Effects of Joint Orientation in Tunneling

Selvasekaran R, Appuhami KAIS, Kumarasiri SAJ, Fernandopulle SN, Lakmal HMAG and *Dharmaratne PGR

Department of Earth Resources Engineering, University of Moratuwa

*Corresponding author; e-mail: dharme27@yahoo.com

Abstract: This research is focused on the effects of joint orientation with respect to the direction of tunnel axis. It is expected that the stability of surrounding rock is affected by the strike and dip of the joints and the direction of the tunnel axis, whether it is with the dip or against dip etc. similarly the spacing of joints will also affect the stability. The orientation of joints in different directions can form blocks liable to fall. The objective of this research project is to determine the degree of influence of joints' strike and dip orientation in tunneling. Field works related to this project was carried out at the Bogala Graphite Lanka Ltd. Tunnel mapping and other observations related to the project were made at 489.6 m level in Bogala mine. Models were made with joint spacing of 15 mm with two joint sets (joint sets parallel to tunnel axis and joint sets perpendicular to tunnel axis). Tunnels were created with 90 mm diameter with dip angles of joints are 0^0, 30^0, 60^0, and 90^0. The tunnels models are loaded using UCS machine and observed the behavior of rock mass around the tunnels during loading. From the results the most preferable dip angle for the joint strike perpendicular to the tunnel axis would be the 90^0 and for the joint strike parallel to the tunnel axis would be 0^0.

Key words: Dip, Dip direction, Discontinuity, Joint orientation

1. Introduction

Sri Lanka is underlain with Precambrian metamorphic rocks having a ragged terrain concentrated in central hilly areas. There is a long history of tunnelling for hydropower, transportation, Irrigation and Mining.

Jointed rock masses are often encountered during underground excavation. Many failures of underground openings during excavation and in operation reported are closely related to joints. Joints usually occur in sets which are more or less parallel and regularly spaced. There also are usually several sets in very different directions so that the

Dharmaratne PGR ,C.Eng,FIE(Sl) B.A.Sc(Hons)(Moratuwa),M.Sc, PhD, FMME,FGG, FGA
Senior Professor, Department of Earth Resources Engineering, University of Moratuwa
Selvasekaran R, AppuhamiKAIS, Kumarasiri SAJ, Fernandopulle SN, Lakmal HMAG , Final year undergraduate students in the Department of Earth Resources Engineering, University of Moratuwa

rock mass is broken up into a blocky structure. Because of the low shear strength and tensile strength, as well as the looseness of rock mass due to the unloading by excavation, the rock blocks tend to slide along structural plane or to detach, flex and break. Under some conditions, the joints may lead to big disasters in tunnel constructions. A general way to investigate the deformation and failure characteristics of tunnel is to carry out model test and numerical analysis.

Although the influences of rock joints and the state of stresses to the stability of underground structures have been studied, both analytically and experimentally, the failure mechanism of underground excavations under complex geological conditions is still far from being complete and satisfactory. A proper understanding about this is essential, and deemed important for a desirable support design and safe excavation. The objective of the study was to investigate the effects of joint orientation (joint strike and dip) with respect to the direction of tunnel axis in jointed rock mass.

2. Methodology

2.1 Study area

The study areas was 489.6 m level in Bogala mine (Bogala Graphite Lanka Ltd).

2.2 Engineering geological mapping

Complete engineering geological mapping (joints' strike and dip) for 100 m was measured and recorded at the level of 489.6 m at Bogala.

2.3 Physical model

A proper physical model for testing the effects of joint orientation with respect to the direction of tunnel axis was developed.

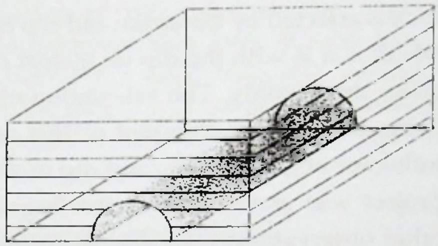

Figure 1. Strike of joint plane parallel or perpendicular to tunnel axis but dip 0⁰.

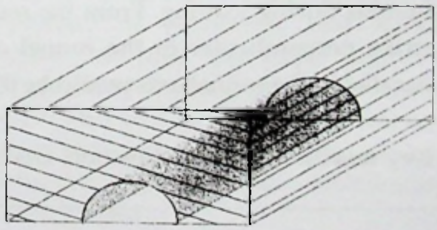

Figure 2. Strike of joint plane parallel to tunnel axis with dip angle 30⁰.

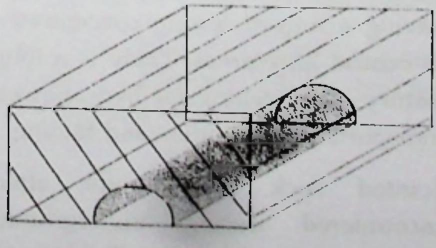

Figure 3. Strike of joint plane parallel to tunnel axis with dip angle 60⁰.

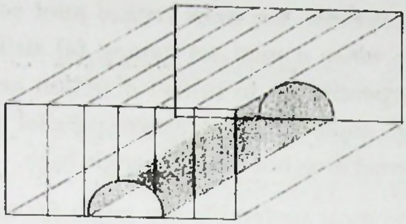

Figure 4. Strike of joint plane parallel to tunnel axis with dip angle 90⁰.

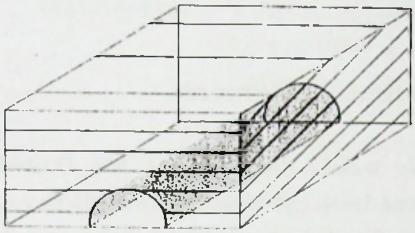

Figure 5. Strike of joint plane perpendicular to tunnel axis with dip angle 30⁰.

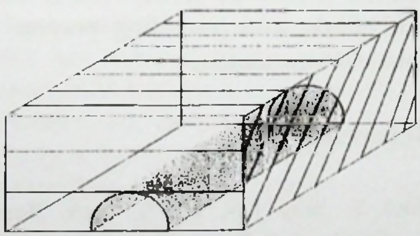

Figure 6. Strike of joint plane perpendicular to tunnel axis with dip angle 60⁰.

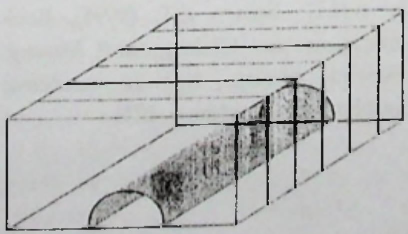

Figure 7. Strike of joint plane perpendicular to tunnel axis with dip angle 60⁰.

Models were made with joint spacing of 15 mm with two joint sets (joint strike parallel to tunnel axis and joint strike perpendicular to tunnel axis) and having a mix proportion of mortar of 1:2:2 (cement: chips: river sand). Tunnels were created with 90 mm diameter with dip angles 0⁰, 30⁰, 60⁰, and 90⁰. Models were cured for 28 days.

2.4 Model testing

Prepared physical models were tested for strength using Compressive strength testing machine at the Rock Mechanic of University of Moratuwa.

3. Results

Table 1. Joint strike parallel to tunnel axis

Dip angle	Stress at failure(N/m^2) x 10^6
0	4.40
30	3.66
60	3.10
90	2.68

Table 2. Joint strike perpendicular to tunnel axis

Dip angle	Stress at failure(N/m^2) x 10^6
0	4.40
30	3.75
60	4.80
90	5.95

Table 3. Preferable joint orientation for tunnelling

Joint strike perpendicular to tunnel axis with dip		Joint strike parallel to tunnel axis with dip	
0 30	60 90	0 30	60 90
Favourable	Best	Fair	Poor

4. Discussion

In underground tunnelling projects, the dip and dip orientation of joints greatly affect the total cost and cycle time of the tunnel. Therefore, it is very important to consider joints in designing tunnel supporting systems and tunnel direction through the rock mass.

The orientation of joints in excavation is concerned with the dip and dip direction of the rock formation and its relatively favourable or unfavourable effect on the rock mass. A commonsense check is to note the relative potential movement of the rock mass into or out of the excavation. These adjustments are important, since how the rock mass is situated in relationship to the direction of the excavation will ultimately determine its stability.

5. Conclusion

According to the results obtained from the physical model testing, when joint sets are encountered at tunnel excavation, the most critical joint sets are when a joint set having (a) strike perpendicular to tunnel direction and dip angle low, (b) strike parallel to tunnel direction and dip angle high.

The most preferable dip angle for the joint strike perpendicular to the tunnel axis would be the 90^0 and for the joint strike parallel to the tunnel axis would be 0^0.

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