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Research paper



Performance of New Austrian Tunneling Method (NATM) in Weak Rock Case Study

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Abstract

The decline in the over ground utilizable space and increment in development of metro structures, cut and cover structures are winding up fairly difficult to conceptualize and build. In this examination, a nonlinear two dimensional limited component investigation was completed to show the New Austrian Tunneling Method (NATM) burrow developed in frail shake utilizing the business limited component with joint programming PHASE 2.The validity of the numerical modeling procedure performed by the author was checked by making back-analysis for an actual case study of Strengen Tunnel which is one of the biggest expressways in western Austria. A comprehensive parametric study was performed on a hypothetical circle tunnel. Two dimensional numerical simulations with the finite element with joint software PHASE 2 have been performed to ground behaviour with the results of the numerical analysis are presented and discussed for recommendations for future work. In general the tangential stress at side wall and crown obtained from finite element with joints are nearly equal or higher than the closed form solution and equivalent continuum.

Keywords: *NATM Tunnelling; Performance; PHASE 2; Strengen Tunnel; Weak Rock.*

1. Introduction

The desire for the stone mass response to the uncovering of a section is a flighty building issue. The energy of the Stone Designer at the arrangement orchestrate is to assess the security conditions of the unearthing in the "characteristic state" (i.e. exactly when no assistance/change measures are presented) and following the choice of suitable systems for entry uncovering/improvement and support. The route to the achievement of such a method is the dimension of understanding achieved in depicting the stone mass conditions (similar to geographical, geotechnical, in situ push, and hydrogeological parameters) and the ability to speak to the foremost parts of shake mass lead, by using appropriate procedures for the examination of stresses and evacuations in the stone mass around the section and in the helper fragments (pre-reinforce/pre-modification measures; basic and keep going help, etc.).

Various techniques are accessible for the pressure examination of passages, from the soonest shut shape answers for the latest numerical displaying strategies. With the computational power today accessible at a sensible cost, it is conceivable to take care of progressively refined issues. Specifically, with the appearance of numerical strategies, we have helped to the advancement of methods which have been imagined to display reasonably the stone mass conduct.

In this paper the ground behavior of NATM tunnel constructed in weak rock has been investigated using 2D numerical simulations with finite element with joint software PHASE 2. A comprehensive parametric study was performed on a hypothetical circle tunnel. Two dimensional numerical simulations with the finite element with joint software PHASE 2 have been performed to ground behaviour with the results of the numerical analysis are presented and discussed for recommendations for future work.

2. Modelling in Tunnel Engineering

The desire for the stone mass response to the uncovering of an entry is a stunning planning issue. The eagerness of the Stone Specialist at the arrangement orchestrate is to review the steadfastness conditions of the evacuation in the "characteristic state" (i.e. exactly when no assistance/change measures are presented) and following the gathering of suitable techniques for entry evacuation/improvement and support. The route to the achievement of such a strategy is the dimension of understanding achieved in depicting the stone mass conditions (similar to land, geotechnical, in situ push, and hydrogeological parameters) and the ability to speak to the key parts of shake mass direct, by using appropriate systems for the examination of stresses and migrations in the stone mass around the section and in the fundamental portions (pre-reinforce pre-change measures; basic and last help, and so forth.) [1]. Closed-form solutions are still of incredible incentive for a theoretical comprehension of the reaction of passages to uncovering. One could make reference to in such manner the solutlons which are by and by accessible for the investigation of the dynamic improvement of disappointment around a roundabout passage in a hydrostatic pressure field see for example[2.3], and for the examination of the communication between the stone mass and the help. Be that as it may, the improvement of current strategies of passage uncovering and development (i.e. the instance of pre-bolster/pre-adjustment measures, the successive selection of pre-treatment in front of the heading in feeble shake masses, the removal groupings, average of expansive passages), what's more, even the multifaceted nature of rockmass conditions and conduct, which are preferable portrayed today over previously, given the cutting edge examination apparatuses accessible, and so on make

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these arrangements of restricted an incentive for configuration purposes [1].

3. Continuum modelling

The utilization of continuum demonstrating in passage building in section structuring makes it principal to reproduce the stone mass response to revealing by showing an equivalent continuum. The most notable way to deal with deal with this issue, which seems to have expanded wide affirmation, is relative the impeccable shake properties down to the stone mass properties by using precisely portrayed associations, for instance, those given by Hoek and Darker [4].

in the event that utilization is made of the Hoek-Dark colored model for depicting the stone mass conduct, the beginning stage of the scaling procedure is the meaning of the unblemished shake material parameters, for example, □ci (uniaxial compressive quality) and mi (material consistent which relies on the properties of the stone), which can be acquired dependent on the aftereffects of uniaxial and triaxial research center testing. At that point, by utilizing surely understood connections (which rely upon the level of unsettling influence to the stone which will fluctuate as indicated by shake type and exhuming technique) with the most every now and again received shake mass records (i.e. truncated Q or RMR qualities, or GSI values), the stone mass parameters, for example, mb and sb (shake mass constants as indicated by the Hoek-Dark colored measure) or c and □ (shake mass union and rubbing point separately) can be assessed as appeared in Fig. 1 [1].

As outlined by Hoek et al. [5] and Startfield and Cundal [6] various PC based numerical techniques have been produced in the course of recent decades and these give the way to acquiring suitable answers for passage building issues in the system of the comparable continuum approach. These numerical techniques can be separated into two classes: limit and space strategies.

The limit strategies contain a few kinds of limit component techniques (BEM) and suggest the subdivision of the limit of the exhuming into components, as the inside of the stone mass is spoken to scientifically as an endless continuum. The space techniques, which incorporate the limited component (FEM) and limited distinction strategies (FDM , infer that a physical issue is demonstrated numerical y by discretizing (i.e. partitioning into zones or components) the issue area, i.e. the stone mass in which the uncovering is to be made [1].

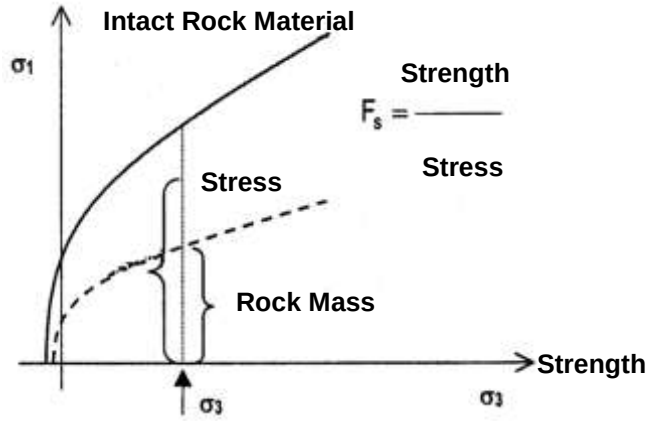


Fig.1: Hoek-Brown failure criterions for the intact rock material and the rock mass [6]

4. Numerical Modeling and Verification

In this section the numerical modeling of tunnels using finite element with joint using PHASE2 software is discussed. All the details regarding numerical modeling including material model, joint model, boundary condition and initial condition are introduced. Also a numerical verification is done using selected section along Strengen Tunnel for check the capability of numerical modeling using finite element of joint (PHASE2) to capture the real behavior [7].

4.1 Numerical modeling description and input parameters

The recreations have been performed for a roundabout passage with a width of 10 m. The attributes of the reproduction demonstrate are condensed as pursues:

Limit conditions: The model limits have been displayed at a separation of five passage breadths from the passage in the two bearings to limit the limit impact on the aftereffects of the investigation. The limit pressure is connected at the best limit with the end goal to reproduce the separate vertical essential pressure. The sidelong weight coefficient (Ko) is set to the coveted esteem and the direct increment of the level essential worry with the expanding profundity is displayed as appeared in Fig. 2.

Square size: The joint separating (js) for both joint sets has been fluctuated between estimations of 2m, 1m and 0.5 m. The definitions huge and medium and little square sizes are utilized for the volumetric joint check, Jv= 1, 2, 4 individually.

Square shape: Two joint sets plunging to one side are demonstrated. The plunge (edge from flat in ccw heading) of the primary joint set is kept steady at 80°. The plunge point of the second joint set is fluctuated from 60° to 0° in 20° advances. As the plunge edge of the second joint set differs, the square shape and size changes all the while. For high plunge edges of the second joint set thin squares are shaped. Squares with more uniform measurements are shaped as the plunge point diminishes. The square shape is characterized with pinnacle edge and the viewpoint proportion of the biggest measurement to the littlest one, lmax/lmin. The biggest measurement is the length through the pinnacle of the square and the littlest one is the length opposite to it as appeared in Fig. 3.

Material parameters: The discontinuous medium around the tunnel is modeled by elastic isotropic blocks and discontinuities. The elastic blocks are chosen to ignore unrealistic deformation of the blocks under high stresses and to reflect the influence of discontinuities. The Coulomb slip model is chosen to model the joint material behavior. The input parameters for the blocks and joints are given in Table 1. Each of the input parameters for stiffness and strength are broken down in terms of three main concepts:

The intact rock between discontinuities

The discontinuum

An equivalent continuum model used in the tunnel analysis

In situ stress conditions: Overburden thicknesses of 600 m have been chosen for the simulations. The K value of 0.5 has been used.

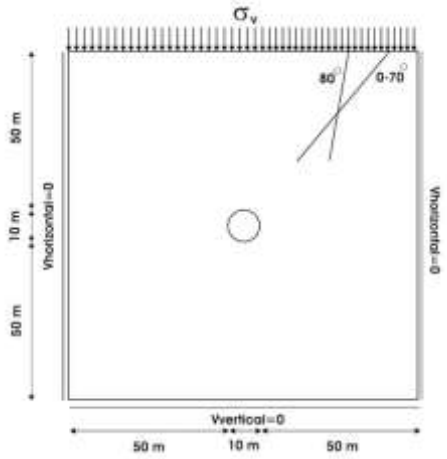


Fig.2: Model for the numerical simulation

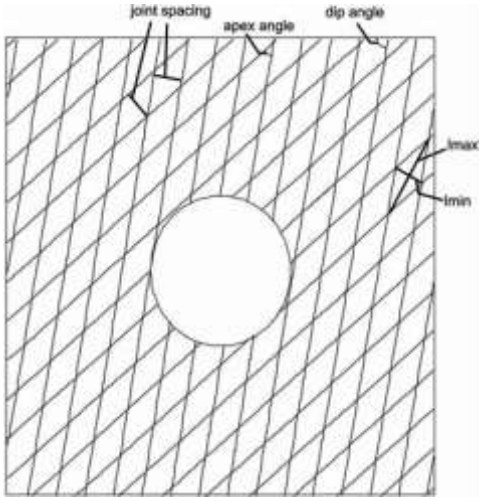


Fig. 3. Nomenclature for the numerical simulations

Table 1: Input parameters for the blocks and joints

Block Parameters	Joint Parameters
mass density=2700 kg/m3 E=20000MPa K=16000Mpa G=8000 MPa v=0.3	jkn=5000 MPa/m jks=2500 MPa/m jc=0.1 MPa jresc=0 jfric=25° jr=0° jdil=0°

4.2. Two dimensional finite element with joints simulations by PHASE2

Phase2 is a 2-dimensional, elasto-plastic FEM program utilized for the examination of complex issues in both shake and soil mechanics. Various constitutive models for materials and joints, and some help types and groundwater models are worked in to rendition 7. Every single constitutive model utilized for this examination are worked in to the product specifically. The examination of 2-dimensional issues is either performed under plane strain or axisymmetric conditions [7].

A key component of the program is the capacity to determine joint sets to the model through the joint system usefulness. The product program Phase2 incorporates the "Goodman joint component", and Form 7 incorporates a joint systems administration include. This element has the unmistakable favorable position of giving the capacity to indicate a 2-dimensional arrangement of joints.

Various deterministic and probabilistic calculations are accessible for the age of the joint systems. The straightforwardness and proficiency of the Adaptation 7 UI concerning the formation of discontinuities, or sets of discontinuities, and this usefulness has been the major contributing component to the determination of Phase2 for the demonstrating utilized in this examination.

4.3. Case Study: Strengen Tunnel

The Strengen Tunnel is part of the S16 expressway in western Austria. The two double lane tubes have a length of. 5800 m, the diameter is approximately 10 m. The dominating rock type is quartz phyllite, consisting mainly of quartz phyllonites and phyllonitic mica schists. The uniaxial compressive strength of the phyllites is between 15-25 MPa. The foliation dips steeply towards the south.

The foliation is the dominating discontinuity throughout the tunnel. There are other geological features like faults and joint sets, which enable formation of blocks. The strike of the foliation relative to the tunnel axis is shown in Fig. 4. [8,9]. Due to high kinematical freedom given by this condition, the measured displacements reached up to 80 cm.

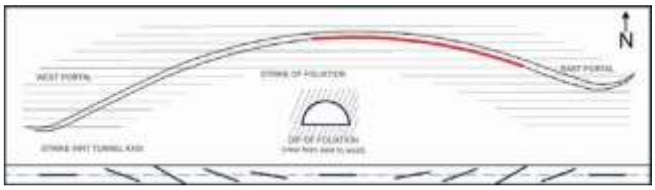


Fig.4. Strike of foliation relative to the tunnel axis [8]

The selected section is from km 1+725 at the north tube. Besides the steeply dipping foliation (180/75), three faults (172/55, 200/45, 150/30) with lower dip angles and 1-15 cm cataclastic zones have been mapped at the face. The behaviour from the site data is compared to the one evaluated from ground behaviour evaluation with numerical simulation and the relevant sketches are shown in Fig. 5.

The general behaviour has been caught in ground behaviour evaluation with numerical simulation. The ground behaviour has been categorized as BT 3- shallow stress induced failure of the rock mass. The key parameters in the simulation model are apex angle=30°, Jv=2 and φr=22°. The simulation shows that the displacement magnitudes are rather uniform with a magnitude of around 5 cm. The displacement vector orientations and relative magnitude in the crown and right sidewall are pretty similar to those observed on site. The high displacement magnitude observed on site at the left side wall differs from the results of the numerical analysis. The reason for the high displacement might be a fault outside the excavation area, which has not been recorded, or a more pronounced shearing along the foliation.

4.4 Evaluation of ground behavior for the stress conditions H=600 m , K=0.5

The underlying stage in the stone mass depiction is the confirmation of the key parameters. The ground lead is evaluated considering those parameters in blend with the affecting components relative presentation of discontinuities, groundwater and in-situ extend conditions. In jointed shake masses the standard key parameters are flawless shake and abnormality properties.

One point of this theory is to think about the ground practices in jointed shake masses by the limited component technique with joints. Two dimensional numerical investigation utilizing continuum display with joints (PHASE2 code) [7] has been performed with the end goal to assess the impact of the geographical structure (square shape, and square size) under various in situ stretch condition on the ground conduct around the passage in blocky shake masses and characterize the distinction of the qualities of the watched ground practices for different mixes of above characterized factors by utilizing this numerical methodology. Shut frame arrangement and proportionate continuum have been executed as datum and with the end goal to make a correlation.

The numerical reenactments are utilized to decide the ground conduct. Diverse blends of key parameters result in different ground rehearses. The ground rehearses are grouped by the watched disappointment instrument and the removal design. Delimiting criteria for the quantitative appraisal of the ground rehearses have been developed reliant on the movement degree and significance of dissatisfaction zone [1]. They are recorded in Table 2. Significance of disillusionment zone demonstrates the domain where the stone mass quality is outperformed. Since adaptable squares are used in the examination the mistake can happen just along the joints.

Table 2: Delimiting criteria for the behaviour type [1]

Behaviour Type	Displacement/Tunnel radius	Depth of failure zone/Tunnel radius
BT 1	<1%	0
BT 3	>1% <3 %	< 1.0
BT 4	>3 %	> 1.0

The attributes of each ground conduct type are depicted in the accompanying segments. Limit conditions, square shape, square size and joint quality, prompting the talked about ground practices are characterized.

Fig. 6 through Fig. 8 demonstrates the digressive worries at side dividers and crown for various peak point and dispersing between joints for the two utilized numerical moved toward limited component with joint and discrete component.

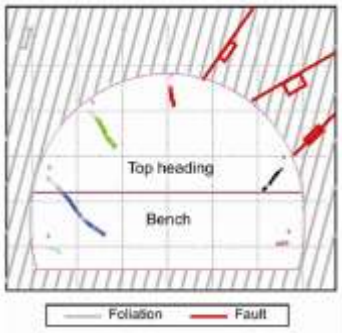
When all is said in done the digressive worry at side divider and crown got from limited component with joints are almost equivalent or higher than the shut shape arrangement and proportional continuum. This reality can be clarified as the bracing of squares into one another and bringing about a practically higher side weight coefficient. Along the edge dividers the distracting pressure dispersion is spasmodic because of the nearness of a few joints.

5. Conclusions

- The numerical simulations with two dimensional finite element with joints has been performed to evaluate the influence of the key parameters block shape, block size and in-situ stresses on the ground behaviors.
- Different combinations of the key parameters and in-situ stresses result in a variation of the ground behaviors. The observed ground behaviors are classified into categories and sub categories according to the observed failure mechanisms and deformation behavior.
- In general the tangential stress at side wall and crown obtained from finite element with joints are nearly equal or higher than the closed form solution and equivalent continuum.
- Finally, in continuum modeling, it is difficult to select a failure criterion which describes the particular problem to be analyzed in the best way. Good knowledge about the in-situ stresses is necessary to obtain reliable analysis results since the magnitude of especially horizontal in-situ stresses may have crucial influence on the general stability.

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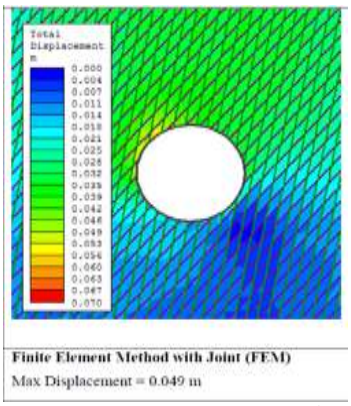


Fig. 5: The displacement vectors at cross section from site data (left), km:1+725- north tube and ground behaviour evaluation with numerical simulation (right)

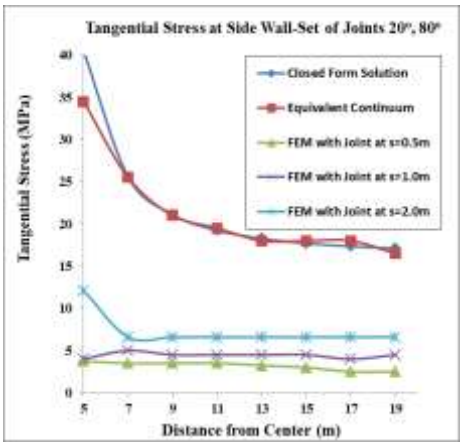


Fig. 6 (a): Tangential stress at side wall at set of joints 20° and 80°

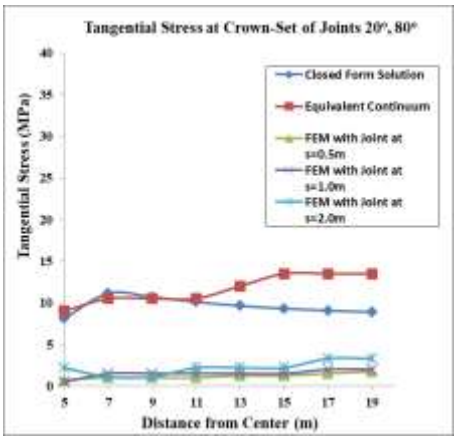


Fig. 6 (b): Tangential stress at crown at set of joints 20° and 80°

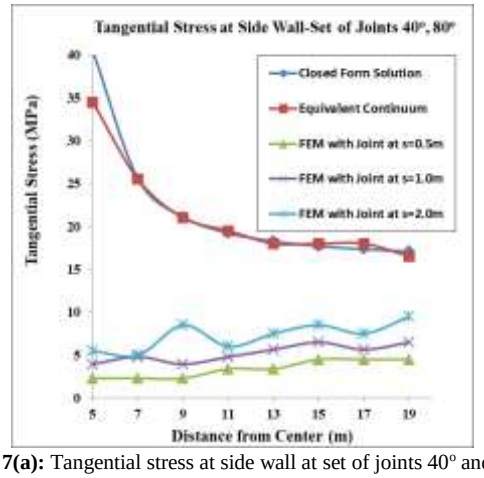


Fig. 7(a): Tangential stress at side wall at set of joints 40° and 80°

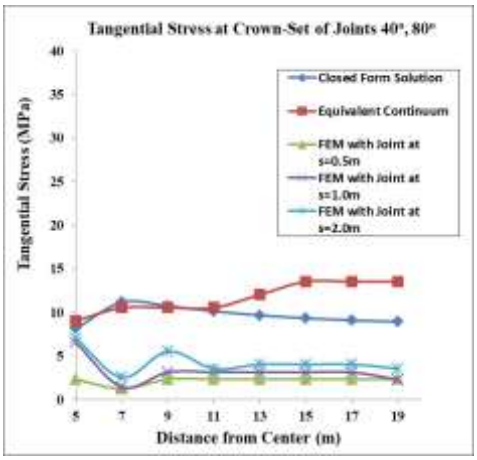


Fig. 7 (b): Tangential stress at crown at set of joints 40° and 80°

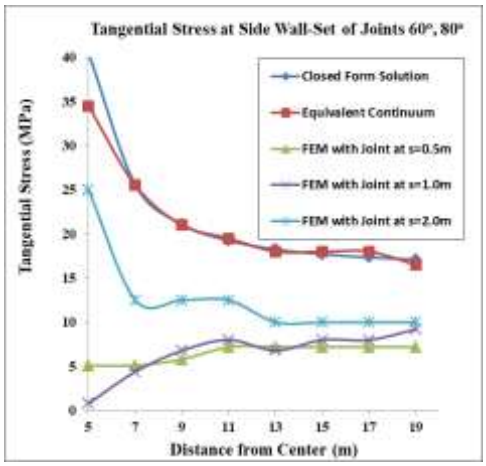


Fig. 8 (a): Tangential stress at side wall at set of joints 60° and 80°

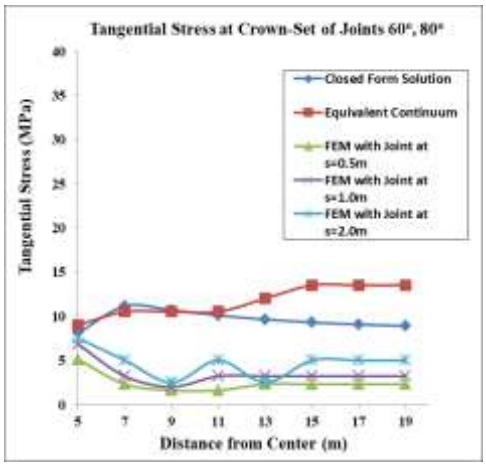


Fig. 8 (b): Tangential stress at crown at set of joints 60° and 80°

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