iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VII **Month of publication:** July 2021

DOI: https://doi.org/10.22214/ijraset.2021.37092

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

Analysis of Load-Bearing Capacity of Initial lining in Tunnels

Md Waquar Alam[1], Sanket Tirpude[2]

Abstract: ***Large displacements during excavation are regularly observed in Squeezing ground condition and Rock-burst condition with high overburden. The expected displacement has to be estimated prior to excavation to provide enough allowance for the displacements. The support system need to be well-suited through the estimated imposed strains. As the estimated displacements and thus the strains in the support depend upon the load-bearing capacity of support. The ratio of uniaxial compressive strength of rock mass to maximal insitu stress determines tunnel integrity in the weak region.This ratio estimates the requirements of initial lining to control strain to a stipulated level. The elasto-plastic theory may deliver definitive forecasts providing the strength limitations of rock masses are identified accurately. With the help of empirical analysis, the development of displacements for diverse advance rates and supports can be concluded. As a consequence, a quantitative finite element model based on an advanced built-in model is designed to analyse the load-bearing efficiency of initial lining although taking into consideration the time-dependent and non-linear material behaviour of initial lining. The time-dependent excavation mechanism of the drill-and-blast approach for tunnels guided by full face excavation is considered in the finite element model. The material parameters for the initial lining were computed based on case studies- (A Chibro-Khodri Hydropower Tunnel).***
Keywords: Squeezing condition, Rock-burst condition, Drill-and-Blast method, Finite Element Model, Elasto-Plastic Model.

I. INTRODUCTION

As tunnel construction is carried out across porous and deformable terrain, such as that found inside heavily tectonized areas at great depth, it poses significant challenges. Generalized time-dependent and anisotropic deformations occur in this condition known as'squeezing surface.'

A squeezing terrain necessitates extra work to design adapted structural measures, which may result in significant changes to both the drilling process and the support structure, increasing the project's expense and delay. Furthermore, the consequences of this action can be seen even after the construction activities are over, with an overloading of the support system.

The excavation method can be adapted and changed during the works by using traditional methods, depending on the ground conditions encountered. To deal with the massive convergences, a deformable support may be added.

Tunneling in weak rock faces major difficulties for design engineers, as errors in support system construction will result in very expensive failures. To know the problems in designing support for tunneling in weak rock, it's important to examine at some fundamental ideas about behaviour of rock mass surrounding a tunnel and how support structures act to monitor the deformation. The accomplishment of the tunneling procedures is dependent on an accuracy of geological estimates.

The ideas of tunnel support system are :

1) To steady the tunnel portals.
2) To diminish ground movements.
3) To permit the tunnel to operate over the design life.

In general, the first two functions are provided by an initial support system, whereas the third function is preserved with a final lining.

II. PREDICTION OF SQUEEZING CONDITION

The assessment and prediction of squeezing condition is critical prior to the start of the project. Existing solutions are often observational or semi-empirical in nature. **Muir-Wood (1972)** suggested one of the first tools for determining tunnel stability, which was dependent on the competency metric, it is the ratio of uniaxial compressive strength σ_{cm} and preliminary stress condition $\sigma_{o.}$

$$N_c = \sigma_{cm} / \sigma_o \qquad (1)$$

©IJRASET: All Rights are Reserved

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

III. EMPIRICAL STRATEGIES

This method category is focused on classification schemes that allow for the identification of possible squeezing conditions. The influence of the rock mass consistency index Q **(Barton et al, 1974)** and overburden (H) on the squeezing conditions, a cut boundary line to distinguish between squeezing and non-squeezing situations (fig.1). The expression used for this division line is given in (Eq.2).

$$H = 350\,Q^{1/3}\ [m] \tag{2}$$

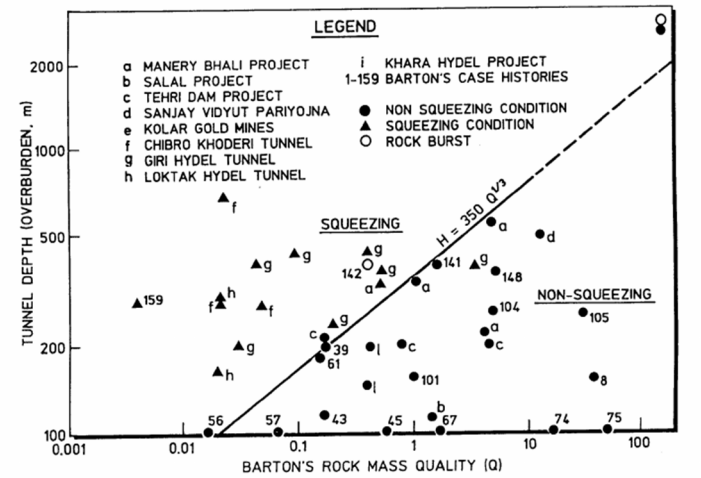


Fig.1 A graph for detemining squeezing behaviour (after Singh et al., 1992).

On the basis of rock mass number (N) given as stress free Q-index (for obtaining the exact value of SRF can be avoided by taking SRF value as 1).

$$N = [Q]_{SRF=1} \tag{2}$$

as well as the diameter of the tunnel, **Goel et al. (1995)** suggested another expression based on the tunnel span or diameter.

$$H = (275N^{0.33})B^{-1}\ [m] \tag{3}$$

A line distinguishes the squeezing and non-squeezing situations in Fig.2. For the prediction of a "rock bursting" case also in Fig.2.

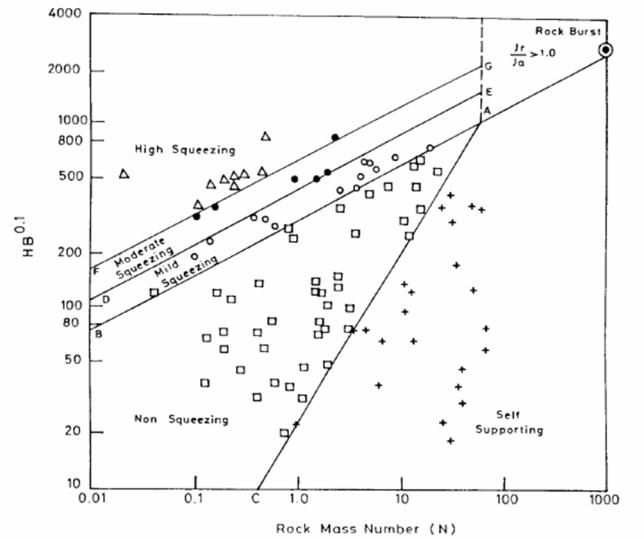


Fig.2. A graph for detemining squeezing behaviour (Goel, 1995)

©IJRASET: All Rights are Reserved

Goel et al. (1995) proposed a more accurate approach than Singh (1992), so that squeezing condition as well the degree of squeezing can be estimated.

1) Mild squeezing (convergence in between 1-3% of tunnel dia.)
2) Moderate squeezing (convergence in between 3-5% of tunnel dia.)
3) High squeezing (convergence greater than 5% tunnel dia.)

IV. SEMI-EMPIRICAL STRATEGIES

Semi-empirical methods attempt to estimate deformation around the tunnel and the necessary support pressure to withstand the radial pressure applied by the rock, in addition to identifying the possible squeezing action of a ground.

Jethwa et al. (1984) used the "stability factor" to determine the degree of pressing. Different degrees of squeezing ability can be considered depending on the value of N_C, Fig.3:

1) $N_C < 0.4$; Highly Squeezing Condition.
2) $0.4 < N_C < 0.8$; Modrately Squeezing Condition.
3) $0.8 < N_C < 2.0$; Midly Squeezing Condition.
4) $2.0 < N_C$; Non-Squeezing Condition.

If the ground has an elasto-plastic behaviour and N*c* > 2.0, the ground can behave elastically during the excavation. Squeezing is considered for this approach as soon as there is plasticity.

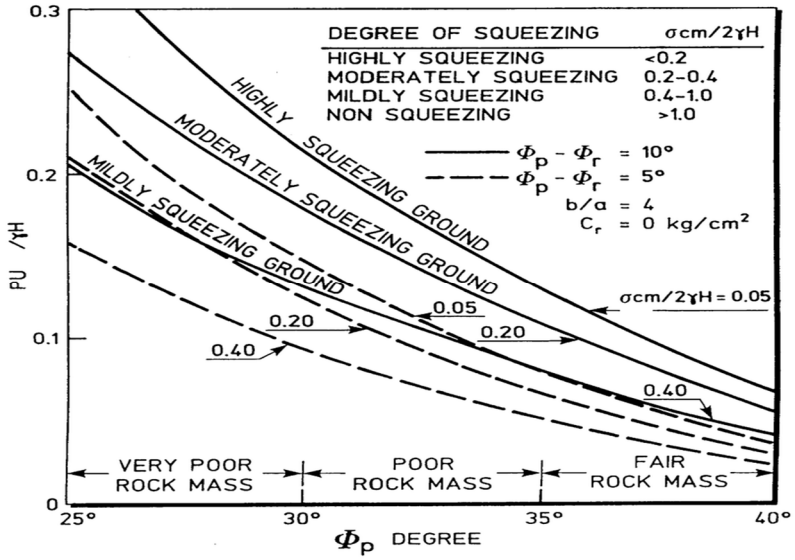


Fig.3 A method for prediction of squeezing behaviour given by Jethwa et al. (1984)

On the basis of generalized deformation at the tunnel wall, **Aydan et al. (1996)** suggested a technique for predicting five degrees of squeezing action. The deformation is determine as the proportion of the tangential deformation around the tunnel ($\varepsilon_\theta^\alpha$) to the minimum elastic deformation (ε_θ^e) (where $\varepsilon_\theta^e = \sigma_{ci}$):

a) $\varepsilon_\theta^\alpha/\varepsilon_\theta^e \leq 1$; Non-Squeezing condition
b) $1 < \varepsilon_\theta^\alpha/\varepsilon_\theta^e \leq \dot{\eta}_p$; Light-Squeezing condition
c) $\dot{\eta}_p < \varepsilon_\theta^\alpha/\varepsilon_\theta^e \leq \dot{\eta}_s$; Fair-Squeezing condition
d) $\dot{\eta}_s < \varepsilon_\theta^\alpha/\varepsilon_\theta^e \leq \dot{\eta}_f$; Heavy- Squeezing condition
e) $\dot{\eta}_f < \varepsilon_\theta^\alpha/\varepsilon_\theta^e$; Very heavy-Squeezing condition

where the normalised deformation levels are given as a function of the uniaxial intensity of the intact rock:

$\dot{\eta}_p = 2\ \sigma_{ci}^{-0.17}$, $\dot{\eta}_s = 3\ \sigma_{ci}^{-025}$, $\dot{\eta}_f = 3\ \sigma_{ci}^{-0.32}$

©IJRASET: All Rights are Reserved

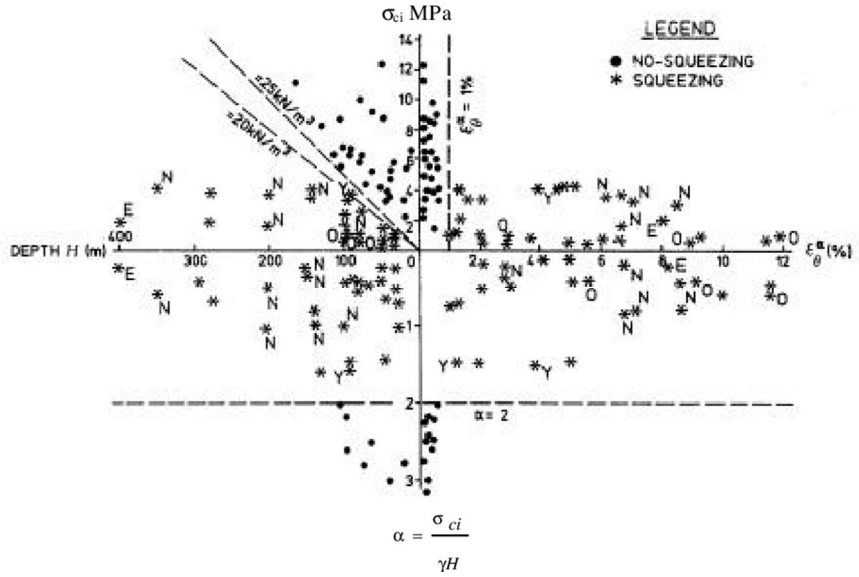


Fig.4 Squeezing conditions can be predicted using this technique (Aydan et al., 1993)

Hoek & Marinos (2000) suggested a squeezing stage classification based on the deformation around the tunnel (ε_t). When the squeezing conditions are extreme, the deformation can exceed 10% :

- $\varepsilon_t \leq 1\%$; Few Support problem
- $1\% < \varepsilon_t \leq 2.5\%$; Minor-Squeezing problem
- $2.5\% < \varepsilon_t \leq 5\%$; Severe Squeezing problem
- $5\% < \varepsilon_t \leq 10\%$; Very severe Squeezing problem
- $10\% < \varepsilon_t$; Extreme squeezing problem

For estimating ε_t Hoek (2001) suggested a closed-form solution based on the factor σ_{cm}/σ_o and also on p_u/σ_o

$$\varepsilon_t \% = 0.15\left(1 - \frac{p_u}{\sigma_o}\right) \frac{\sigma_{cm}^{-\left(\frac{3p_u}{\sigma_o}+1\right)/\left(\frac{3.8p_u}{\sigma_o}+0.54\right)}}{\sigma_o} \quad (4)$$

In contrast to Aydan et al. (1993), the method of Hoek (2000) encompasses a wider spectrum of squeezing actions so intense squeezing can also be detected.

V. DESIGN PARAMETERS

The input parameters for designing of tunnel based on Chibro-Khodri hydropower tunnel.

Material	r_i (m)	Overburden(m)	γ (kN/m^3)	Q	c (MPa)	φ (˚)	P_o (MPa)
Shale	1.5	280	27.3	0.025	0.1	30	7.64
Clay	4.5	280	26.4	0.016	0.1	25	7.39

VI. FINITE ELEMENT METHOD

The RocScience software application was used for the analysis (RS2). A model is developed in phases to estimate the support requirements and ground movements caused by huge overburden.

The following are the primary assumptions used in numerical modelling to build the Tunnel's support system.

1) The tunnel shape is consistent over its length, allowing the three-dimensional issue to be represented in two dimensions via a plane-strain analysis.

2) The surrounding rock mass is homogeneous and isotropic in all directions.

©IJRASET: All Rights are Reserved

Material Parameter	Shale	Clay
Poisson's Ratio	0.3	0.4
Failure Criteria	Mohr – Coulomb	Mohr – Coulomb
Peak Tensile Strength	0	0
Peak Friction Angle	30˚	20˚
Peak Cohesion	0.1	0.1

Table.1 Design properties for shale and clay

A. Initial Liner

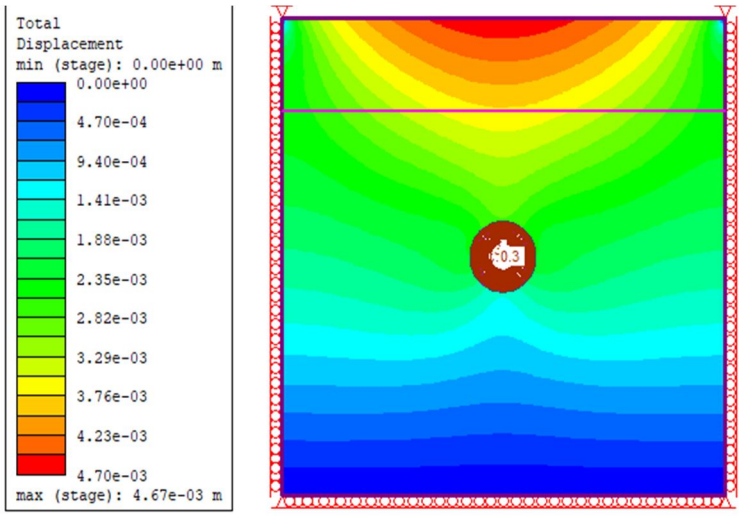
The shotcrete liner is modelled as Reinforce Concrete. The liner details utilised in the analysis are presented in the Tables.2. One of the chosen support components in the Platform Tunnel will be shotcrete. The table highlights the strength and stiffness parameters for the shotcrete grades that were employed in the analysis.

Shotcrete Grade	Compressive Strength	Young's Modulus
M30	30 N/mm^2	27400 MPa

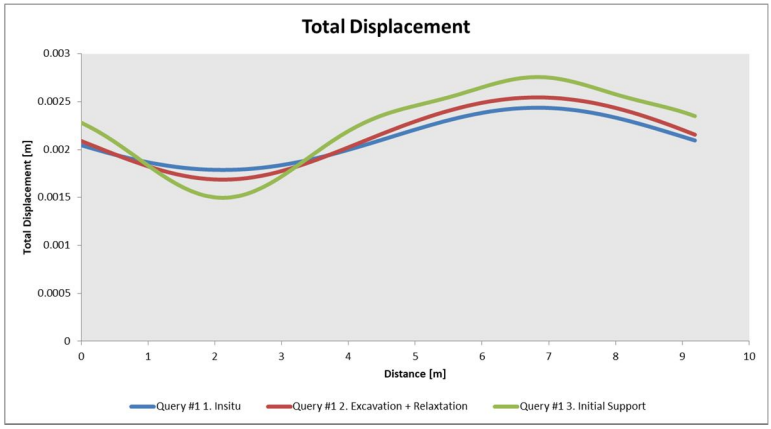
B

VII. RESULTS

1) RS2 Model-01(Shale): Tunnel diameter is 3m and overburden of tunnel is 280m.

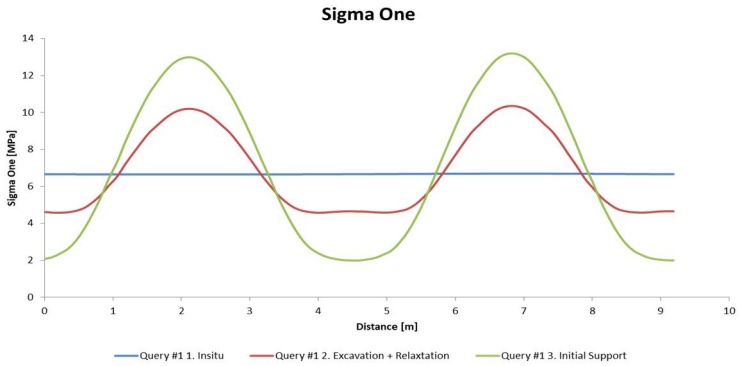


Interpretation results of total displacement

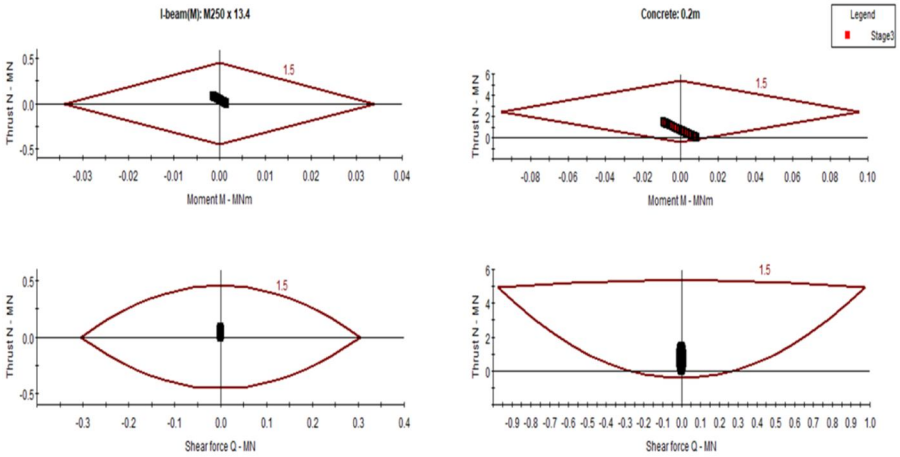


Graphical representation of total displacement

©IJRASET: All Rights are Reserved

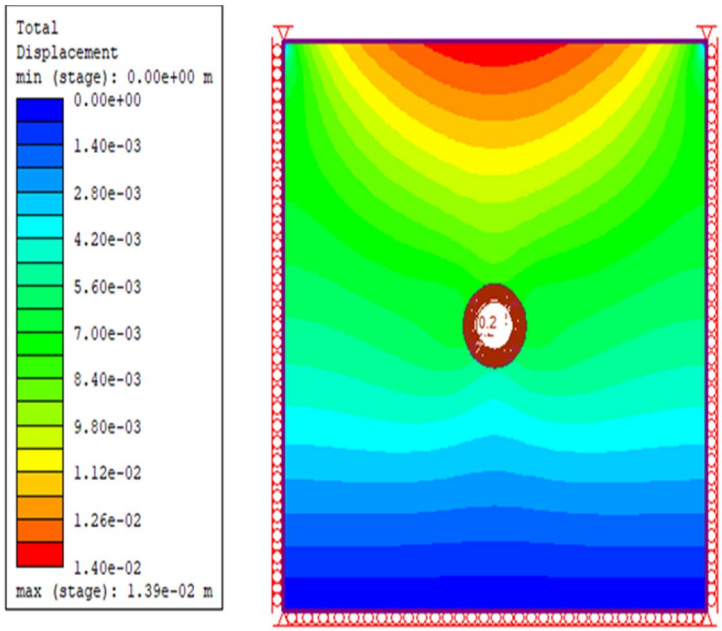


Graphical representation of sigma 1



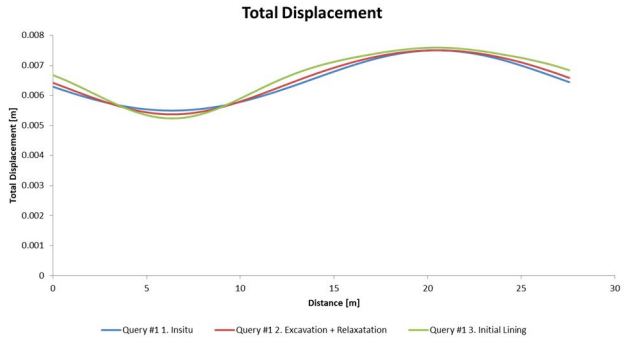
Graphical representation of Initial support

2) RS2 Model-02(Clay): Tunnel diameter is 9m and overburden of tunnel is 280m.

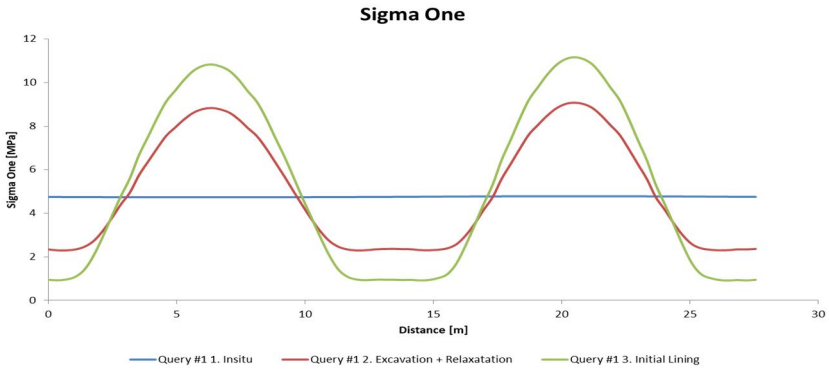


Interpretation results of total displacement

©IJRASET: All Rights are Reserved



Graphical representation of total displacement



Graphical representation of sigma 1

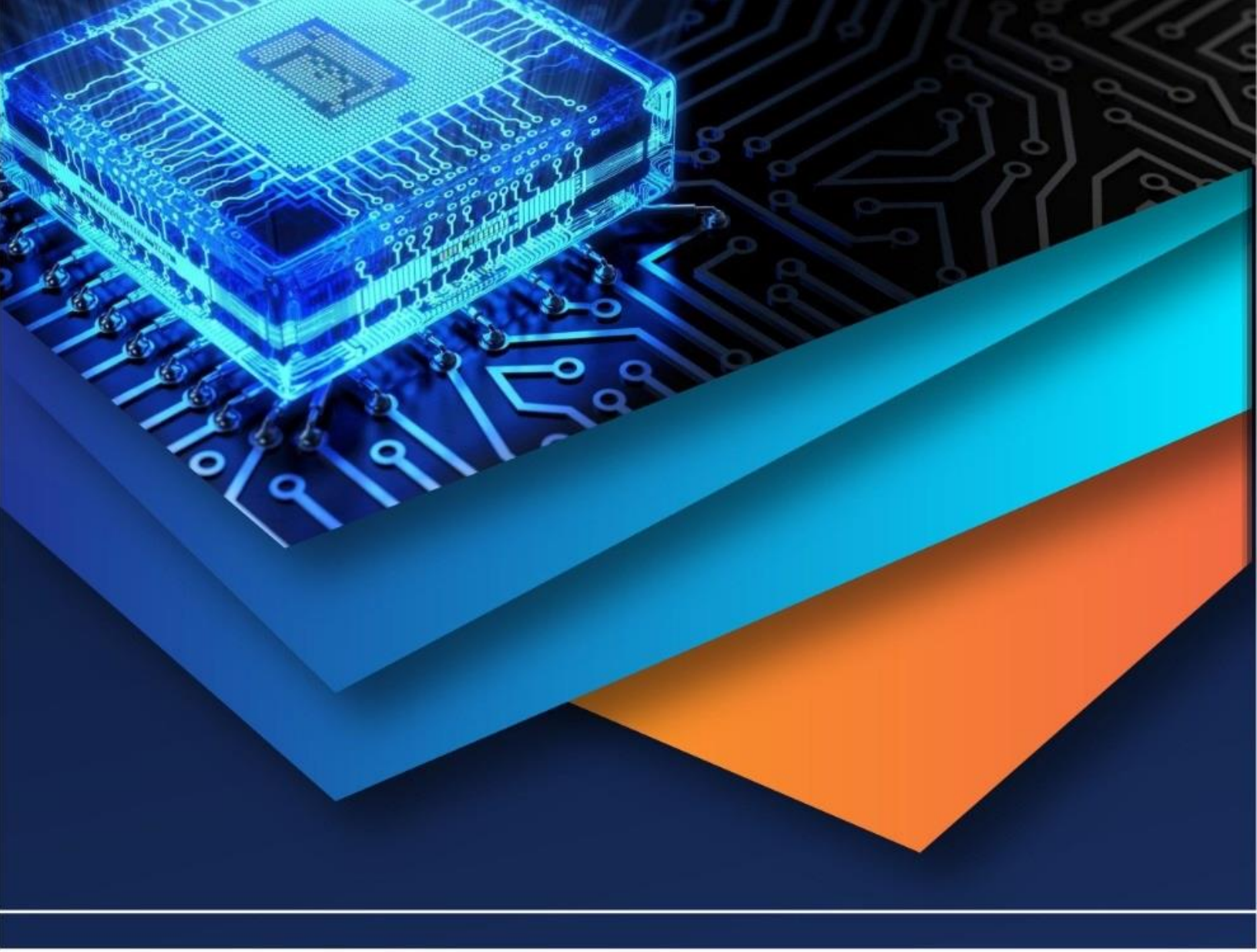
VIII. CONCLUSION

This study presents a strength criteria, which is verified using experimental data from various material types under the same overburden. The main advantages are the little fluctuation of strength parameters with confining stress and the ease of linking with other standard criterion. To assess the stress conditions surrounding underground openings, a closed-form solution based on the suggested criterion is constructed. This numerical analysis assess the weakness of the rock mass in the Chibro-Khodri Tunnel. In compared to previous current approaches, the suggested technique predicts squeezing pressure with more accuracy.

REFERENCES

[1] Aydan, 0., T. Akagi, and T. Kawamoto. 1993. The squcczing potcntial arrack around tunnels: thcory and prediction.
[2] Hoek E, Brown ET. Empirical strength criterion for rock masses. Journal of the Geotechnical Engineering Division, ASCE 1980.
[3] Hoek E, Diederichs MS. Empirical estimation of rock mass modulus. Int J Rock Mech Min Sci 2006.
[4] Hoek E. A brief history of the Hoek-Brown failure criterion. 2002. http://www.rockscience.com.
[5] Hoek, E., Marinos, P., 2000/2001. Predicting tunnel squeezing problems in weak heterogeneousrock masses. Part 1 & Part 2, Tunnels and Tunnelling International.
[6] J. L. Jethwa, Evaluation of Rock Pressures in Tunnels through Squeezing Ground in Lower Himalayas, University of Roorkee,Roorkee, India, 1981.
[7] Jethwa JL, Singh B, Singh B, Mithal RS. Influence of geology on tunneling conditions and deformational behaviour of supports in faulted zones – A case history of the Chhibro-Khodri tunnel in India. Engineering Geology 1980.
[8] Jethwa, J.L. (1981). Evaluation of Rock Pressure in Tunnels through Squeezing Ground in Low Himalayas.
[9] Jethwa, J.L., Dube, A.K. Singh, and B.singh,(1979). Estimation of Rock Pressure and Support Requirements for Unexcavated Portions of Lok-tak Hydel Tunnel.
[10] R. Goel, “Correlations for predicting support pressures andnclosures in tunnels,” Ph.D. thesis, Nagpur University, Nagpur,India, 1994.

©IJRASET: All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)