Design of tunnel by using GEO5 Software

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Abstract - *Tunnels are very important structures which are being used in various construction; like in road, railway for defense purpose and laying of pipelines etc. All the tunnels have different shapes on the basis of their uses and the ground conditions and the availability of materials. Tunnel have many functional systems, such as lighting, ventilation, drainage, fire detectors and alarms, fire suppression, communications and traffic control. Construction of different types of tunnels include some vary basic operations or steps which are to be followed in sequence in order to built or to construct a tunnel this are called basic tunneling operations. This tunneling operations may differ in comparison to older times and this modern time. We are designing a tunnel on GEO5 software, basically GEO5 is Geotechnical software designed to solve various geotechnical problems. The common geotechnical engineering tasks such as foundations, retaining walls, slope stability also includes applications for the analysis of tunnels, building damage due to tunneling or stability of rock slopes. GEO5 consists of wide range of programs based on both analytical method as well as Finite Element Method. Analytical methods of computation such as slope stability, sheeting design allows users to design and check structures quickly and efficiently. The designed structure may be transferred into the FEM program where the analysis is performed by using the Finite Element Method. This application saves designer time.*

***Key Words*: Finite element method, GEO5 software, Analytical method, Tunnel design, Traffic control And New Austrian Tunnelling Method.**

1. INTRODUCTION

Tunnel is an artificial underground passage, which one built through a hill or under a building, road, or river. Tunnels are not only structures constructed of concrete, steel, masonry, and timber or bored in rock, but also use numerous functional systems to perform roles for the tunnels to function properly.

All tunnels has various degrees of complexity depending on function and safety needs or the code requirements at the time of construction, but most tunnels employ one or many functional systems, such as lighting, ventilation (shafts), drainage, fire detectors and alarms, fire suppression and traffic control. With the limited access and confined conditions within a tunnel; the operation, maintenance and inspection of a tunnel must be thoroughly manipulate to provide an adequate level of safety for the traveling public. Construction of a different types of tunnels include some vary basic operations or steps which are to be followed in sequence in order to built or to construct a tunnel. This are called basic tunneling operations. This tunneling operations may differ in comparison to older times and this modern time. This paper provides information on tunnels, various tunneling operations involved to make tunnel and also provide information related to old methods of tunneling and new methods of tunneling using ultra-modern technology. Also specify suitable methods for designing of tunnel. There is no design standard for tunnels included in the India Standards. All design standards for road tunnels in developed countries are quite similar to Japan is the one of the most experienced countries in tunneling in the world, and as the geology and geotechnical condition of Japan is very similar country to the India, the present study for tunneling for these Project is based upon the experiences in Japan and the design of the tunnel is based on the Standard of NEXCO (Nippon Expressway Company, former Japan Highway Corporation), which is applied to all the highway tunnels and most of national road tunnels in Japan, most of which have been constructed.

Result of Data Collection Survey shows that proposed width of the road in tunnel is 2 x 3.5m lanes with the 2.5m wide lane for emergency parking at the east bound direction and 0.5m wide shoulders on both sides; a walk way for maintenance of the facilities, 75cm wide and 2.0m high, is required at one side. None side walk is designed because for the safety of the traffic; non-motorized traffic, such as pedestrians, cycle, bicycles, hand carts and animal traction carts, or agricultural tractors are not allowed to enter the tunnel. Thus, total width of the tunnel is about 12 m and the height is about 7 m. Tunnel design shall follows the above dimensions and clearance in height for the traffic is determined as 5.0m which is the standard for the Asian Highways. Slopes surrounding tunnel portals shall be maintained stable permanently and stream waters shall be managed not to harm the tunnel. In the planning of tunneling method it must be shows that there distributes to some an extent hard massive sand stones which may be very difficult for mechanical excavation. Another point of importance is that tunneling method and support design shall be adequate to scope with fault zones to be encountered during tunneling although the exact location and nature of the fault zones are not identified yet. All of the above issues are to be reflected in the design of tunnel support and method of excavation for tunnel.

1.1 Positive Environmental Impacts

This method deals with the positive impacts of the project. If we consider Metro Rail tunnel will also yield benefits from non-tangible parameters such as saving due to equivalent reduction in road construction and maintenance, vehicle operating costs, atmospheric air pollution is less and socio-economic benefits of travel time, better accessibility, better comfort and quality of life. Overall benefits cannot be evaluated in financial terms due to non- availability of universally accepted norms.

The various parameters such as economic growth, improve the quality of life, reduction in public health problems due to reduction in pollution, etc. have not been quantified. Various positive impacts have been listed that is Employment Opportunities, Benefit to Economy, Mobility, Safety, Traffic Congestion Reduction, Reduction in the number of Vehicle, Less Fuel Consumption, Reduction in Air Pollution, Carbon Dioxide Reduction, Reduction in Number of Buses, Saving in Road Infrastructure, and Traffic Noise Reduction.

1.2 Negative Environmental Impacts

This method deals with the negative impacts of the project. The various parameters such as soil erosion due to run off, traffic diversion due to construction works, muck disposal, loss of trees, air pollution, noise pollution, vibration impacts.

2. METHODS OF CONSTRUCTION OF TUNNEL

2.1 cut and cover method

Cut and cover method of tunnel construction is generally used to build a shallow tunnels. In this method a trench is cut in to the soil and is covered by some support which can be capable of bearing load on it. One is of bottom up method in which a tunnel is excavated under the surface using the ground support.

Another method is top-down method and in which side support walls are constructed by slurry walling method or continuous bored piling. Roofs at the top of the wall and excavation is carried out. Most of Underground metro rails stations are constructed using cut and cover method.

Fig -1: Cut and cover method

2.2 Bored Tunnel Method of Tunnel Construction

In this case, tunnel boring machines are used which automatically works and makes the entire tunneling process easier. It is one of the quick process and good method to build tunnel in high track areas. Tunnels boring machines TBM's are avail in different types which is suitable for different ground conditions. These machines can be use in difficult conditions like below the water table etc.

A pressurized compartment is provided for TBM to work in below water table conditions. The labors should not enter that compartment except for repair works. Care must be taken while TBM is in working conditions. The major difficulty with this TBM is its heavy weight.

Fig -2: Bored tunnel method

2.3 Clay Kicking Method of Tunnel Construction

This method is used for the strong clayey soil conditions. This is an old method, used for small works like sewage pipes installations etc. In this method, hole is excavated into the ground and after some depth tunnel is excavated which is done by clay kicker which a plank at 45o angle.

An excavating tool is provided under the clay kicker foot. An excavated using that tool is collected by other workers. This is a well famous because it is the method used by English men to put mines under the German empire during First World War.

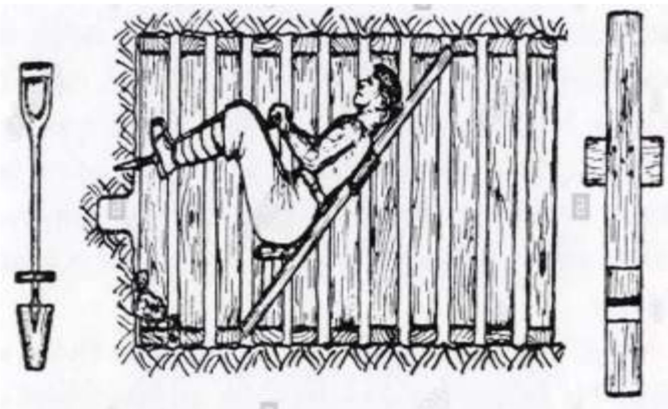

Fig -3: Clay kicking method

2.4 Shaft Method of Tunnel Construction

In this method tunnel is constructed at a greater depth from the ground surface. A shaft is built up to the depth where tunnel is required.

Shaft is a permanent structure which is like well within concrete walls. At required depth, tunnel are excavated using TBM's. Intermediate shafts also provided if tunnel is too long.

Fig -4: Shaft method

2.5 Pipe Jacking Methods of Tunnel Construction

Pipe jacking method is used to construct tunnel under existing structures like road ways, railways etc. In this method, specially made pipes are driven into the underground using hydraulic jacks. Maximum size of 3.2m diameter is allows for tunnel.

The Pipe Jacking trench less technology method is a system of directly installing prefabricated pipes behind a tunnel shield by the pipes form a continuous string in the ground in the direction of the target shaft.

Fig -5: Pipe jacking method

3. DESIGN OF TUNNEL BY GEO5 SOFTWARE

The GEO5 FEM is used to compute the displacements, internal forces in structural elements, stresses and strains and plastic zones in the soil and other quantities in every construction stage. With extension modules the program also performs the Tunnel excavation analysis, the steady state or transient Water Flow analysis or the coupled Consolidation analysis. The tunnel will be drill Excavation Method) with the excavation sequence consisting of a top heading, a bench and an invert (the so called horizontal sequence).

The 200 mm thick primary lining is in C 20/25 spray concrete. The excavation crown is supported with hydraulically expanded rock bolts (HUIS, type WIBOLT EXP) with the capacity of 120kN. We assume on the basis of the assessment of the stages ensuring a conventional tunneling method (the New Austrian Tunneling Method, the Sequential of survey.

Various soil parameter are directly affecting in tunnel design, these parameter are shows specification of soil or rocks either the soil/rocks is sand, slates, gravel, etc.

Table -1: Parameters of Soil and Rock

Soil, rock (specification)	Profile (m)	γ kN / m3	Φ ef (°)	Cef (kPa)
Silty sand (S4 /SM)	0-3	19.5	29	10
Silty gravel G4 / GM	3-5	19.5	33	8
Heavily weather slate (R5)	5-10	24	29	30
Slightly weather slate (R3)	Over 10	26	38	250
Anchor region (R5)	-	24	29	63

We used the GEO5 –FEM based program to analyze this problem. In the table below, we will describe the solution to this example step by step:

Table -2: Construction Stages in Tunnel Design

Topology	Settings the problems and modelling (contact elements, modelling of the lining).
Construction Stage 1	Primary geostatic stress state of rock mass.
Construction Stage 2	Modelling top heading excavation and activation of the unsupported excavated opening.
Construction Stage 3	Supporting the heading vault with an immature concrete primary lining.
Construction Stage 4	Heading portion is Improved by material characteristics of mature concrete.
Construction Stage 5	Modelling of the tunnel bench excavation and activation of the unsupported excavated opening.
Construction Stage 6	Supporting a bench side-walls with an immature concrete primary lining.
Construction Stage 7	Improving material characteristics of mature concrete (bench).

3.1 Topology: Setting the frame

Specifying the problems profile interfaces and soil parameters. In the "Settings" frame, we will do the analysis of Construction Stage 1 to be in geostatic stress state. In addition, we will switch on the "Tunnels" mode, which allows us to model the course of the primary tunnel lining construction realistically.

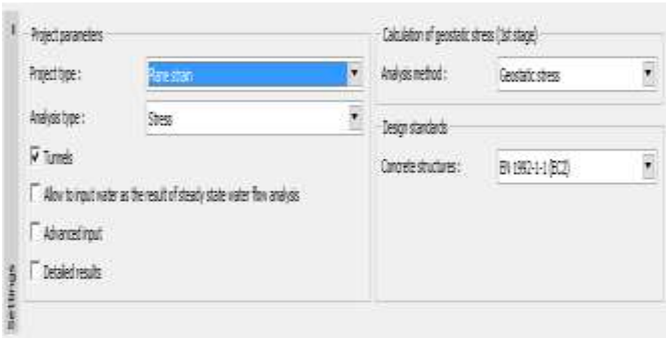

Fig -6: Frame setting

3.2 Construction stage 1: primary geostatic stress state

First generate the FE mesh we will switch to construction stage 1 and will carry out the analysis of the primary geostatic stress state of the massif. Then we will maintain the "Standard" analysis setting for all construction stages (for more details visit Help – F1).

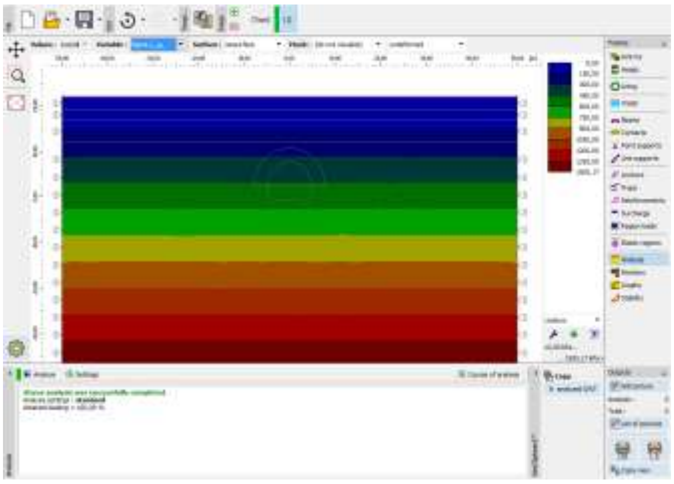

Fig -7: Frame analysis

3.3 Construction stage 2: activation of the unsupported excavation and top heading excavation

First generate the FE mesh we will switch on to construction stage 1 and will carry out the analysis of the primary geostatic stress state of the massif. We will maintain the "Standard" analysis setting for all the construction stages (for more details visit Help – F1).

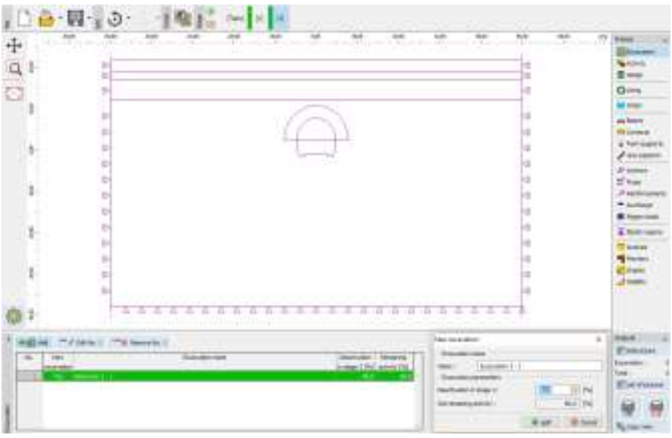

Fig -8: Excavation shows in dialogue window

3.4 Construction stage 3: Supporting the top heading vault portion with an immature concrete primary lining

In next step we will add construction stage 3. First of all, we will do the top heading vault portion with support at 200 mm thick immature concrete primary lining in the "Beams" frame .In the "Assign" frame we change the rock in region No. 5 (to the "anchored R5" option), in which we will take the anchoring with hydraulically expanded steel rock bolts into consideration.

Fig -8: Primary lining of top heading with new beams

3.5 Construction stage 4: Top heading portion is improved by material characteristics of mature concrete

In construction stage 4, we will improve the material characteristics of the already mature concrete supporting the top heading portion. In the window "Modify beam properties", we will be select the "Strengthening" option and will set the respective values of the modules of elasticity. We will be activate the remaining 30 % of the load acting on the rock mass. The procedure of the editing the properties of the excavation is similar to that used in previous construction stages.

Fig -9: Bending moment analysis

3.6 Construction stage 5: Activation of the unsupported excavated opening and modelling of the tunnel bench excavation

In these step, we will add construction stage 5. In this construction stage we will take deactivation of soil, or the action of 40% of the load, into consideration. The remaining action of soil, or the massif in the vicinity of tunnel bench excavation N, is therefore 60 %.

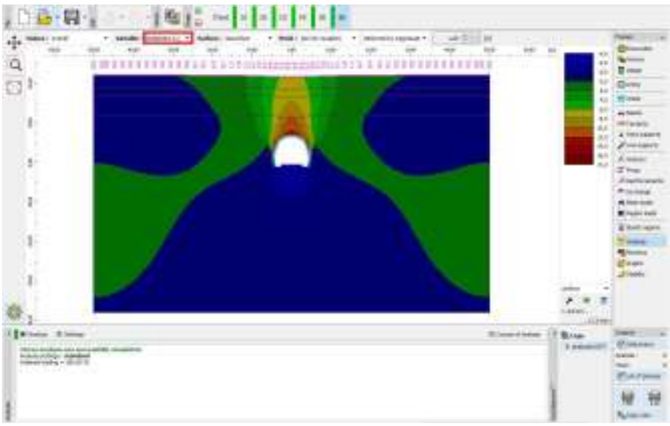

Fig -10: frame analysis with vertical displacement and settlement

3.7 Construction stage 6: Supporting the bench side-walls with an immature concrete primary lining

In these construction stage 6 we will set the support of the bench side-walls with a 200 mm thick immature sprayed concrete primary lining. The top heading lining will remain unchanged in these stage.

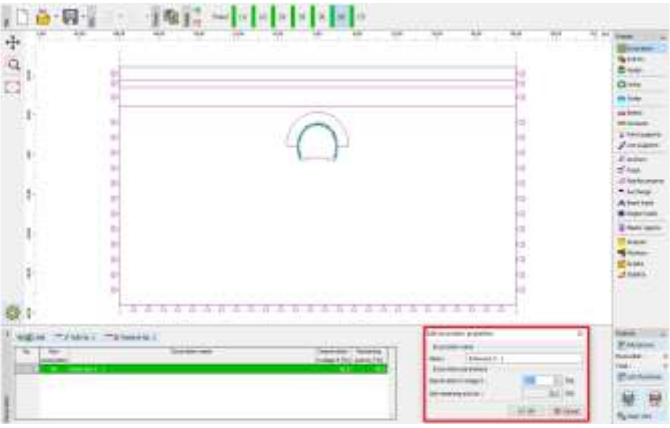

Fig -11: Edit excavation properties

3.8 Construction stage 7: Benching improve material characteristics of mature concrete

In the last construction stage we will be improve the material characteristics of already mature concrete supporting the tunnel bench excavation. The procedure of increasing capacity of the beams is similar to that used in the construction stage. We will be activate the remaining 30% of the load induced by the rock massif. By taking this step, we remove all soils from the excavation space and the loading therefore acts on primary tunnel lining (inclusive of the top heading and bench walls) at 100 %. We will be carry out the analysis of the last construction stage.

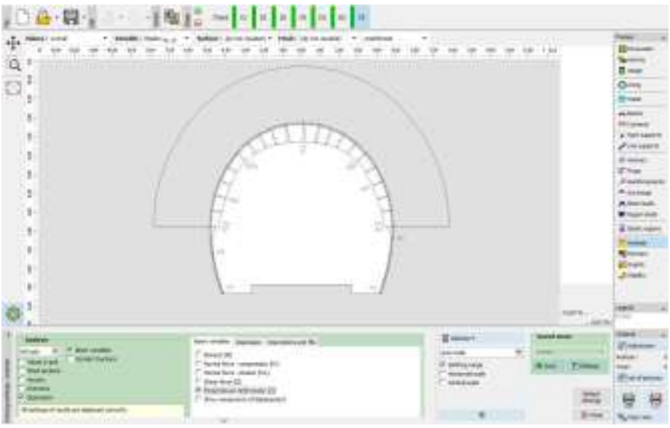

Fig -12: Assessment of results

4. CONCLUSION

We have over viewed all the design methods such as Analytical methods & Numerical methods. Especially the Finite Element method. We are studied GEO 5 application, GEO 5 is geotechnical engineering based software used for analysis and design of tunnel. In the present study and attempt is made to understand the tunnel damage under the static and dynamic loading conditions.

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