EFFECTS ON UNDERGROUND TUNNEL WITH OR WITHOUT BUILDING AT TOP IN DIFFERENT GROUND STRATA

Sumit Ghangus

Assistant Professor, Structural Engineering, (ASAP), Amity University Haryana, India

---***---

Abstract – *This paper gives the idea of the settlement occurrence at the surface of soil due to tunnelling. The trough formed due to the tunnelling at various depths in Greenfield ground condition is compared with the formation of trough due to the presence of building at the top of tunnel. The tunnel section adopted is a modified horseshoe tunnel section, were this is taken from the Bharbai-Aizawl Railway Project Tunnel No.1. The soil settlement at top of surface is tried to reduce to minimum with the help of varying depths and varying lengths of construction stages. The prediction was that the settlement can be controlled by increase in depth of tunnel, but the experiment done shows the new path to control this formation of troughs. The soil profiles selected are the medium soil & the soft rock. This study has its importance to check the building effect due to the tunnel and what kind of possible damages could occur to existing structure. The building can face the minor-major cracks in the infill and minor crack to the main structural elements. These cracks can be controlled if settlement or differential settlement occurrence lies in allowable limits.*

Key Words: *Trough, Greenfield ground, construction stages, modified horseshoe.*

1. INTRODUCTION

The aim of our study is to find the impact of tunnelling over the existing structures. The work is progressed using the Numerical Methods approach in 3D by using the software MIDAS GEN for the building and the GTS NX for the tunnel and foundation of building. In this paper, the settlement curves are shown, these curves were formed due to the tunnelling and the comparison of the results were made for the Greenfield ground conditions & due to the presence of building over the tunnel. The building height is 33 meters and this is a G+10 storey building. The building is symmetric in nature and the tunnel passes just at the middle bottom of the building. The response of settlement occurrence at the building base is described in this paper and the actual formed trough due to tunnelling is given. The response of Building in dynamic loading and Tunnel Shell response due to building presence are kept for other parts for presenting in future for this paper.

2. BUILDING

The building under which the tunnel passes is a high rise structure of height 33 meters and is a G+10 storey building. The plane of the building is symmetric and its size is 20X20 Sq.m. The design of building is done using the software MIDAS GEN following the code IS 456:2000. The section passes designs are 300mm X 400mm for the beams and 600mm X 600mm for the column. The afterwards the model is imported to the GTS NX the imported model brings only the material properties and the mesh of the building. The loads were assigned again for the load combination of 1.5(DL+LL), considering it as the critical load combination. The vertical reaction at the column base is coming maximum as 2567 KN & minimum as 1315 KN. The pile foundation is designed for this maximum coming load for all the columns of building. The pile sections are designed manually for both the soil types and the four numbers of piles are coming under each column of diameter 600mm and length 6meter for medium soil and 4meter for softrock. The plan of building is given below in figure 1. Where the sections passes design are shown in figure 2.

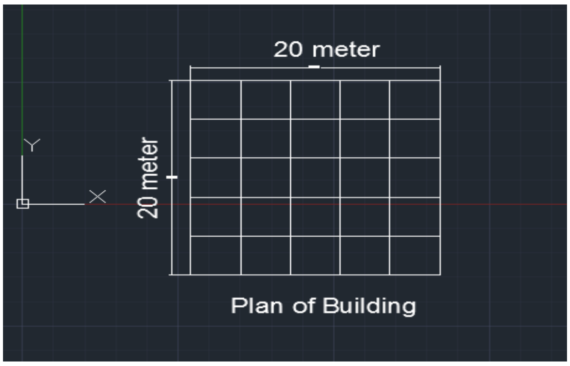
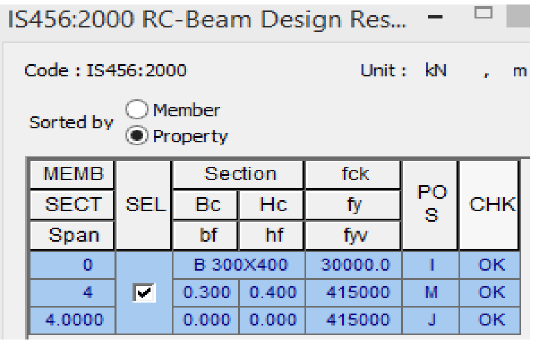


Figure 1: Shows the Plan of Building



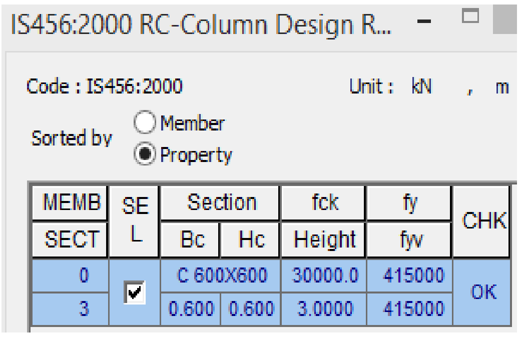
IS456:2000 RC-Beam Design Res...

Code : IS456:2000 Unit : kN , m

Sorted by Member / Property

MEMB / SECT / Span	SEL	Section / Bc / bf	Hc / hf	fck / fy / fyv	POS	CHK
0	☑	B 300X400		30000.0	I	OK
4		0.300	0.400	415000	M	OK
4.0000		0.000	0.000	415000	J	OK

Fig -2(a)



IS456:2000 RC-Column Design R...

Code : IS456:2000 Unit : kN , m

Sorted by Member / Property

MEMB / SECT	SEL	Section / Bc	Hc	fck / Height	fy / fyv	CHK
0	☑	C 600X600		30000.0	415000	OK
3		0.600	0.600	3.0000	415000	

Fig -2(b)

Fig – 2(a & b): Shows the passed Beam and Column sections

The foundation is provided for the maximum coming load at the tip of column. The pile caps of size 3meter X 3meter and thickness 1meter is taken for each column at base. The four number of piles are provided under each column. The properties of the soil for the medium clay and soft rock are given below in Table 1.

The building foundation is designed for the L/D= 30-40 & 1.5 percent steel. The pile are designed using the IS code 2911:1979. The values of shear stiffness modulus (Kt) and normal stiffness modulus (Kn) are taken as Kn=1000Es & Kt=0.01Kn. The ultimate shear force is calculated using formula G=Es/2*(1+μ). The tip bearing capacity and spring stiffness (Ks) are taken as Kn=1000Es & Kt=0.01Kn. The ultimate shear force is calculated using formula G=Es/2*(1+μ). The tip bearing capacity and spring stiffness (Ks) are calculated using formula Ks= P(x)/d(x) where, P(x) is foundation pressure & d(x) is settlement of underlying soil.

3. TUNNELLING

The tunnel section selected is a modified horseshoe section, the Bhairabi-Aizawl Railway project tunnel no.1 is taken in our study. The length of tunnel is kept 70 meters were the depths of tunnel are varying in different cases. The occurrence of settlement due to construction of this tunnel at the surface in Greenfield ground and in presence of building at ground is recorded. The section of tunnel is shown below in figure 3.

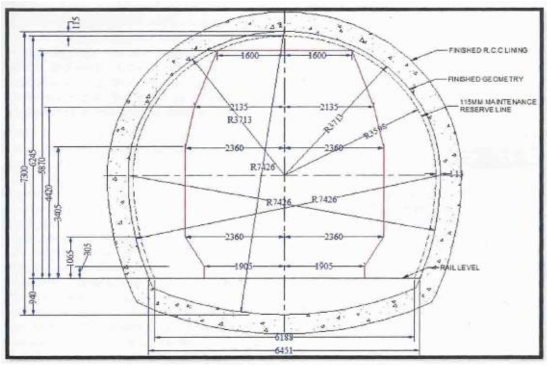


Figure 3: Shows the Section of Tunnel

The construction is done at various depths and with different length construction stages. The lengths of construction stage are kept 1.5meter, 3meter & 4meter throughout the tunnel length for different tunnel depths.

The initial and final stages of tunnel at the faces and ends were kept 0.5 metre to control the sudden falling of these faces. The faces and overall tunnel shell deflections were not allowed to deflect more than 20mm in Z-direction. The tunnel shell thickness is kept 650mm throughout the tunnel section. The incorporated model of building, foundation & tunnel is shown below in figure 4.

TABLE 1: Properties of Soil Profiles Clay and Weathered Rock

Sr.No.	Soil Type	Young's Modulus (E) KN/m^2	Poission's Ratio (μ)	Dry Unit weight (Ɣ) KN/m^3	Cohesion (C) KN/m^2	Friction Angle (ϕ) deg.
1	Clay	82500	0.33	19.8	33	33
2	Weathered Rock	385000	0.33	25.3	38.5	36.3

This incorporated model is made repeatedly for all the different conditions and the comparisons of the results were made in future through these models.

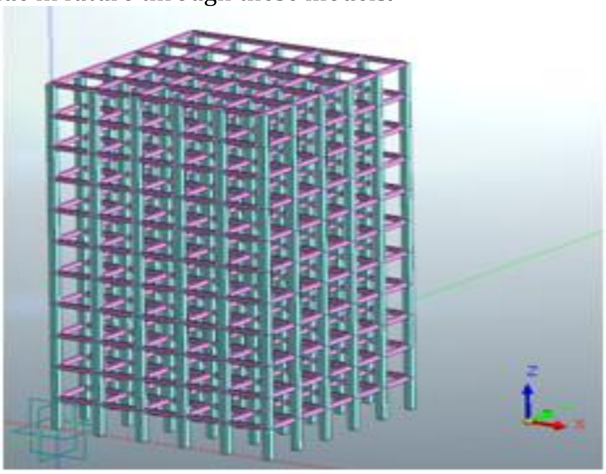


Fig - 4(a): Shows the Building model

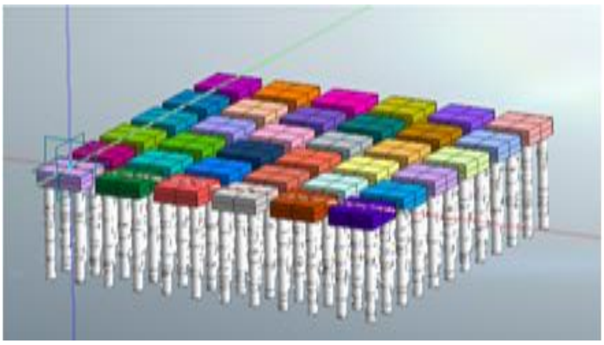


Fig - 4(b): Pile Foundation for the Building

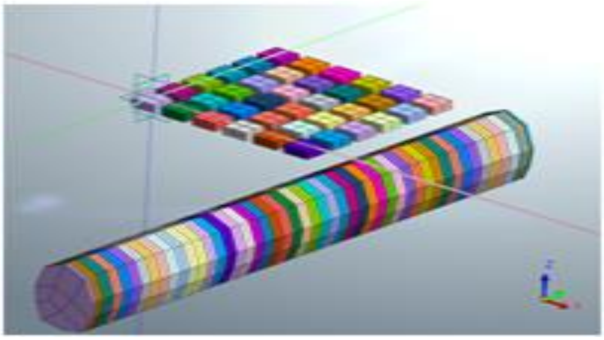


Fig - 4(c): Tunnel section below Building

These models for the building, foundation & tunnel were incorporated to one model and the combined model is prepared the effect of the tunnel construction over these existing structure can be recorded from this new approach of Numerical Methods in 3D. The combined model is given in figure 5 on the next page. The complete model is prepared in GTS NX where the depths and the construction stages were changing for the different incorporated models as described in detail in result section of this paper.

tunnelling construction at 15meter depth and Construction stages of 1.5 meters.

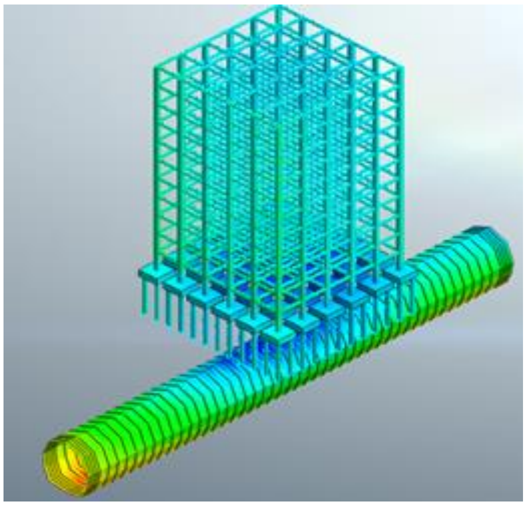


Fig - 5(a)

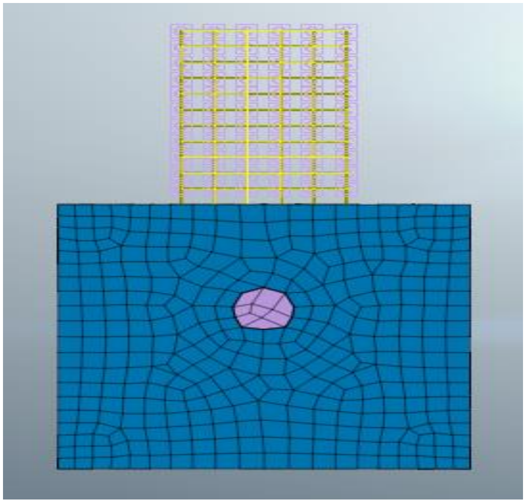
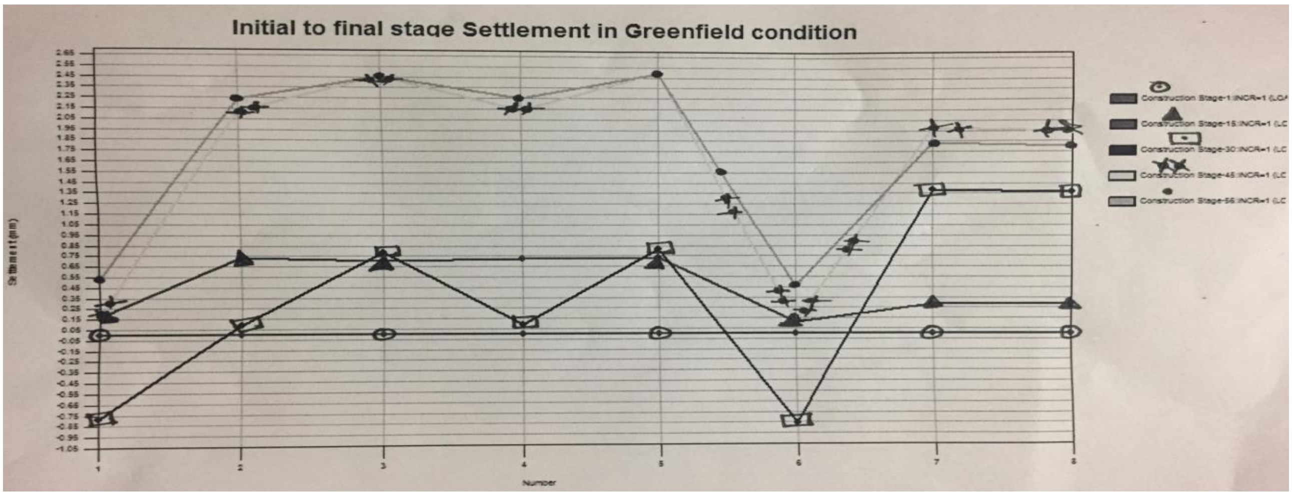


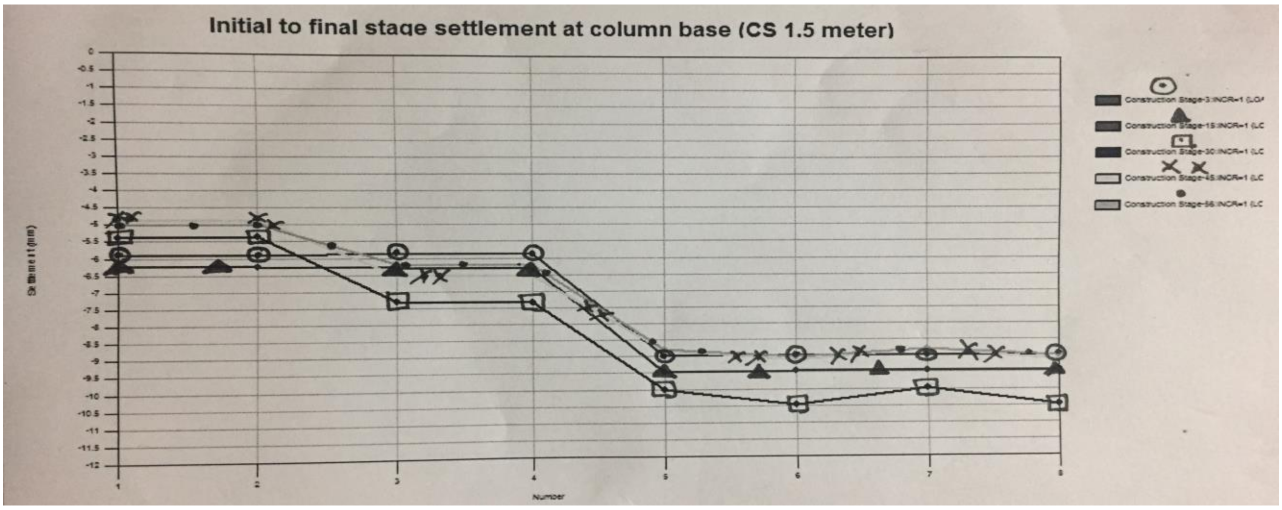
Fig - 5(b)

Fig -5(a & b): Shows the Building,foundation & Tunnel Incorporated model

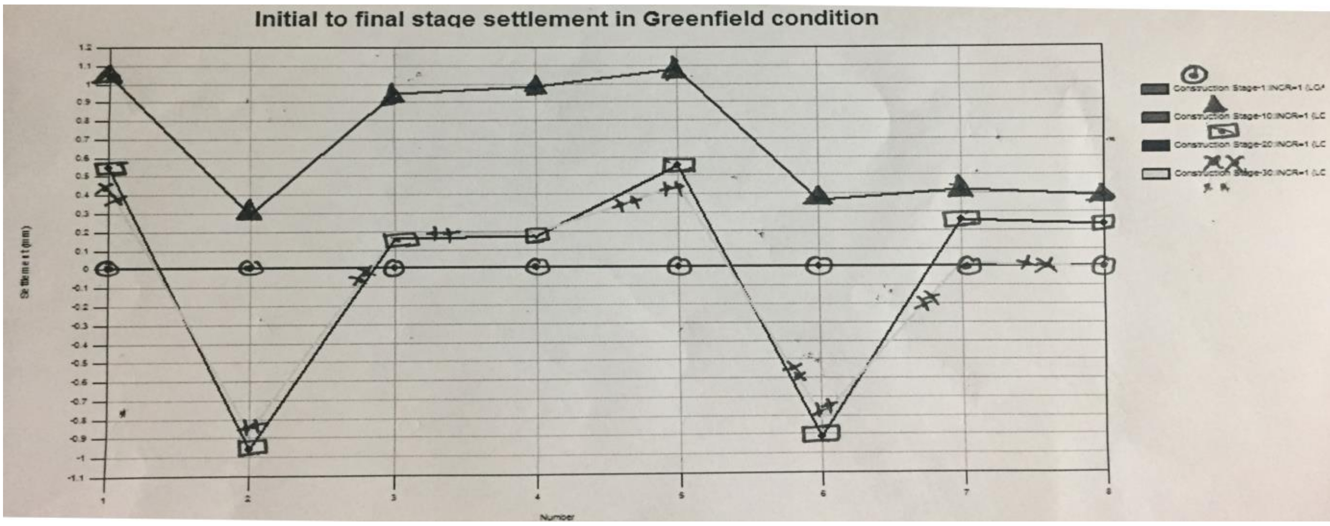
4. RESULT

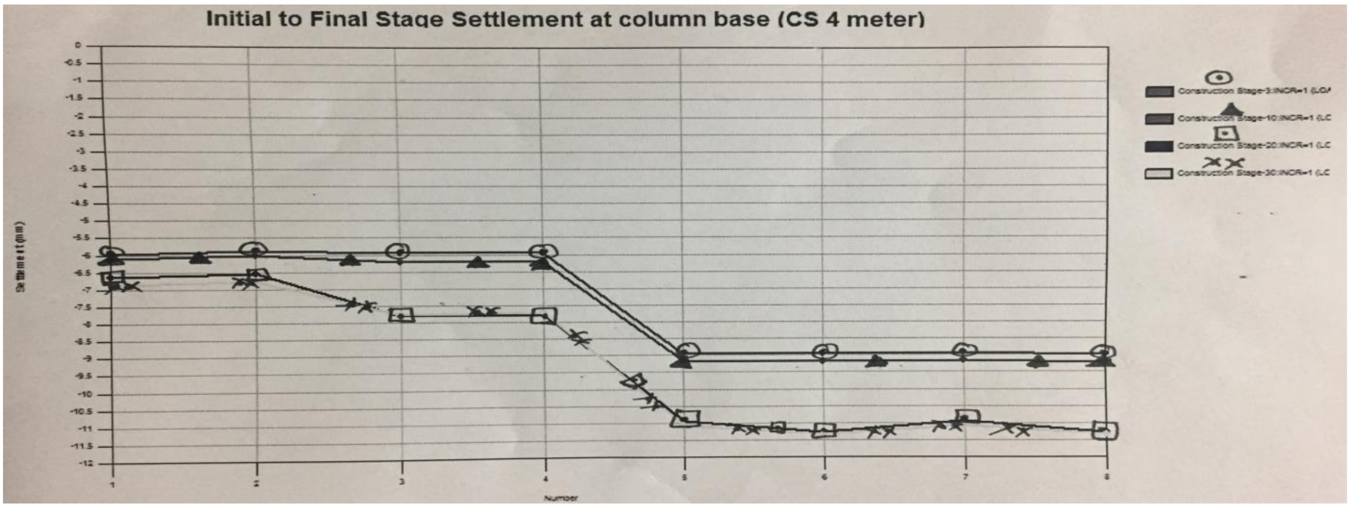
The comparisons of the settlement results were made between different depth tunnels in Greenfield ground and in presence of building at top of tunnel. Some of the results for the clay and the soft rock are presented here in figures below. The tunnel at depth 15 meters, 20meters, 30meters & 40meters below the ground with the construction stages of 1.5 meters, 3meters & 4meters are described in the results. First the experiment is done with the clay at different depths of tunnel. In the Clay the excavation of tunnel is done at 15 meters depth with the construction stages 1.5 meters. The results of settlement at surface for the points/nodes just below the columns are presented below, so that the 3D settlement curve can be formed easily. For clay in Greenfield ground & with presence of Building, for



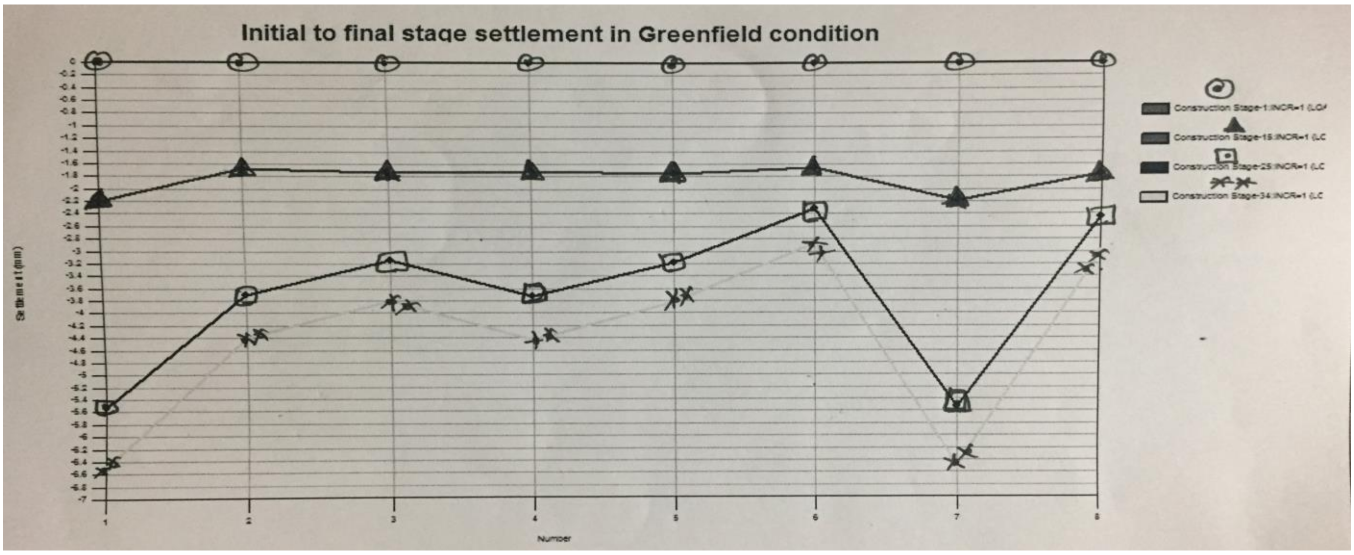


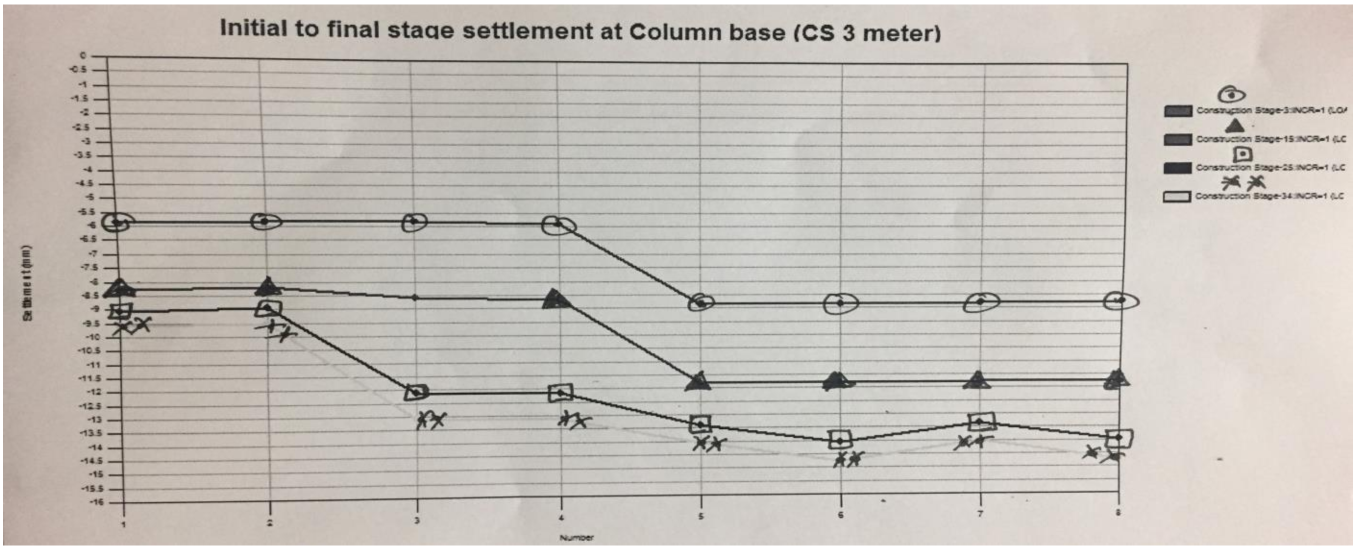
With construction stages of 4 meter the settlement at surface is given here similarly the results were recorded for the other depths of tunnel at 20 meter, 30meter and 40 meters. These results were for the Clay where the results of settlement at surface for the softrock are also done are there comparisons with the clay were made for both the condition types of with and without building. The settlement results changes with construction stages of tunnel excavation.





The different colour line expresses the different construction stages where all 8 nodes express the all 8 selected points of the column base. The changes due to tunnel construction in various construction stages are shown in these figures. The results for 30 meters depth tunnel with construction stages 3 meter are given below.





Similarly the results were observed for the other depths of tunnel in Clay. Softrock settlement occurrence at surface is also observed and compared with clay for both the cases of Greenfield ground conditions and with presence of Building at top of tunnel section. The conclusions from observed results of this new approach of Numerical methods in 3D for the case of building presence at top of tunnel in any megacity and for plain ground are discussed ahead.

5. CONCLUSIONS

5.1 With and Without Building-

The test results shows that the settlement values obtained for the Greenfield ground conditions are also creating the heaps over the surface during the tunnel construction. The heaps formation is observed during the tunneling at 15 meters depth with the construction stages of 1.5 meter where the similar results are found for the 4 meter construction stages, the difference in both is that 4meter stages are not forming high heaps and limiting to 0.43mm only while in case of 1.5 meter stages their height is up to 2.4mm. With the interaction of building with tunnel these results were modified to better values as for this case there is no formation of heaps and only some settlement is observed. This is good to control the differential settlement occur at building column base.

The maximum differential settlement for the cases of Greenfield ground conditions is 1.9mm as rise and 4.5mm as settlement, while for the case with building present at top no rise is observed and the maximum differential settlement is 5.8mm. This maximum differential settlement is for the tunnel at 40 meters depth with 1.5meter construction stages and the minimum is obtained as 4.6mm for the 15meters tunnel depth with stages 1.5meter. The results conclude that the soil mass surcharge has a main role for the soft and medium type soils, as here we see with increase in soil mass the settlement varies rapidly. The building weight is affecting very much in settlement and the increase in settlement up to 40% is observed at surface while comparing with the Greenfield ground conditions. It shows building has a large impact on settlement so its presence can't be ignore.

5.2 Clay and Weathered Rock-

The selection of suitable soil profile is always very important before execution of geotechnical works. This can be observed from the results, as in the weathered rock cases the maximum settlement obtained during tunnel construction is 2.28mm & for the clay it is 8.2mm. This settlement is obtained for the 40 meter depth tunnel with construction stages 1.5 meter for weathered rock & for the clay. As at 40 meter depth both in clay and weathered rock the maximum settlements are recorded. The weathered rock is a strong strata and its ability to deform with excavation is also not so easy. The rock selected is a soft rock type and the horseshoe shape is known for their suitability in soft rock type.

By comparing the results for the changes occur in settlement during tunnel construction it is found that minimum2.6 times clay settlement is more than that for rock. The maximum value calculated is 6 times and this is observed for the 15meter tunneling with stages 4meter. The weathered rock through this observation represents it strength and prove itself average 4 times better than the clay. This concludes that the tunneling in weathered rocks is showing the better results to transfer lesser settlement at the surface during its construction. Also the building will suffer low differential settlements in weathered rock than that of clay, so it is good to choose the hard strata for the tunneling as weather rock is much better than the clay in our case study.

REFERENCES

[1] Mair, R.J. and Taylor, R.N.(2001). Elizabeth House – settlement predictions. Ch14 in "building response to tunneling. Case studies from the jubilee line extension, London, vol.1. Projects and methods" Burland J.B., Standing J.R. and jardine F.M. eds (CIRIA Special publication 200. CIRIA and Thomas telford) 2001, pp 195-215.
[2] Standing, J.R and burland, J.B. (2006). Unexpected tunneling volume losses in the Westminster area , London. Geotechnique, vol. 56, no.1,pp 11-26.
[3] Nyren, R.J., Standing, J.R., and Burland,J.B.(2001). Surface displacements at St. James's Park Greenfield reference site above twins tunnels through the London clay. Ch25 in "Building Response to tunneling. Case studies from the jubilee line extension, London, vol.2,case studies" Burland J.B., Standing J.R. and Jardine F.M. eds (CIRIA special publication 200. CIRIA and Thomas Telford), PP 387-400.
[4] Skeptom, A.W. and Macdonald, D.H. (1956). Allowable settlement of buildings. Proc. Instn. Civ. Engrs., Pt. III, vol. 5, pp 727-768.
[5] Standing, J R., Withers, A. D. and Nyren, R.J. (2001). Measuring techniques and their accuracy. Ch18 in "Building response to tunneling. Case studies from the jubilee Line Extension, London, vol. 2, case studies from the jubilee line extension, London, vol. 1 , projects and methods" Burland J.B., Standing J.R. and Jardine F.M. eds (CIRIA special publication 200. CIRIA and Thomas Telford), PP 273-299.
[6] O'Reilly, M.P. (1988). Evaluating and predicting ground settlements caused by tunneling in London clay. Tunneling 88, London, IMM, pp 231-241.
[7] Viggiani, G. and Standing, J.R.(2001) "The Treasury" Ch26 in "Building response to tunneling.Case studies from the jubilee line extension, London, vol.2,case studies" Burland J.B., Standing J.R. and Jardine F.M. eds (CIRIA special publication 200. CIRIA and Thomas Telford), PP 401-432.
[8] Sutherland, j. (2003). Contribution to discussion session 1: prediction of damage to buildings from

tunneling. Proc. Int. conf. Response of buildings to excavation-induced ground movements, London 2001, Jardine F.M. eds (CIRIA), London pp 4-6.
[9] Potts, D.M. and addenbrooke, T.I. (1997). A structure's influence on tunneling-induced ground movements. Proc. Instn. Civil Engrs, Geotechnical Engineering, vol. 125, pp 109-125.

[10] New, B. M. and O'Reilly, M.P.(1991) tunnelling induced ground movements; prediction their magnitude and effects. Proc. 4th Int. conf. on Ground Movements and Structures, Cardiff, invited review paper, 1991, pentech press, pp. 671-697.

[11]Burland, J.B., Broms, B.B. and de Mello, V.F.B.(1977). Behavior of foundations and structures- SOA report. Proc. 9th Int. Conf. SMFE,Tokyo, vol. 2;pp 495-546.
[12] Mair, R . J., gunn, M.J. and O'Reilly, M.P.(1981). Ground improvement around shallow tunnels in soft clay. Proc. 10th Int. conf. SMFE,Stockholm. Vol.1, pp 323-328.
[13] Maklin,S.R.(1999). The predictionof volume loss due to tunneling in overconsolidated clay.
[14] Johnston, G.(2001). St. James's and St James Park: a brief history of their development ch6 in project & methods.
[15]Macleod,I.A. and Little John, GS(1974).Discussion on session 5.Conf. Settlement of Structures,Cambridge, Pentech press, London,pp792-795.

BIOGRAPHY

Mr. Sumit Ghangus
Assistant Professor, ASAP, Amity University Haryana.
M.Tech in Structural Engineering, National Institute of Technology, Silchar, Assam, India.