Second Semester Examination
2018/2019 Academic Session

June 2019

EAG443 – Rock Engineering and Tunnelling Technology
(Kejuruteraan Batuan dan Teknologi Terowongan)

Duration : 2 hours
(Masa : 2 jam)

Please check that this examination paper consists of **FOURTEEN (14)** pages of printed material including appendix before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **EMPAT BELAS (14)** muka surat yang bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper consists of **FIVE (5)** questions. Answer **FOUR (4)** questions.

*[**Arahan** : Kertas ini mengandungi **LIMA (5)** soalan. Jawab **EMPAT (4)** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

(1). As shown in **Figure 1**, two types of different rock joints were obtained using borehole tele viewer. Based on the Lugeon test, both boreholes give similar Lugeon value although borehole A has a wide fractures system compare to borehole B which has a high frequency of fine fractures.

*Seperti yang ditunjukkan di **Rajah 1**, dua jenis perbezaan kekar telah diperolehi melalui petelelihat lubang gerek. Berdasakan kepada ujian Lugeon, kedua-dua lubang gerek memberikan nilai Lugeon yang hampir sama walapun lubang gerek A mempunyai sistem kekar yang lebih lebar berbanding lubang gerek B yang mempunyai frekuensi kekar lebih halus yang tinggi.*

(a). Define the meaning of Lugeon value and explain when rock mass grouting is needed based on several range of different Lugeon values.

Takrifkan maksud nilai Lugeon dan jelaskan bila penurapan batuan diperlukan berdasarkan kepada beberapa julat nilai Lugeon yang berbeza.

[5 marks/*markah*]

(b). Explain with the help of sketches and Cubic Law equation why both borehole A and B can have a similar Lugeon values in different joints system conditions.

Jelaskan dengan berbantukan lakaran dan persamaan Hukum Kuasa Tiga bagaimana kedua-dua lubang gerek A dan B boleh mempunyai nilai Lugeon yang hampir sama di dalam keadaan sistem kekar yang berbeza.

[6 marks/*markah*]

(c). Propose rock mass grouting processes together with the grouting parameter that are suitable to reduce the permeability of both rock mass in boreholes A and B.

Cadangkan proses penurapan batuan berserta parameter penurapan yang sesuai dijalankan bagi mengurangkan kebolehtelapan batuan di kedua-dua lubang gerek A dan B.

[8 marks/*markah*]

(d). Assuming both boreholes A and B were grouted using the same mix ratio, draw the possible grout intake curve with time for both boreholes and justify the curves drawn.

Andaikan kedua-dua lubang gerek A dan B diturap menggunakan nisbah campuran yang sama, lukiskan lengkungan pengambilan turap dengan masa yang mungkin bagi kedua-dua lubang gerek dan berikan justifkasi kepada lengkungan yang dilukis.

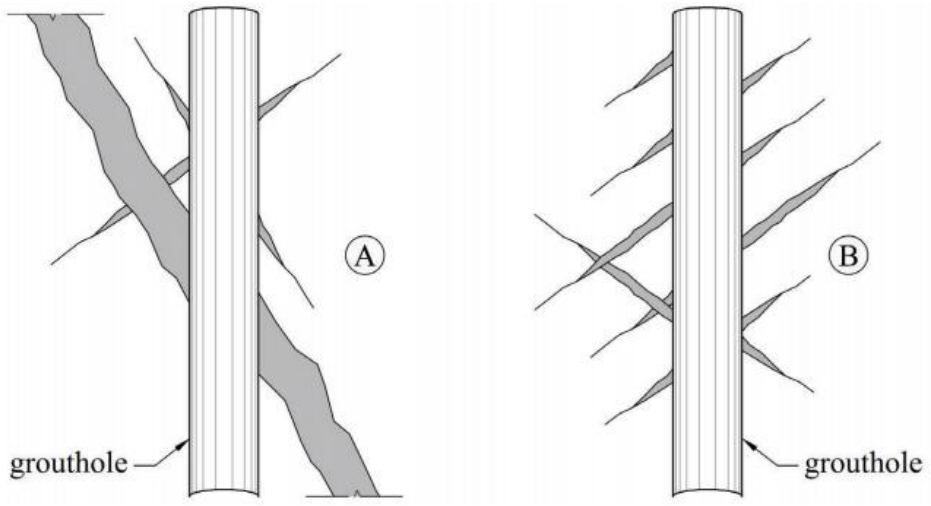

Figure 1/*Rajah 1*

[6 marks/*markah*]

(2). Rock Quality Designation (RQD) is a commonly used index for the description of rock mass fractured state.

Penentuan Kualiti Batuan (RQD) merupakan indeks yang sering digunakan untuk memperihalkan keadaan rekahan batuan.

(a). State **THREE (3)** main reasons for determining RQD values in rock mass and explain how these values are used in Q Qlassification System and Rock Mass Rating (RMR) system.

*Nyatakan **TIGA (3)** sebab utama untuk menentukan nilai RQD batuan dan jelaskan bagaiman nilai RQD ini digunakan dalam Sistem Pengelasan Q dan Sistem Kadaran Batuan (RMR).*

[8 marks/*markah*]

(b). In tunnel excavation work, the engineer is often required to estimate RQD value without timely access to core log or without historical logs of RQD. In that situation, describe **ONE (1)** example with the help of sketch the indirect method that can be used to calculate RQD values.

*Dalam pengorekan batuan, jurutera selalunya perlu untuk menganggarkan nilai RQD tanpa akses kepada log teras atau tanpa log sejarah RQD. Dalam keadaan tersebut, jelaskan **SATU (1)** contoh dengan berbantukan lakaran kaedah tidak langsung yang dapat digunakan untuk mengira nilai RQD.*

[6 marks/*markah*]

(c). Based on the schematic three core logs record of rock sample in 1 m core length run given in **Figure 2**, calculate the estimated RQD values for all the three rock core logs samples and describe the rocks quality based on the estimated values. Justify all the RQD values obtained for all the three core logs and give reasoning why RQD values for Core Logs 2 and 3 need to be further evaluated.

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Berdasarkan kepada tiga rekod log teras sampel batuan dengan 1 m panjang teras seperti yang diberikan di ***Rajah 2****, kirakan anggaran nilai RQD bagi ketiga-tiga sampel log teras batuan tersebut dan perihalkan kualiti batuan tersebut berdasarkan nilai yang dianggarkan. Berikan justifikasi terhadap kesemua nilai RQD yang diperolehi dan nyatakan sebab kenapa nila RQD bagi log teras 2 dan 3 perlu penilaian lanjut.*

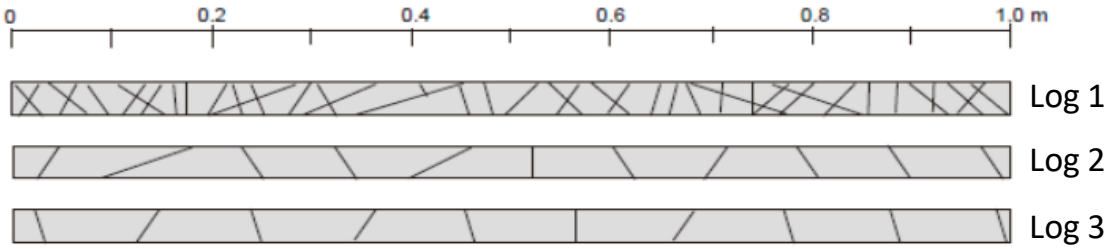

Figure 2/*Rajah 2*

[11 marks/*markah*]

(3). (a). A TBM tunnel for the tunnel construction for the road diversion project is rated using the Q Classification System. From the information on the tunnel face mapping obtained, RQD is 30%; joint set number is 9; joint roughness number is 1; joint alteration number is 2; and joint water reduction is 0.5 and stress reduction factor is 1.0.

Terowong TBM untuk pembinaan terowong bagi projek pengubahan laluan telah ditaraf menggunakan sistem pengelasan Q. Daripada maklumat pemetaan permukaan terowong yang diperolehi, RQD ialah 30%; nombor set kekar ialah 9; nombor kekasaran kekar ialah 1; nombor perubahan kekar ialah 2; pengurangan air kekar ialah 0.5 dan faktor pengurangan tegasan ialah 1.0.

(i). Write the equation for the Q Classification System and explain the meaning of each quotient from the equation.

Tulis persamaan bagi sistem pengelasan Q dan jelaskan maksud setiap hasil bahagi daripada persamaan tersebut.

[5 marks/*markah*]

(ii). Determine the Q value from the information of the tunnel face mapping obtained.

Tentukan nilai Q daripada maklumat pemetaan permukaan terowong yang diperolehi.

[4 marks/*markah*]

(b). To assist the TBM through difficult rock condition as experienced in (a), it is decided that pre-grouting is applied to improve the rock conditions. From the reevaluated tunnel face mapping obtained, RQD is 50%; joint set number is 6; joint roughness number is 2; joint alteration number is 1; and joint water reduction is 1 and stress reduction factor is 1.0.

Untuk membantu TBM melalui keadaan batuan yang sukar seperti yang dilalui di (a), adalah ditentukan bahawa pra-penurapan dilaksanakan bagi menambahbaik keadaan batuan. Daripada keputusan pemetaan permukaan terowong yang dinilai semula, RQD ialah 50%; nombor set kekar ialah 6; nombor kekasaran kekar ialah 1; nombor perubahan kekar ialah 1; pengurangan air kekar ialah 1 dan faktor pengurangan tegasan ialah 1.0.

(i). Determine the Q value from the information of the tunnel face mapping obtained after pre-grouting work has been done.

Tentukan nilai Q daripada maklumat pemetaan permukaan terowong yang diperolehi selepas kerja pra-penurapan selesai dilaksanakan.

[4 marks/*markah*]

(ii). With the help of sketches, explain the effect and mechanism of improvement based on the pre-grouting work to each of the Q-system parameter.

Dengan berbantukan lakaran, jelaskan kesan dan mekanisme penambahbaikan berdasarkan kerja pra-penurapan terhadap setiap parameter sistem Q.

[10 marks/*markah*]

(iii). Justify why stress reduction factor is not changing even after the pre-grouting work has been carried out.

Justifikasikan kenapa faktor pengurangan tegasan tidak berubah walaupun selepas kerja pra-penurapan selesai dijalankan.

[2 marks/*markah*]

(4). (a). In many tunneling projects involving Tunnel Boring Machine (TBM), the selection of TBM in a given set of geological conditions are difficult to estimate. Describe **THREE (3)** important TBM parameters in hard rock that need to be estimated prior to the TBM selection in order to evaluate their effects on project economics.

Dalam kebanyakkan projek terowongan yang melibatkan mesin pengorek terowong (TBM), pemilihan TBM mengikut keadaan geologi tertentu adalah sukar diramalkan. Jelaskan ***TIGA (3)*** *parameter utama TBM dalam batuan keras yang perlu dianggarkan sebelum pemilihan TBM bagi menilai kesan pemilihan tersebut terhadap ekonomi projek.*

(i). Penetration rate
Kadar penembusan

[2 marks/*markah*]

(ii). Advance rate
Kadar lajakan

[2 marks/*markah*]

(iii). Utilization factor
Faktor pengunaan

[2 marks/*markah*]

(b). Majority of TBM excavation in rocks lies between the good and poor lines as shown in **Figure 3** developed by Nick Barton in 1999. From **Figure 3,** it is clearly shown that the utilization factor, U as represented by the lines decreases with time. Explain in detail **THREE (3)** reasons why such conditions occurred in most of the tunneling projects that utilize TBM.

Majoriti pengorekan TBM di dalam batuan terletak di antara garisan baik dan lemah seperti ditunjukkan di ***Rajah 3*** *yang dihasilkan oleh Nick Barton pada tahun 1999. Daripada* ***Rajah 3****, adalah jelas bahawa faktor penggunaan, U yang diwakili oleh garisan menurun dengan masa. Jelaskan secara terperinci* ***TIGA (3)*** *sebab utama kenapa keadaan sebegitu berlaku pada kebanyakkan projek terowongan yang menggunakan TBM.*

[9 marks/*markah*]

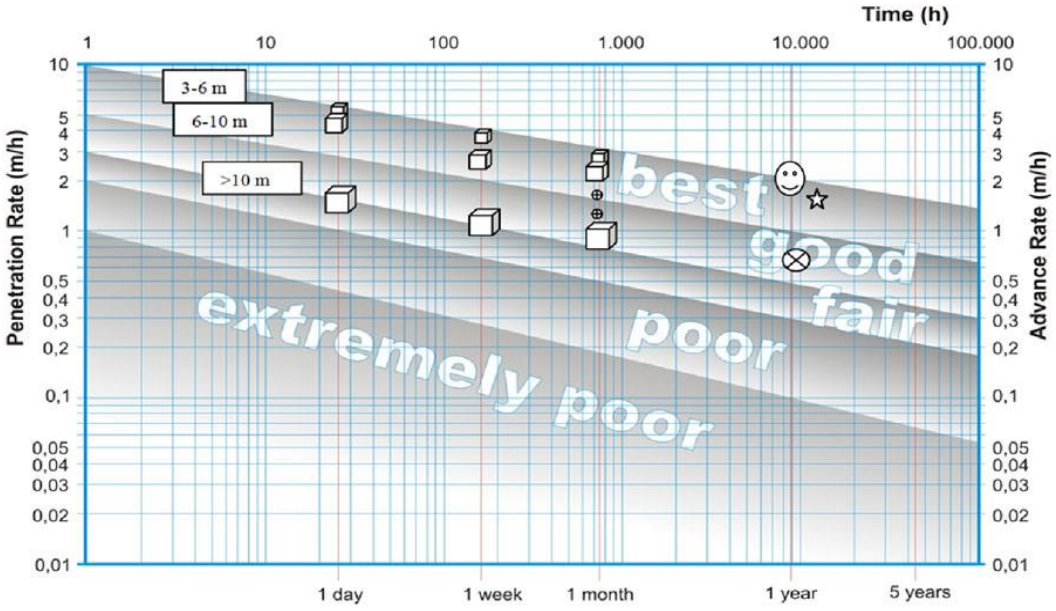

Figure 3/*Rajah 3*

(c). The type of TBM machine used depends on the particular geology of the project, the amount of ground water present and other factors. State **FOUR (4)** types of TBM machine and explain the function for each type of TBM.

*Jenis mesin TBM yang digunakan bergantung kepada keadaan geologi sesuatu projek, jumlah air bumi yang wujud dan juga beberapa faktor lain. Nyatakan **EMPAT (4)** jenis mesin TBM dan jelaskan fungsi setiap satu mesin tersebut.*

[10 marks/*markah*]

(5). A rock weighing 300 MN rests on another rock with the contact plane dipping 40º in the direction of S30E. The angle of friction between the rocks is 30º. An empty stereonet is given in **Figure 4** for you to carry out analysis.

*Suatu batuan seberat 300 MN terletak di atas suatu batuan lain dengan permukaan satah sentuhannya menjunam 40º pada arah S30E. Sudut geseran antara batuan tersebut adalah 30º. Stereonet kosong diberi di **Rajah 4** untuk tujuan menjalankan analisis.*

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(a). On the stereographic projection, plot the force vector representing the weight of the block. On the same projection, plot the normal to the contact plane and the small circle around it representing the safe area should the resultant force associated with the block be plotted within the circle.

Pada suatu unjuran stereograf, plotkan vektor daya yang mewakili berat bungkah tersebut. Pada unjuran stereograf yang sama, plotkan pugak satah sentuhan dan bulatan kecil di sekelilingnya yang menunjukkan kawasan selamat jika paduan daya yang berkaitan dengan bungkah terplot di dalamnya.

[5 marks/*markah*]

(b). On the same projection, plot another small circle around the joint normal to the plane to represent the safe area and with a Factor of Safety of at least 2.0, should the resultant force associated with the block be plotted within the circle.

Pada unjuran yang sama, plotkan satu lagi bulatan kecil di sekeliling titik pugak satah yang menunjukkan kawasan selamat dengan Faktor Keselamatan sekurang-kurangnya 2.0 jika paduan daya yang berkaitan dengan bungkah terplot di dalamnya.

[5 marks/*markah*]

(c). Should a bolt be used to stabilize the block with Factor of Safety of 2.0 against sliding, determine its orientation and the required tension.

Sekiranya suatu bolt digunakan bagi menstabilkan bungkah dengan Faktor Keselamatan 2.0 daripada tergelongsor, tentukan arahnya dan tegangan yang diperlukan.

[5 marks/*markah*]

(d). The length of bolt required depends on its orientation when installed in the field. Determine the orientation of the bolt such that its use in the above case would require minimum length.

Panjang bolt yang diperlukan bergantung kepada arah pemasangan di lapangan.Tentukan arah pemasangan bolt agar panjangnya paling minimum bagi kes di atas.

[5 marks/*markah*]

(e). If a ground acceleration amounting to 0.1g occurs towards N, therefore the inertial force on the block is directed towards S, after placing the bolt as in (c), determine the Factor of Safety against sliding at the time when this ground acceleration takes place.

Jika pecutan bumi 0.1g berlaku pada arah N, oleh itu daya inertia ke atas bungkah menghala ke arah S, selepas bolt dipasang seperti di soalan (c), tentukan Faktor Keselamatan daripada gelongsoran semasa berlakunya pecutan bumi tersebut.

[5 marks/*markah*]

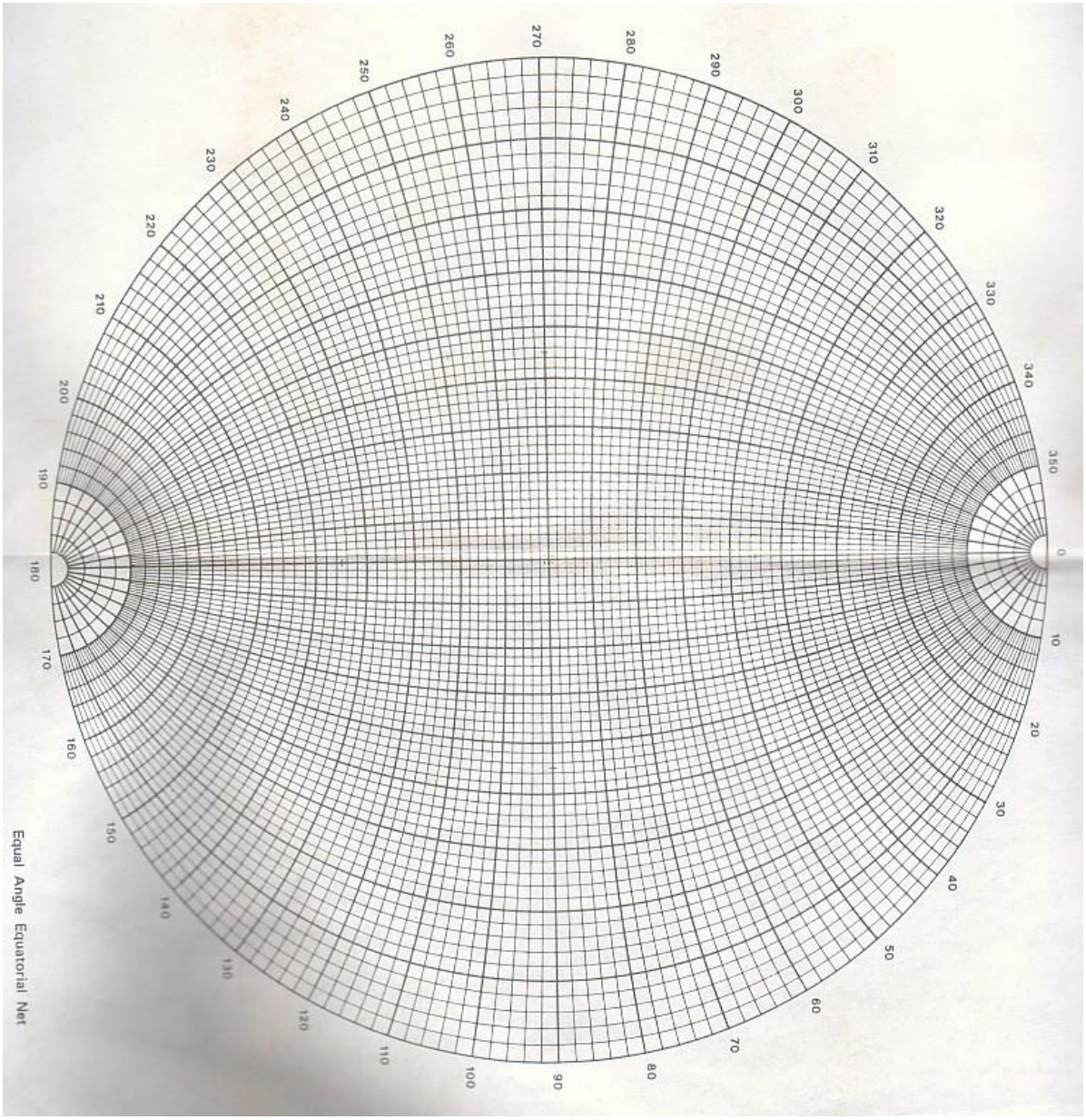

Figure 4/*Rajah 4*

APPENDIX

Classification of individual parameters used in the Tunneling Quality Index Q

DESCRIPTION	VALUE	NOTES
1. ROCK QUALITY DESIGNATION	***RQD***	
A. Very poor	0 - 25	1. Where *RQD* is reported or measured as ≤ 10 (including 0), a nominal value of 10 is used to evaluate *Q*.
B. Poor	25 - 50	
C. Fair	50 - 75	
D. Good	75 - 90	2. *RQD* intervals of 5, i.e. 100, 95, 90 etc. are sufficiently accurate.
E. Excellent	90 - 100	
2. JOINT SET NUMBER	J_n	
A. Massive, no or few joints	0.5 - 1.0	
B. One joint set	2	
C. One joint set plus random	3	
D. Two joint sets	4	
E. Two joint sets plus random	6	
F. Three joint sets	9	1. For intersections use ($3.0 \times J_n$)
G. Three joint sets plus random	12	
H. Four or more joint sets, random, heavily jointed, 'sugar cube', etc.	15	2. For portals use ($2.0 \times J_n$)
J. Crushed rock, earthlike	20	
3. JOINT ROUGHNESS NUMBER	J_r	
a. Rock wall contact		
b. Rock wall contact before 10 cm shear		
A. Discontinuous joints	4	
B. Rough and irregular, undulating	3	
C. Smooth undulating	2	
D. Slickensided undulating	1.5	1. Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m.
E. Rough or irregular, planar	1.5	
F. Smooth, planar	1.0	
G. Slickensided, planar	0.5	2. J_r = 0.5 can be used for planar, slickensided joints having lineations, provided that the lineations are oriented for minimum strength.
c. No rock wall contact when sheared		
H. Zones containing clay minerals thick enough to prevent rock wall contact	1.0 (nominal)	
J. Sandy, gravely or crushed zone thick enough to prevent rock wall contact	1.0 (nominal)	
4. JOINT ALTERATION NUMBER	J_a	ϕr degrees (approx.)
a. Rock wall contact		
A. Tightly healed, hard, non-softening, impermeable filling	0.75	1. Values of ϕr, the residual friction angle, are intended as an approximate guide to the mineralogical properties of the alteration products, if present.
B. Unaltered joint walls, surface staining only	1.0	25 - 35
C. Slightly altered joint walls, non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc.	2.0	25 - 30
D. Silty-, or sandy-clay coatings, small clay-fraction (non-softening)	3.0	20 - 25
E. Softening or low-friction clay mineral coatings, i.e. kaolinite, mica. Also chlorite, talc, gypsum and graphite etc., and small quantities of swelling clays. (Discontinuous coatings, 1 - 2 mm or less)	4.0	8 - 16

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4, JOINT ALTERATION NUMBER	J_a	ϕr degrees (approx.)	
b. Rock wall contact before 10 cm shear			
F. Sandy particles, clay-free, disintegrating rock etc.	4.0	25 - 30	
G. Strongly over-consolidated, non-softening clay mineral fillings (continuous < 5 mm thick)	6.0	16 - 24	
H. Medium or low over-consolidation, softening clay mineral fillings (continuous < 5 mm thick)	8.0	12 - 16	
J. Swelling clay fillings, i.e. montmorillonite, (continuous < 5 mm thick). Values of J_a depend on percent of swelling clay-size particles, and access to water.	8.0 - 12.0	6 - 12	
c. No rock wall contact when sheared			
K. Zones or bands of disintegrated or crushed	6.0		
L. rock and clay (see G, H and J for clay	8.0		
M. conditions)	8.0 - 12.0	6 - 24	
N. Zones or bands of silty- or sandy-clay, small clay fraction, non-softening	5.0		
O. Thick continuous zones or bands of clay	10.0 - 13.0		
P. & R. (see G.H and J for clay conditions)	6.0 - 24.0		
5. JOINT WATER REDUCTION	J_w	approx. water pressure (kgf/cm^2)	
A. Dry excavation or minor inflow i.e. < 5 l/m locally	1.0	< 1.0	
B. Medium inflow or pressure, occasional outwash of joint fillings	0.66	1.0 - 2.5	
C. Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5 - 10.0	1. Factors C to F are crude estimates; increase J_w if drainage installed.
D. Large inflow or high pressure	0.33	2.5 - 10.0	
E. Exceptionally high inflow or pressure at blasting, decaying with time	0.2 - 0.1	> 10	2. Special problems caused by ice formation are not considered.
F. Exceptionally high inflow or pressure	0.1 - 0.05	> 10	
6. STRESS REDUCTION FACTOR ***a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated***		***SRF***	
A. Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock any depth)		10.0	1. Reduce these values of *SRF* by 25 - 50% but only if the relevant shear zones influence do not intersect the excavation
B. Single weakness zones containing clay, or chemically disintegrated rock (excavation depth < 50 m)		5.0	
C. Single weakness zones containing clay, or chemically disintegrated rock (excavation depth > 50 m)		2.5	
D. Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth)		7.5	
E. Single shear zone in competent rock (clay free). (depth of excavation < 50 m)		5.0	
F. Single shear zone in competent rock (clay free). (depth of excavation > 50 m)		2.5	
G. Loose open joints, heavily jointed or 'sugar cube', (any depth)		5.0	

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