# THE EFFECT OF THE ROCKMASS PROPERTIES AND GROUNDWATER INFLOW RELATED TO PERFORMANCE OF TUNNEL BORING MACHINE (TBM) AT PAHANG SELANGOR RAW WATER TRANSFER TUNNEL PROJECT (PSRWT)

by

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# LIST OF SYMBOLS

| | |
|---|---|
| C | Cohesion |
| d | Distance |
| D | Specimen diameter |
| E | Young's Modulus |
| L | Length of the specimen |
| P | Maximum load at failure |
| p,q,r | Invariants |
| R | Radius |
| $t_s$ | Travel time |
| Vp | Velocity of P-wave |
| $\nu$ | Poisson's Ratio |
| $\sigma$ | Horizontal stress |
| $\beta$ | Angle between the normal to the fracture plane and the horizontal plane |
| $\varphi$ | Friction angle of the fracture |
| $\sigma_c$ | Uniaxial compressive strength of rock |
| $\sigma_{1,f}$ | Major principle stress at failure |
| $\sigma_{a,f}$ | Applied failure stress |
| $\sigma_{d,w}$ | Pressure resulting from dead weight of top disk and loading ram |
| $s_V$ | Overburden Load |
| $\sigma_x$ | Normal stress distribution in x-direction |
| $\sigma_y$ | Normal stress distribution in y-direction |
| $\sigma_{xy}$ | Shear stress distribution |

| | |
|---|---|
| $\sigma_{d,w}$ | Pressure resulting from dead weight of top disk and loading ram (kPa) |
| $\partial x$ | Direction of rock blocks |

# LIST OF ABBREVIATION

| | |
|---|---|
| AR | Advancing Rate |
| ASTM | American Society for Testing and Materials |
| BE | Boring Energy |
| BTS | Brazillian Tensile Strength Test |
| Ch. | Chainage |
| FEM | Finite Element Method |
| IMIA | International Association of Engineering Insurers (IMIA) |
| ISRM | International Society for Rock Mechanics |
| JHS | Japanese Highway System |
| Jn | Joint set number |
| Jr | Joint roughness number |
| Jw | Joint water reduction factor |
| L-x | Lineament |
| MGT | Mesin Gerekan Terowong |
| PR | Penetration rate |
| RMR | Rock mass rating |
| SRF | Stress reduction factor |
| TBM | Tunnel boring machine |
| SRTM | Shaded relief topographical map |
| SHR | Schmidt hammer rebound |
| TD | Tunnel distance |
| UCS | Uniaxial Compressional Strength Test |

**KESAN DARI CIRI-CIRI JASAD BATUAN DAN PERGERAKAN AIR BAWAH TANAH TERHADAP PRESTASI MESIN GEREKAN TEROWONG (MGT) BAGI PROJEK PENYALURAN AIR MENTAH PAHANG SELANGOR (PPAMPS)**

## ABSTRAK

Pergerakan air bawah tanah ke dalam terowong boleh mengakibatkan bahaya dan merupakan faktor penting yang mempengaruhi kemajuan prestasi gerekan terowong. Di dalam kajian ini, sistem kekar lokal dianalisis bagi menghubungkan pergerakan air bawah tanah dan orientasi kekar di sepanjang 2000 meter tempat kajian TBM-1, Karak sepanjang pembinaan Projek Penyaluran Air Mentah Pahang – Selangor (PPAMPS). Geologi kawasan terowong adalah terdiri daripada batuan granit Main Range dan bersambungan dengan batuan meta-sedimen daripada Formasi Karak. Secara strukturnya, TBM-1 didominasi oleh arah Utara- Selatan, Utara Barat - Tenggara dan Timur Laut-Tenggara. Sesar yang memotong batuan granit Main Range menyebabkan banyak kekar terhasil di daerah Karak. Lokasi yang berpotensi dengan kemasukan air bawah tanah yang banyak adalah terbahagi kepada tiga; iaitu set kekar yang selari dengan garisan lineamen utama, iaitu 90 darjah dengan arah pandu terowong, 45 darjah dengan garisan lineamen atau kedua-dua sistem linemen dan membelah lompang dan membentuk zon poket air. Sekurang-kurangnya kesemua set garisan lineamen topografik berkait dengan zon sesar-air. Analisis unjuran streografik dan plot Rosette mendapati bahawa orientasi kekar didominasi oleh 3 tren silang-potong antara satu sama lain. Kekar tersebut adalah terdiri daripada ; tren Kuala Lumpur – Bukit Tinggi, tren Utara-Selatan and tren Tenggara-Barat

Daya, yang berkait dengan Barat Laut-Tenggara Bukit Tinggi dan Zon Sesar Kuala Lumpur, sesar Utara-Selatan dan sesar Tenggara-Barat Daya. Keputusan dari ujian mekanikal seperti Ujian Kekuatan Mampatan Sepaksi, Kekuatan Tensi Brazil dan Kekuatan Mampatan Tiga Paksi menunjukkan bahawa jasad batuan menjadi lemah dengan nilai basah adalah hampir separuh daripada nilai kering. Melalui ujian kaedah finit elemen yang dilakukan dengan menggunakan parameter daripada ujian mekanikal mendapati bahawa dengan kehadiran air bawah tanah dan kualiti jasad batuan yang rendah boleh mengakibatkan berlakunya deformasi pada terowong.

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## ABSTRACT

Groundwater inflow into tunnels can constitute a potential hazard and an important factor influencing the performance of tunnel excavation. In this research, the results on analyses of localised jointing system are presented to study the link of groundwater inflow and the joint orientations along the 2000 meters of TBM-1 site, Karak in conjunction to the construction of Pahang Selangor Raw Water Transfer Tunnel project (PSRWT). The geology along the tunnel route is predominantly the Main Range granite batholith with a lesser extent of meta-sedimentary rocks of the Karak Formation. Structurally, TBM-1 is dominated by joints orientated at N-S, NW-SE and NE-SW direction. Faults that cross-cut the intrusive Main Range Granite rocks trending faults formed the most prominent structures in the vicinity of the Karak. Potential leakage places are identified of three main types of joints orientations; the most permeable place is parallel along the main lineament orientation, followed by perpendicular to 90 degrees to the tunnel drive direction, 45 degrees to the lineament line or combinations of both joints and crossing some of voids which creating pocket water zones. At least three sets of prominent topographic lineaments correspond to fault-zones permeability related. Based on the stereographical projection and rosette diagram analysis, the dominant orientations of joints seem to have occurred at the intersection of 3 cross-cutting trends. They are the