# PREDICTION OF CLOSURE AND ROCK LOADS FOR TUNNELS IN SQUEEZING GROUNDS

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CERTIFICATE

This is to certify that the thesis entitled "PREDICTION OF CLOSURE AND ROCK LOADS FOR TUNNELS IN SQUEEZING GROUNDS" submitted by Mr. V. M. Sharma, to the Indian Institute of Technology, Delhi, for the award of degree of DOCTOR OF PHILOSOPHY is a record of the *bona fide* research work carried out by him. Mr. Sharma has worked under my supervision for the submission of this thesis, which, to my knowledge, has reached the requisite standard.

The thesis, or any part thereof has not been submitted to any other University or Institution for the award of any Degree or Diploma.

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## ABSTRACT

There are three main approaches namely analytical, observational and empirical, available for the design of support system of tunnels. The empirical approaches are based on rock mass classification systems, the observational approach basically represents a 'build as you go' philosophy, and the analytical solutions are mostly based on some simplifying assumptions about the ground behaviour. In the absence of any better technique being available, the designers mostly depend upon one empirical method or the other.

Improvements in the design methods of tunnel supports and lining are obviously needed. It is necessary to understand the mechanism of behaviour of the system comprising support system and the surrounding medium, which, it is believed, can be achieved by a combination of theoretical considerations and studies of tunnel behaviour in the field.

In this thesis, the convergence confinement method of ground-support interaction has been used as the basic technique to explain the phenomenon. The method of Brown et. al for calculating the radial convergence of a circular tunnel in a hydro-static stress field assuming the ground behaviour as elastic-strain softening-plastic using finite difference approach has been extended. Based on available experimental evidence, the relationship between two principal strains has been taken as non-linear. Finite difference approach has been replaced by part-integration and part numerical method. It is seen that the modified method converges faster and for

particular cases, its results are closer to the results obtained by closed form solutions.

Using the method outlined above, a parametric study has been carried out to see the relative influence of different parameters on the ground convergence. Based on the results produced by a small computer programme developed for this study, a correlation between ground convergence and three dimensionless factors has been worked out. With this correlation, it is possible to develop a ground convergence curve if the unconfined compressive strength of intact rock material, the rock mass rating and the amount of rock cover are known. Radial deformations calculated from the above correlation compare well with those calculated by rigorous procedure or obtained by field observations.

An evaluation of Terzaghi's rock load theory on the basis of interaction concept has been done. It is seen that the rock loads calculated on the basis of Terzaghi's theory are generally on the higher side.

In addition to elastic and plastic deformation, the tunnels may also undergo deformations which are time-dependent. It is very difficult to determine the visco-elastic coefficients in the laboratory or in the field and still more difficult to use them. However, by using the linear relationship between the logarithm of the rate of convergence and time, it is possible to predict the long term deformation on the basis of short term measurement data. Such a relationship has been given and examples show that it works fairly well.

Data from four projects namely Giri Project (Himachal Pradesh), Yamuna Project (Uttar Pradesh), Maneri Bhali Project (Uttar Pradesh) and Kielder Experimental Tunnel have been presented, which include the details of the geology, the rock mass properties and the measured performance of the tunnels. The data have been analysed in the light of presentations made earlier.

As the ground convergence is considered the key factor controlling the tunnel performance, a rock mass classification system has been suggested on its basis. It has also been stated that a lot more data would have to be collected and analysed to make the system more comprehensive.

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