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Analysis and Design of Underground Tunnel Support by FEM

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ABSTRACT: Underground structures have recently gained importance all over the world. Successfully completed these projects are based on careful and realistic design, one that is neither optimistic, conservative, and considerate. It is the need of the moment. This article presents a comparative study of media design, such as Terzhagi's load theory. Quantitative methods for rock mass quality (Q) and rock mass assessment on Bieniawski and RS2 Numerical modeling. The results showed that the final support measures such as casting, thickness, rocky dome, length, The frequency, and requirements of steel support are better. Based on engineering reasoning and analytical methods, PSAs for tunnels have been obtained.

KEYWORDS: RMR, Design, Support measures, Rocks

I. INTRODUCTION

The work of core drilling is carried out with Long year/ L&T make L-38/ Vol-90/ Voltas make or equivalent models of hydraulic feed, engine driven machines, mounted on skids duly provided with rotary head. A drilling to the bottom of a core barrel, which is turn is attached to the bottom of a string of hollow drill rods, is rotated at a high speed with a downward thrust by the hydraulic drilling rig. On rotation with downward thrust, the coring bit cuts an angular space in the strata and an intact core enters the barrel, to be removed as a sample. Water is continuously pumped down the drill rods with the help of triplex water pumps of Voltas/ Royal beam make (model TD-200 & TD-400) having suitable feeding capacity for drilling up to required depth. This water emerges under pressure through holes in the bit on barrel. The drilling fluid (water) cools and lubricants the bits and carried up the cuttings to the surface. The drilling rig is provided with necessary facilities to regulate the spindle speed, bit pressure and water pressure during core drilling to get good core recovery. Casing pipes of suitable size are lowered in the borehole end seated on bedrock or in a firm formation to prevent casing in of the borehole. The recovered core is pleased in wooden core boxes with proper markings according to scale as per IS: 4078-1980. All the core drilling observations are recorded in the field registered as per IS: 5313-1980.

1.1 Bore Hole Sketch

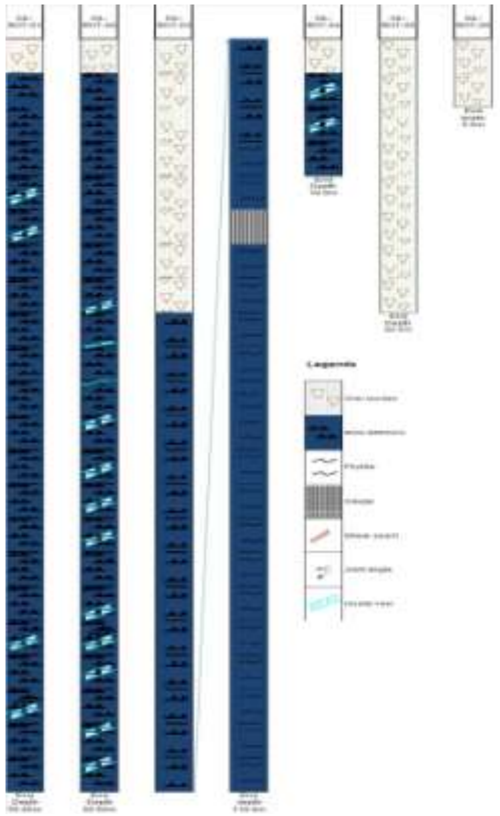

Figure 1.1: Showing sketch of drill holes

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Figure 1.2: Drilling Rig

1.2 Software used

For the calculation the finite element program RS 2 (Rock science) V.9.014 was used. For the converting Rock mass parameters between Hoek-Brown and Mohr-Coulomb failure criterion, the program Rock Lab (Rock science) V.1.033 was used.

1.3 Standard Cross-Section

The following figures show the excavation geometry for the standard cross section without invert and with invert for difficult ground conditions, respectively. The thickness of shotcrete of the tunnel support will vary between 15 and 25 cm. The radius from the centre to the axis of the shotcrete lining is approximately 7.35 m.

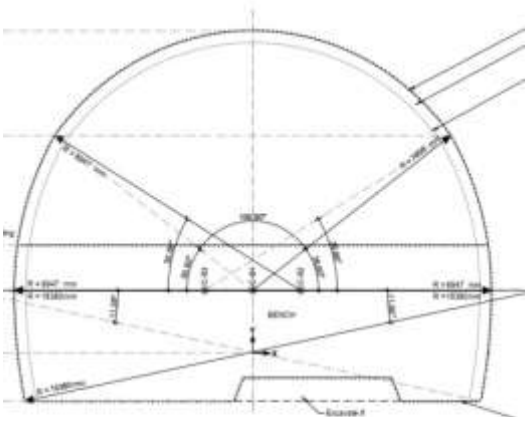

Figure 1.3: Excavation Geometry for standard cross-section without invert

The height of the profile is roughly 11 m (13 meters for profile with invert). The support classes include different rock bolt patterns and may furthermore include a temporary invert in the top heading or an invert at the final stage according to requirements.

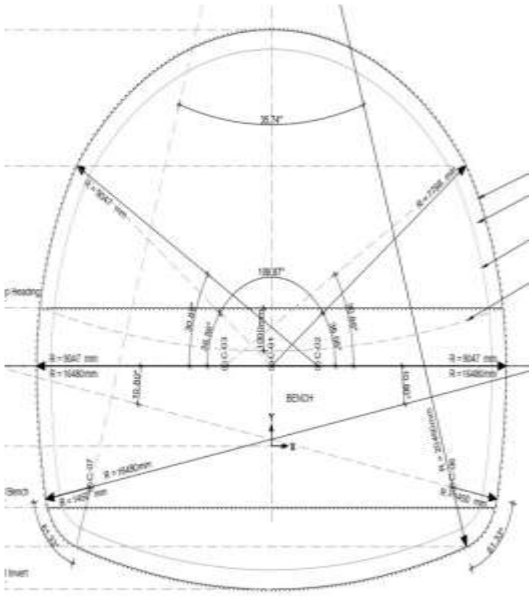

Figure 1.4: Excavation Geometry for standard cross-section with invert

1.4 Ground behaviour types (GBT)

As per definition, the ground behaviour describes the response of the ground to full face excavation, considering ground type and influencing factors without the influence of supports, division of face or auxiliary measures.

II. METHODOLOGY

For the design of the support measures two independent approaches were used:

- Analytical Approach: Convergence-confinement-method (CC-Method)
- Finite-Element Approach

The convergence confinement method is a widely spread and recognized approach for estimating the interaction between rock mass and support resistance during excavation. It is based on a cylindrical hole in a Mohr- Coulomb-Medium assuming linear elastic - perfectly plastic material behaviour and a plane stress state. It is a handy and demonstrative tool to analyse the system behaviour of underground excavations.

The tunnel support was designed, considering only the resistance of shotcrete and bolts. Steel girders and meshes were not considered.

The finite-element approach is the state-of –the-art method for the design of tunnel constructions. In

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addition to the general behaviour of rock mass and tunnel support it allows a more detailed analysis of stress-strain relations, deformations, and acting forces.

The FEM-Modelling provides the sequenced excavation of top heading, bench and invert, as required and furthermore allows modelling the temporary development of the tunnel advance in axial direction by considering increasing rock mass convergence and changing stiffness of support measures.

2.1 Determination of the ground reaction line

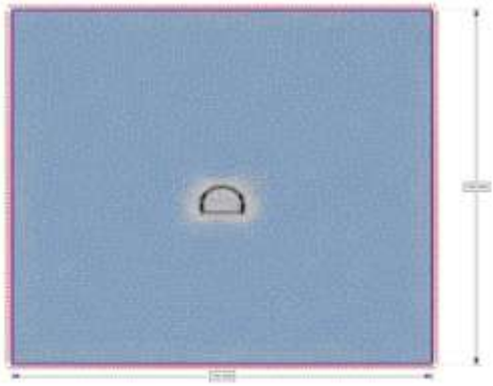


Figure2.1: Model for ground reaction line determination

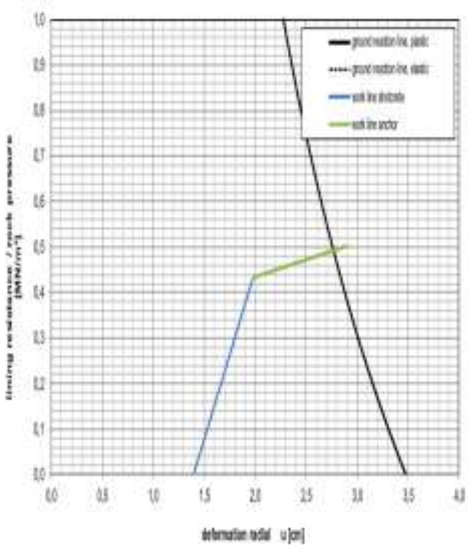


Figure2.2: Exemplary figure for the convergence confinement method

2.2 Calculated cross-sections

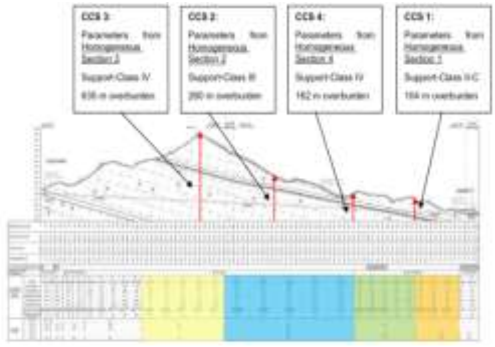
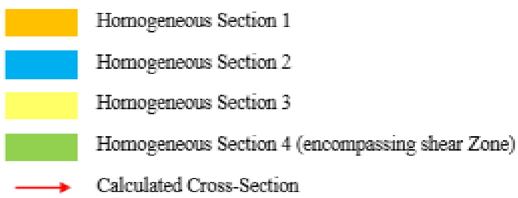


Figure2.3: Overview: Calculated Cross-Sections

In the following, the investigated cross-sections will be described. For each cross section, an adequate support- class was selected and the structural proof was performed using both design approaches described in the previous chapters. The figure below shows an overview of the tunnel alignment. Subsequently, each cross-section will be described briefly.



2.3 CCS 1, SC II-C, 104 m overburden

The calculated cross-section “CCS 1” was modelled using the support-class II-C with rock mass parameters for homogeneous section 1. The excavation will be performed in two steps (top heading, bench). The tunnel lining is of 15 cm thickness with an advance of 2.0 m in the top heading.

Rock bolts are installed with a length of 6 m and distance across tunnel of 1.75 m each round (only considered in analytical approach).

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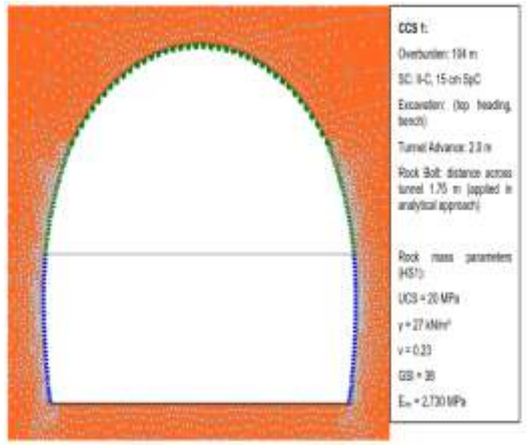

Figure 2.4: Calculation cross-section 1, 104 m OB, SC: II-C

2.4 CCS 2, SC III, 260 m overburden

The calculated cross-section “CCS 2” was modelled using the support-class III with rock mass parameters for homogeneous section 2. The excavation will be performed in two steps (top heading, bench). The tunnel lining is of 20 cm thickness with an advance of 1.5 m in the top heading.

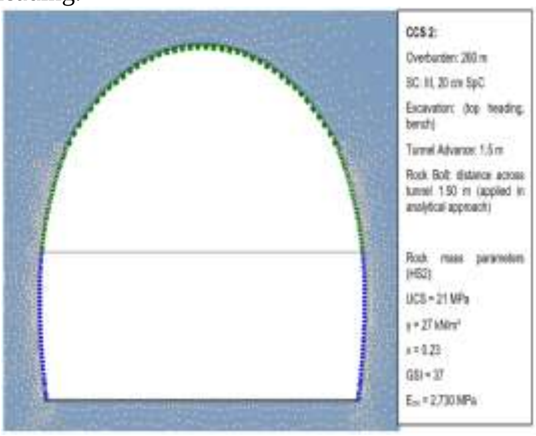

Figure2.5: Calculation cross-section 2, 260 m OB, SC: III

Rock bolts are installed with a length of 6 m and distance across tunnel of 1.50 m each round (only considered in analytical approach).

III. RESULTS AND DISCUSSION

3.1 FEM-Analysis in RS2

Ground Reaction Line:

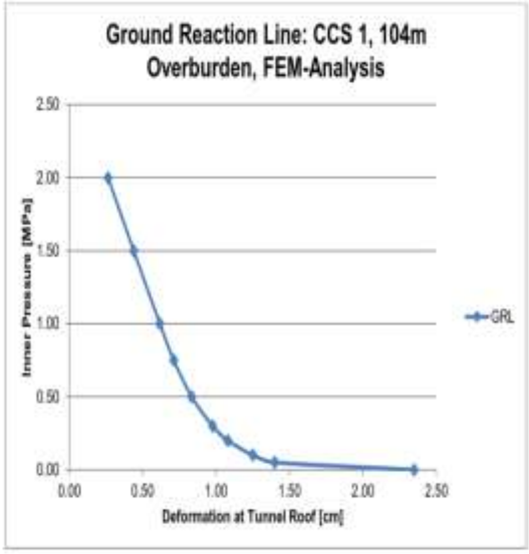

Figure3.1: Ground Reaction Line, CCS 1, 104 m OB, FEM-Analysis

Preforming:

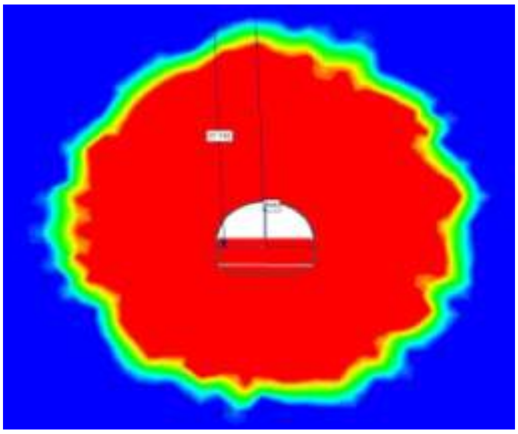

Figure3.2: Plastic Radius excavation of TH: CCS 3, 635 m OB

As a result of the interface between tunnel lining and rock mass, the shear bond causes a gradual increase of axial force with peaks along the tunnel roof. As shotcrete inherits a distinct creeping behaviour, it is very likely that these peaks will distribute and average over a larger area of the tunnel lining. In order to respect this behaviour, the characteristic axial force used for the design of the support will be averaged along the tunnel roof.

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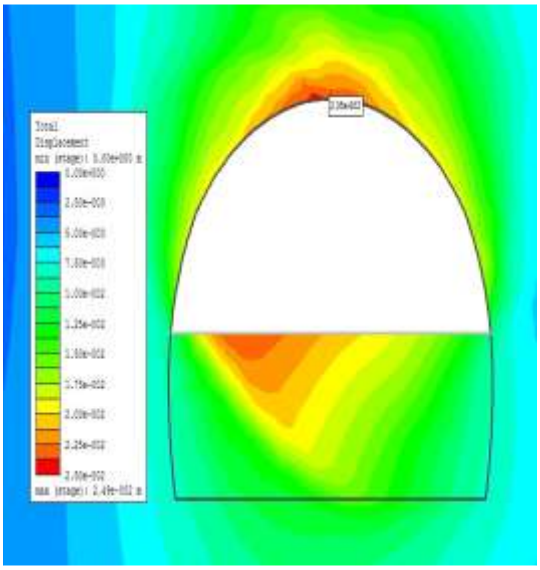

Figure3.3: Final Deformation, excavation of TH: CCS 1, 104 m OB

3.2 Primary Stress State:

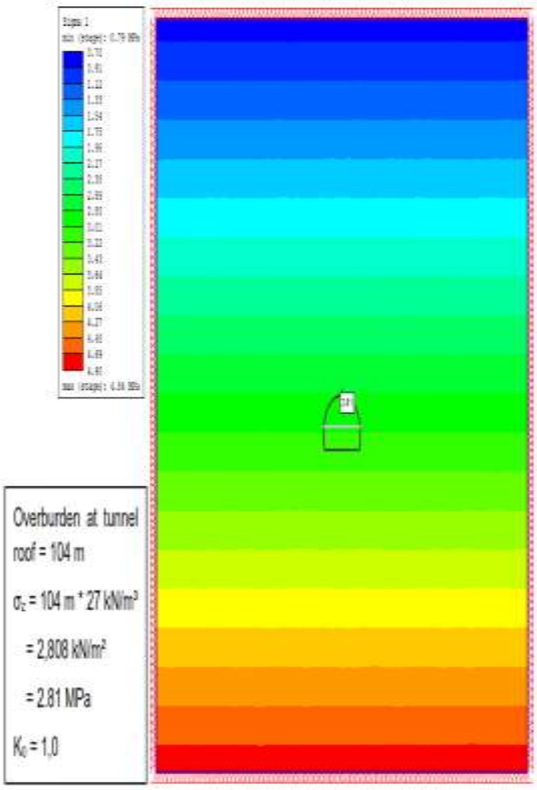

Figure3.4: Primary Stress State: CCS 1, 104 m OB, SC: II-C

Simulation Results

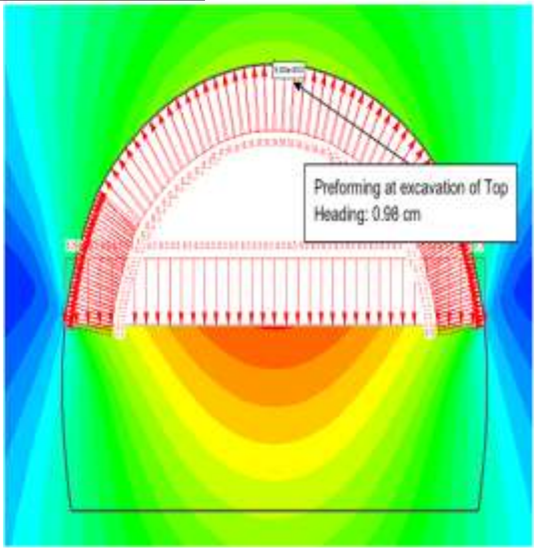

Figure3.5: Preforming at excavation of top heading: CCS 1, 104 m OB, SC: II-C

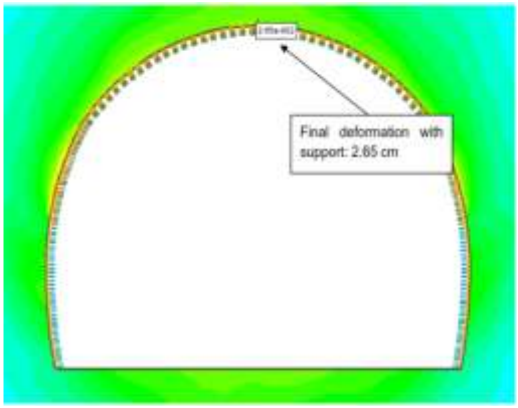

Figure3.6: Final Deformation with support: CCS 1, 104 m OB, SC: II-C

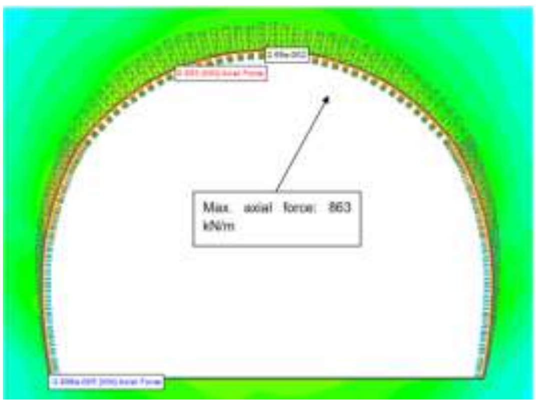

Figure3.7: Axial Forces in tunnel lining: CCS 1, 104 m OB, SC: II-C

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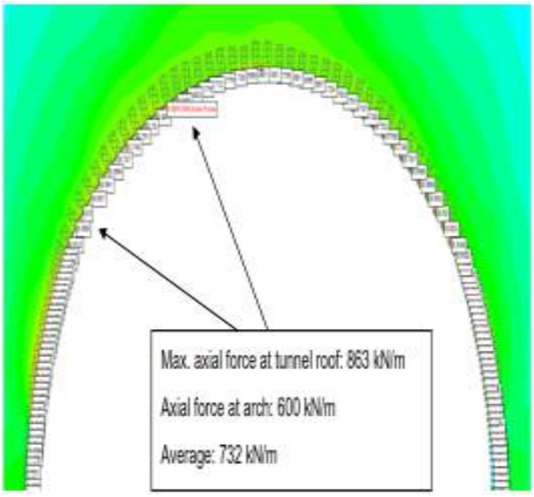

Figure 3.8: Averaging of axial force in tunnel roof: CCS 1, 104 m OB, SC: II-C

As a result of the interface between tunnel lining and rock mass, the shear bond causes a gradual increase of axial force with peaks along the tunnel roof. As shotcrete inherits a distinct creeping behaviour, it is very likely that these peaks will distribute and average over a larger area of the tunnel lining. In order to respect this behaviour, the characteristic axial force used for the design of the support will be averaged along the tunnel roof.

IV. CONCLUSION

During investigation stage, the tunnelling media was classified on the basis of observation made by surface mapping, drill hole data and resistivity survey. In order to achieve realistic values of ground types and ground behaviour types, details of rock mass characteristics were recorded from the surface outcrop and borehole data and accordingly projected in the tunnel grade.

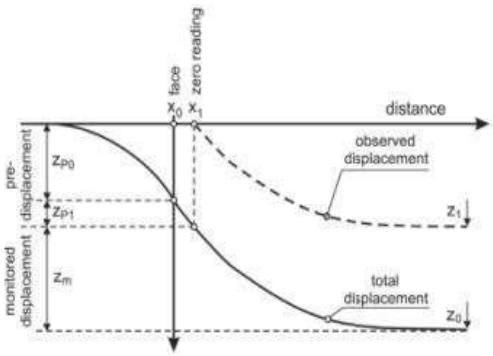

Figure 4.1: Excerpt from OEGG guideline "Geotechnical Monitoring in Conventional Tunnelling" 2014

However, there are structural limitation to project the discontinuities/ share zones at the tunnel grade but affords have been made to justify the geological uncertainties to be encountered during tunnelling.

As displacements already start to develop before excavation and their velocity is likely to be highest right after excavation, the importance of timely (maximum 2-3h after excavation) zero reading is emphasized at this point. The following figure shows a typical course of displacement during tunnel advance.

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