left side node of the tunnel but with negative sign.

Fig. 3.4 shows the variation of axial force F_{xx} at crown for different types of soil. Here maximum axial force Fxx at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are -17.905 kN/m, -45.02 kN/m, -8.808 kN/m, 25.18 kN/m, 65.53 kN/m and 137.62 kN/m respectively. Fig. 3.5 shows the variation of axial force F_{xx} at Left side nodes for different types of soil. Here axial force Fxx at node 1 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are -12.83 kN/m, -178.66 kN/m, -112.91 kN/m, -189.34 kN/m, -221.41 kN/m and -307.62 kN/m respectively.The graph (Fig. 3.5) is about the variation of axial force Fxx at left side nodes along the length of the tunnel. As can be seen from the graph, the maximum value of axial force Fxx for soft rock and gravel soil occur at node 1, whereas hard rock, weathered rock, clay soil and silty soil got the maximum value at node 2 which are -12.868 kN/m, -112.908 kN/m, -221.409 kN/m and -307.615 kN/m respectively. Fig. 3.6 shows the variation of axial force F_{xx} at right side nodes for different types of soil. Here the maximum value of axial force Fxx for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are -12.84 kN/m at node1, -178.71 kN/m at node1, -112.96 kN/mat node2, -189.43 kN/m at node2, -221.45 kN/m at node 2 and -308.203 kN/m at node5 respectively

Fig. 3.7 shows the shear force F_{xy} at crown nodes. The maximum values of shear force (Fxy) for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 13.43E-03 kN/m at node 14, 25.97E-03 kN/m at node 14, -79.59E-03 kN/m at node 13, 34.64E-03 kN/m at node 10, 52.76E-03 kN/m at node 12 and 113.09E-03kN/mat node 13 respectively. Fig. 3.8 shows the shear force F_{xy} at left side nodes. The maximum values of shear force (Fxy) for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are -33.93E-03 kN/m at node 16, 182.88E-03 kN/m at node 16, -55.71E-03 kN/m at node 16, 90.52E-03 kN/m at node 9, -50.69E-03 kN/m at node 10 and 83.42E-03 kN/mat node 20 respectively. Fig. 3.9 shows the shear force F_{xy} at right side nodes . The maximum values of shear force (Fxy) for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 23.37E-03 kN/m at node 16, -172.53E-03 kN/m at node 6, 29.75E-03 kN/m at node 16, -35.46E-03 kN/m at node 6, -41.51E-03 kN/m at node 6 and -111.52E-03 kN/mat node 6 respectively.

Fig. 3.10 shows Moment Mxx at crown for different types of soil. The maximum values of moment (Mxx) at node 2 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 0.67E-03kNm/m, -1.48E-03 kNm/m, -40.99E-03 kNm/m, -80.45E-03 kNm/m, -140.107E-03 kNm/m and -244.49E-03 kNm/m respectively. Fig. 3.11 shows Moment Mxx at left side nodes for different types of soil. At left side nodes the maximum values of moment (Mxx) at node 2 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 31.0262E-03 kNm/m, 191.26E-03 kNm/m, 97.19E-03 kNm/m, 210.82E-03 kNm/m, 241.82E-03 kNm/m, and 344.86E-03 kNm/m respectively. Fig. 3.12 shows Moment Mxx at right side nodes for different types of soil. At right side nodes the maximum values of moment (Mxx) at node 2 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 3.12E-03 kNm/m, 190.90E-03 kNm/m, 97.06E-03 kNm/m, 211.21E-03 kNm/m, 241.51E-03 kNm/m and -344.66E-03 kNm/m respectively.

Fig. 3.13 shows Moment Myy at crown nodes for different types of soil. At crown nodes the maximum values of moment(Myy)at node 4 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 0.54E-03 kNm/m, 0.84E-03 kNm/m, -26.51E-03 kNm/m, -52.20E-03 kNm/m, -90.98E-03 kNm/m and -158.83E-03 kNm/m respectively. Fig. 3.14 shows Moment Myy at crown nodes for different types of soil

nodesAt left side nodes the maximum values of moment (Mxx) for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 2.12E-03 kNm/m, 123.78E-03 kNm/m, 62.15E-03 kNm/m, 135.22E-03 kNm/m, 154.52E-03 kNm/m, and 220.30E-03 kNm/m respectively. Fig. 3.15 shows Moment Myy at right side nodes for different types of soil. At right side nodes the maximum values of moment (Mxx) at node 2 for hard rock, soft rock, weathered rock, gravel soil, clay soil and silty soil are 2.15E-03 kNm/m, 91.18E-03 kNm/m, 46.64E-03 kNm/m, 101.22E-03 kNm/m, 114.703E-03 kNm/m and -164.32E-03 kNm/m respectively

5. CONCLUSION

A D shape tunnel having length of 20 m, hight 8.84 m and width 8.66 m have been thoroughly studied .The results are obtained for all the six different types of soil at crown, left and right periphery of the tunnel. From graph(Fig.1) displacement vs node no we can observed that the displacement in hard rock is much less than other type of soil. But displacement in silty soil is much more than other type of soil. Similarly from graph (Fig.4) shear force vs node no we can observed that the shear force in hard rock is much less than other type of soil. But shear force in silty soil is much more than other type of soil. For bending moment in hard rock is very less, but bending moment in silty soil is much more than other type of soil. These gives an idea how the change in soil property effects the shotcrete thickness of a D shape tunnel.

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