UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2009/2010

SUBJECT NAME	:	ENGINEERING GEOLOGY
SUBJECT CODE	:	BFC 3013
COURSE	:	2 BFF
EXAMINATION DATE	:	APRIL 2010
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ALL QUESTIONS FROM PART A AND ONE (1) QUESTION FROM PART B

THIS PAPER CONSIST OF TWENTY SEVEN (27) PAGES

PART A (75 marks)

Q1 (a) Geological structure is the study of the permanent deformation and rock failure created by the changes in stress through geological time. It is by far the most important aspect of geology for the engineer to understand.

(i) Describe **THREE (3)** types of stress in rock deformation.

(3 marks)

(ii) List all categories of fault and fold.

(4 marks)

(iii) Define the terms of joint, fault and fold.

(3 marks)

(b) The study of rocks in civil engineering is very important because it involves the construction materials and as part of the civil engineering structure.

(i) Explain the phaneritic and aphanetic texture in igneous rock.

(4 marks)

(ii) Give the types of sediments which produce:

(a) Mudstone
(b) Siltstone
(c) Sandstone
(d) Conglomerate or breccias

(2 marks)

(iii) State **FOUR (4)** types of foliation texture derived from the foliated metamorphic rock.

(2 marks)

(c) Conducting site investigations are the core of the engineering geologist practice. The engineering geologist applies their geologic skills to the practical solution of engineering problems.

(i) Justify **ONE (1)** reason of why sometimes the Rock Quality Designation (RQD) data obtained in site investigation could not be trusted.

(1 mark)

(ii) Explain the basic concept of seismic refraction in geophysical site investigation.

(3 marks)

(iii) Proposed **THREE (3)** advantages of gravity measurement in geophysical site investigation.

(3 marks)

(ii) Estimate and plot the mean poles for each data plotted from **Q3(a)** and draw the great circle for all respective mean poles. Determine the values of dip direction and dip angle for all mean great circles plotted and tabulate the values in Figure **Q3(c)**.

(3 marks)

(b) Answer the following question with reference to Figure **Q3**.

(i) Determine the values of strikes and dip directions for the proposed cut slope A, B and C tabulate the values in Figure **Q3(d)**.

(3 marks)

(ii) By using the answer from **Q3(b)(i)**, draw the great circle for the cut slope on all direction (A, B and C).

(2 marks)

(iii) A study of joint sets reveals that all joints have a friction angle of 25°. Draw the friction angle for slope A, B and C on the same tracing paper.

(2 marks)

(c) Based on the answers from **Q3(a)** and **Q3(b)**, analyze the entire mode of failure at the proposed rock slope (A, B and C) and state the criteria as an evidence. Tabulate the results in the Figure **Q3(e)**.

(11 marks)

PART B (25 marks)

Q4 (a) During a site study, it was found that a tension crack was 4.0 meter deep and was in a dry condition. The friction angle value is the same as given in **Q3(b)(iii)**. Other information from the site study and laboratory works are given as follows:

Rock unit weight = 27 kN/m^3
Water unit weight = 9.81 kN/m^3
Height of plane = 70 m
Cohesion of all discontinuities = 50 kPa
Bars for Y_{25} = 10 ton = 100 kN

Using the cut slope data from **Q3(b)**.

(i) Calculate the safety factor for plane failure for slope based on the formula given in Figure **Q4(a)**.

(8 marks)

(ii) Conclude the safety factor value for plane failure based on the value obtained from **Q4(a)(i)**.

(1 mark)

(b) From **Q4(a),** estimate the required reinforcement with tensioned anchor bolts (T) of slope based on the formula given in Figure **Q4(a)**. Given the installation of anchor bolts at angle (Ω) is 20° and the safety factor needed by the client is 1.7.

(5 marks)

(c) Give an assessment on the RQD value obtained from **Q2(a)** and propose the appropriate excavation and support system based on the Q value obtained from **Q2(b)** according to the Figure **Q4(b)** and Figure **Q4(c)**.

(4 marks)

(d) The shallow footing will be constructed on granite rock formation without dipping formation. The c and ϕ from RMR calculation are 60 MPa and 20° respectively, and unit weight of rock is 22 kN/m^3.

(i) Calculate the allowable bearing capacity of the footing if the safety factor value is given by 3.0 based on the formula given below and the bearing capacity factors are available in the Figure **Q4(d)** and Figure **Q4(e)**.

$$q_a = \frac{C_{f1}cNc + C_{f2}(B\gamma/2)N_\gamma + \gamma D N_q}{SF}$$

(3 marks)

(ii) Determine the size of the square footing to retain 200 MN of vertical loading.
(3 marks)

(iii) Based on **Q4(d)(ii)**, how much the magnitude of settlement for that loading. Assumed the Young modulus, E of the granite is 60 GPa.
(1 mark)

Q5 (a) Describe **TWO (2)** methods (completed with necessary parameters) to obtain bearing capacity of foundation on rock.
(2 marks)

(b) Describe the differences between:

(i) Uniaxial Compressive Strength of intact rock; $\sigma_{u(r)}$ and Uniaxial Compressive Strength of rock mass; σ_c

(ii) Vertical Stress; σ_1 and Horizontal Stress; σ_3

(iii) Ultimate Bearing Capacity; q_u and Allowable Bearing Capacity; q_{all}
(3 marks)

(c) Explain why the stability calculations of the foundation design on rock mostly determined by bearing capacity instead of settlement control?
(2 marks)

(d) A 36 in (900 mm) diameter drilled pile is supported on un-weathered rock socketted 1.8 m into rock, the sizes and spacing of discontinuities are 1 mm and 50 mm respectively. The rock was siltstone with core of Uniaxial Compressive Strength, σ_c = 90 MPa.

(i) Estimate the allowable point bearing capacity of the pile by using the Figure **Q5(a)** and formula:

$$q_a = (\sigma_c)\, K_{sp}\, d\,; \quad d = [0.8 + 0.2(L_s / B)] < 2$$

(3 marks)

(ii) Based on **Q5(d)**, explain why this formula is applied without calculation of $q_{ultimate}$?
(2 marks)

(e) According to the RMR value obtained from **Q2(c)**

(i) Determine the values of cohesion and friction angle for the quartzite based on Figure **Q2(c)**.
(2 marks)

(ii) Assess the stand up time of the tunnel without support based the on Figure **Q2(c)**.

(1 mark)

(iii) Propose the appropriate excavation and support system based on Figure **Q5(b)**.

(4 marks)

(f) Propose the rock test for determination of the following parameters:

(i) Denseness degree of rock
(ii) Uniaxial Compressive Strength of rock
(iii) Resistance index of a rock when subjected to weathering
(iv) Tensile strength of rock

(2 marks)

(g) Propose the relevant discontinuities physical properties data and information required during the discontinuity survey in order to support the stability analysis result of the cut slope involved.

(4 marks)

BAHAGIAN A (75 markah)

S1 (a) Geologi struktur merupakan bidang kajian berkenaan perubahan bentuk tetap dan kegagalan batuan yang dihasilkan oleh perubahan tegasan di sepanjang skala masa geologi dan amat penting bagi seseorang jurutera untuk memahaminya.

(i) Terangkan **TIGA (3)** jenis tegasan dalam pencacatan batuan.

(3 markah)

(ii) Senaraikan kesemua kategori sesar dan lipatan.

(4 markah)

(iii) Berikan definisi kekar, sesar dan lipatan.

(3 markah)

(b) Bidang kajian batuan merupakan bidang yang penting dalam kejuruteraan awam kerana ianya melibatkan bahan dan struktur binaan kejuruteraan awam.

(i) Terangkan tekstur *phaneritic* dan *aphanetic* dalam batuan igneus.

(4 markah)

(ii) Berikan jenis bahan endapan yang menghasilkan:

(a) Batu lumpur
(b) Batu lodak
(c) Batu pasir
(d) Konglomerat dan bresia

(2 markah)

(iii) Nyatakan **EMPAT (4)** jenis tekstur foliasi yang terdapat dalam batuan metamorfik berfoliasi.

(2 markah)

(c) Penyiasatan tapak merupakan teras kepada bidang geologi kejuruteraan. Jurutera perlu mempraktikkan kemahiran geologi terhadap penyelesaian masalah kejuruteraan secara praktikal.

(i) Berikan **SATU (1)** justifikasi mengapakah data Penanda Mutu Batuan (PMB) yang diperolehi dalam penyiasatan tapak kadangkala tidak boleh dipercayai.

(1 markah)

(ii) Terangkan konsep asas pembiasan seismik dalam penyiasatan tapak geofizik.

(3 markah)

(iii) Cadangkan **TIGA (3)** kelebihan peralatan graviti dalam penyiasatan tapak geofizik.

(3 markah)

S2 (a) Kirakan nilai Penanda Mutu Batuan (PMB) seperti yang ditunjukkan dalam Rajah **Q2(a)**.

(2 markah)

(b) Sebuah lombong terbuka tetap sepanjang 18 m rentangan untuk lombong bawah tanah akan dikorek pada kedalaman 2100 m dari aras permukaan bumi. Kestabilan jasad batuan bergantung kepada dua set kekar tambah rawak. Kekar tersebut adalah licin dan beralun. Sentuhan dinding batuan adalah kekar dinding sedikit terubah, mineral keras berselaput, berbutir pasir, penyepaian batuan tanpa tanah liat dan lain-lain. Ujikaji makmal pada sampel korekan batuan sempurna memberikan nilai purata kekuatan mampatan satu paksi sebanyak 150 MPa. Arah tegasan prinsip adalah dianggarkan mendatar dan pugak dan magnitud tegasan prinsip mendatar adalah dianggarkan sebanyak 1.5 lebih daripada tegasan prinsip pugak. Batuan bersifat kompeten dan mengalami masalah tegasan. Jasad batuan berkeadaan lembap dengan pengaliran air sederhana. Dengan menggunakan nilai PMB daripada **S2(a)**, kirakan nilai Q dengan berpandukan Rajah **Q2(b)**.

(8 markah)

(c) Sebuah terowong dibina melalui batuan kuarzit terluluhawa sederhana di mana kekar dominannya bersudut kemiringan 70° dan miring searah dengan arah laluan masuk pembinaan terowong. Jurus ketakselanjaran adalah berserenjang dengan paksi terowong. Berdasarkan ujian beban titik, kekuatan batuan adalah 10 MPa. Kekar menunjukkan sifat permukaan sedikit kasar, panjang kekar berpurata 2 m, bukaan kekar berukuran antara 1 mm hingga 5 mm dengan bahan isian lembut sebanyak 5 mm dan purata jarak antara kekar adalah 150 mm. Keadaan aras air bumi terowong adalah dijangka menjadi basah. Dengan menggunakan nilai PMB daripada **S2(a)**, kirakan nilai *Rock Mass Rating* (RMR) dengan berpandukan kepada Rajah **Q2(c)**.

(15 markah)

S3 (a) Cadangan pembinaan jajaran lebuhraya melalui pergunungan batuan adalah seperti yang diberikan dalam Rajah **Q3**. Nilai sudut kemiringan bagi cerun potong A dan B telah diukur sebanyak 65°. Kerja-kerja tinjauan ketakselanjaran telah dilakukan di sepanjang cadangan cerun potong (A, B dan C) dan keputusannya adalah seperti yang diberikan dalam Jadual **1**.

Table 1

Set kekar 1, °	Set kekar 2, °	Set kekar 3, °
263/48	300/62	041/81
263/57	305/80	041/69
253/48	322/58	033/82
253/57	317/78	031/68

(i) Plotkan kesemua orientasi bagi setiap ketakselanjaran di atas secara plotan kutub dengan menggunakan jaringan stereo sama luas dalam Rajah **Q3(b)** dan kertas surih yang disediakan.

(4 markah)

(ii) Anggarkan dan plotkan kedudukan purata kutub untuk setiap set data yang telah diplot dari **S3(a)** dan lukiskan bulatan besar bagi setiap purata kutub untuk setiap set. Berikan nilai untuk arah dan sudut kemiringan bagi setiap set bulatan besar yang telah dilukiskan itu dalam Rajah **Q3(c)**.

(3 markah)

(b) Dengan merujuk kepada Rajah **Q3**, jawab soalan berikut:

(i) Berikan data bagi jurus dan arah miring bagi cerun potong A, B dan C dalam Rajah **Q3(d)**.

(3 markah)

(ii) Berdasarkan jawapan yang diperolehi daripada **S3(b)(i),** lukiskan bulatan besar bagi kesemua arah cerun tersebut (A, B dan C).

(2 markah)

(iii) Kajian set kekar mendapati kesemua nilai sudut geseran kekar batuan pada cerun tersebut adalah 25°. Lukiskan nilai sudut geseran tersebut pada kesemua cerun A, B dan C di atas kertas surih yang sama.

(2 markah)

(c) Berdasarkan jawapan dari **S3(a)** dan **S3(b)**, periksa dan tentukan kesemua mod kegagalan cerun batuan yang dicadangkan tersebut bersama-sama kriterianya sebagai bukti. Jadualkan keputusan tersebut pada Rajah **Q3(e)**.

(11 markah)

BAHAGIAN B (25 Markah)

S4 (a) Semasa kajian tapak, didapati kedalaman retakan ketegangan adalah sepanjang 4.0 meter dan berkeadaan kering. Nilai sudut geseran adalah sama seperti yang diberikan pada **S3(b)(iii)**. Maklumat-maklumat lain yang diperolehi daripada kajian tapak dan makmal adalah seperti berikut:

Berat unit batuan = 25 kN/m^3
Berat unit air = 9.81 kN/m^3
Ketinggian satah = 70 meter
Daya jelekitan kesemua satah ketakselanjaran = 50 kPa
Tetulang jenis Y_{25} = 10 ton = 100 kN

Dengan menggunakan data cerun yang diperolehi daripada **S3(b)**.

(i) Kirakan faktor keselamatan kegagalan satah cerun berpandukan Rajah **Q4(a)**.
(8 markah)

(ii) Simpulkan kestabilannya berdasarkan keputusan yang diperolehi dari **S4(a)(i)**.
(1 markah)

(b) Daripada **S4(a)**, anggarkan tetulang bolt penambat tertegang (T) yang diperlukan oleh cerun jika tetulang bolt penambat tertegang tersebut dimasukkan pada sudut (Ω) 20° pada nilai faktor keselamatan 1.7 seperti yang dikehendaki oleh klien dengan berpandukan Rajah **Q4(a)**.
(5 markah)

(c) Berikan penilaian mengenai sample korekan batuan yang ditunjukkan berdasarkan nilai Petanda Mutu Batuan (PMB) yang diperolehi dari **S2(a)** berpandukan kepada Rajah **Q4(b)** dan cadangkan jenis sistem sokongan dan pengorekan yang perlu digunakan berdasarkan nilai Q yang diperolehi daripada jawapan **S2(b)** berpandukan kepada Rajah **Q4(c)**.
(4 markah)

(d) Sebuah asas cetek akan dibina di atas formasi batuan granit tanpa formasi kemiringan. Nilai kejelekitan, c dan sudut geseran ϕ yang diperolehi dari pengiraan RMR ialah 60 MPa dan 20° masing-masing, manakala nilai berat unit batuan ialah 22 kN/m^3.

(i) Kirakan keupayaan galas tanah yang dibenarkan asas bagi nilai faktor keselamatan, FK = 3 berpandukan faktor keupayaan galas yang diberikan dalam Rajah **Q4(d)** dan Rajah **Q4(e)** dengan menggunakan formula di bawah:

$$q_a = \frac{C_{f1}\mathrm{cNc} + \mathrm{C}_{f2}(B\gamma/2)N_\gamma + \gamma DN_q}{SF}$$

(3 markah)

(ii) Kirakan saiz asas sama sisi yang boleh menampung beban pugak sebanyak 200 MN.

(3 markah)

(iii) Berdasarkan **S4(d)(ii)**, kirakan nilai mendapan bagi beban tersebut jika nilai batuan granit, E ialah 60 GPa.

(1 markah)

S5 (a) Terangkan **DUA (2)** kaedah (lengkap dengan parameter yang diperlukan) untuk mendapatkan keupayaan galas asas yang dibina pada batuan.

(2 markah)

(b) Terangkan perbezaan antara:

(i) Kekuatan mampatan satu paksi batuan teras dan kekuatan mampatan satu paksi jasad batuan.

(ii) Tegasan pugak, σ_1 dan tegasan mendatar, σ_3.

(iii) Keupayaan galas muktamad, q_u dan keupayaan galas yang dibenarkan, q_{all}.

(3 markah)

(c) Berikan justifikasi mengapa pengiraan kestabilan asas pada batuan kebiasaannya adalah diperolehi berdasarkan keupayaan galas berbanding kawalan mendapan.

(2 markah)

(d) Sebuah cerucuk yang mempunyai diameter 36 in. (900 mm) dibina di atas permukaan batuan segar dan ditanam dalam batu tersebut pada kedalaman 1.8m. Saiz dan jarak ketakselanjaran yang diperolehi adalah 1mm dan 50mm. Batuan adalah jenis batu lodak dengan nilai kekuatan mampatan satu paksi sebanyak 90 MPa.

(i) Anggarkan nilai keupayaan galas titik cerucuk yang dibenarkan berpandukan Rajah **Q5(a)** dan formula di bawah:

$$q_a = (\sigma_c)\,K_{sp}\,d\ ;\quad d = [0.8 + 0.2(L_s / B)] \leq 2$$

(3 markah)

(ii) Berdasarkan **S5(d),** terangkan mengapa formula tersebut digunakan tanpa pertimbangan pengiraan keupayaan galas muktamad, $q_{ultimate}$.

(2 markah)

(e) Berdasarkan nilai RMR yang diperolehi daripada **S2(c).**

(i) Berikan penilaian untuk nilai kejelekitan dan sudut geseran batu kuarzit tersebut berpandukan kepada Rajah **Q2(c).**

(2 markah)

(ii) Berikan penilaian mengenai ketahananan terowong tersebut tanpa sokongan berpandukan kepada Rajah **Q2(c).**

(1 markah)

(iii) Cadangkan jenis sistem sokongan dan pengorekan yang perlu digunakan berpandukan kepada Rajah **Q5(b).**

(4 markah)

(f) Cadangkan nama ujikaji batuan bagi mengukur parameter seperti berikut:

(i) Darjah ketumpatan batuan
(ii) Kekuatan mampatan satu paksi batuan
(iii) Ketahanan batuan terhadap luluhawa
(iv) Kekuatan tegangan batuan

(2 markah)

(g) Cadangkan data dan maklumat berkenaan ciri-ciri fizikal ketakselanjaran yang diperlukan dalam kerja-kerja tinjauan ketakselanjaran bagi tujuan menyokong hasil keputusan analisis kestabilan cerun potong yang terlibat.

(4 markah)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010
SUBJECT : GEOLOGI KEJURUTERAAN

COURSE : 2 BFF
SUBJECT CODE : BFC 3013

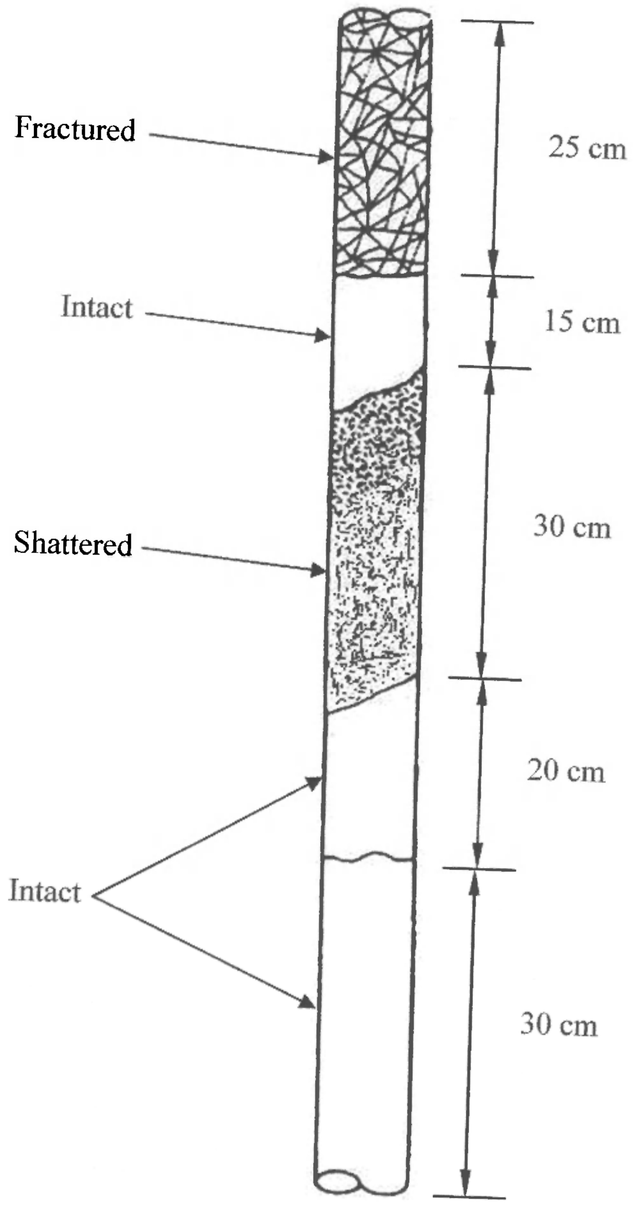


FIGURE Q2(a): Discontinuities on surface of the tunnel wall viewed from the front and lateral

(Drawing: Not to scale)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013

4. JOINT ALTERATION NUMBER	J_a	ϕ_r 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		*SRF*	
a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated			
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 dis-tegrated rock (excavation depth < 50 m)		5.0	
C. Single weakness zones containing clay, or chemically dis-tegrated 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	

FIGURE Q2(b)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013

DESCRIPTION	VALUE			NOTES
6. STRESS REDUCTION FACTOR			*SRF*	
b. Competent rock, rock stress problems				
	σ_c/σ_1	σ_t/σ_1		2. For strongly anisotropic virgin stress field
H. Low stress, near surface	> 200	> 13	2.5	(if measured): when $5 \le \sigma_1/\sigma_3 \le 10$, reduce σ_c
J. Medium stress	200 - 10	13 - 0.66	1.0	to $0.8\sigma_c$ and σ_t to $0.8\sigma_t$. When $\sigma_1/\sigma_3 > 10$,
K. High stress, very tight structure	10 - 5	0.66 - 0.33	0.5 - 2	reduce σ_c and σ_t to $0.6\sigma_c$ and $0.6\sigma_t$, where
(usually favourable to stability, may				σ_c = unconfined compressive strength, and
be unfavourable to wall stability)				σ_t = tensile strength (point load) and σ_1 and
L. Mild rockburst (massive rock)	5 - 2.5	0.33 - 0.16	5 - 10	σ_3 are the major and minor principal stresses.
M. Heavy rockburst (massive rock)	< 2.5	< 0.16	10 - 20	3. Few case records available where depth of
c. Squeezing rock, plastic flow of incompetent rock				crown below surface is less than span width.
under influence of high rock pressure				Suggest *SRF* increase from 2.5 to 5 for such
N. Mild squeezing rock pressure			5 - 10	cases (see H).
O. Heavy squeezing rock pressure			10 - 20	
d. Swelling rock, chemical swelling activity depending on presence of water				
P. Mild swelling rock pressure			5 - 10	
R. Heavy swelling rock pressure			10 - 15	

ADDITIONAL NOTES ON THE USE OF THESE TABLES

When making estimates of the rock mass Quality (*Q*), the following guidelines should be followed in addition to the notes listed in the tables:

1. When borehole core is unavailable, *RQD* can be estimated from the number of joints per unit volume, in which the number of joints per metre for each joint set are added. A simple relationship can be used to convert this number to *RQD* for the case of clay free rock masses: $RQD = 115 - 3.3\,J_v$ (approx.), where J_v = total number of joints per m^3 ($0 < RQD < 100$ for $35 > J_v > 4.5$).
2. The parameter J_n representing the number of joint sets will often be affected by foliation, schistosity, slaty cleavage or bedding etc. If strongly developed, these parallel 'joints' should obviously be counted as a complete joint set. However, if there are few 'joints' visible, or if only occasional breaks in the core are due to these features, then it will be more appropriate to count them as 'random' joints when evaluating J_n.
3. The parameters J_r and J_a (representing shear strength) should be relevant to the weakest significant joint set or clay filled discontinuity in the given zone. However, if the joint set or discontinuity with the minimum value of J_r/J_a is favourably oriented for stability, then a second, less favourably oriented joint set or discontinuity may sometimes be more significant, and its higher value of J_r/J_a should be used when evaluating *Q*. The value of J_r/J_a should in fact relate to the surface most likely to allow failure to initiate.
4. When a rock mass contains clay, the factor *SRF* appropriate to loosening loads should be evaluated. In such cases the strength of the intact rock is of little interest. However, when jointing is minimal and clay is completely absent, the strength of the intact rock may become the weakest link, and the stability will then depend on the ratio rock-stress/rock-strength. A strongly anisotropic stress field is unfavourable for stability and is roughly accounted for as in note 2 in the table for stress reduction factor evaluation.
5. The compressive and tensile strengths (σ_c and σ_t) of the intact rock should be evaluated in the saturated condition if this is appropriate to the present and future in situ conditions. A very conservative estimate of the strength should be made for those rocks that deteriorate when exposed to moist or saturated conditions.

Excavation category		*ESR*
A	Temporary mine openings.	3-5
B	Permanent mine openings, water tunnels for hydro power (excluding high pressure penstocks), pilot tunnels, drifts and headings for large excavations.	1.6
C	Storage rooms, water treatment plants, minor road and railway tunnels, surge chambers, access tunnels.	1.3
D	Power stations, major road and railway tunnels, civil defence chambers, portal intersections.	1.0
E	Underground nuclear power stations, railway stations, sports and public facilities, factories.	0.8

FIGURE Q2(b) continued

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

Parameter			Ranges of values						
1	Strength of intact rock material	Point-load strength index	>10MPa	4-10MPa	2-4MPa	1-2MPa	For this low range-uniaxial compressive test is preferred		
		Uniaxial Compression strength	>250MPa	100-250MPa	50-100MPa	25-50MPa	5-25MPa	1-5MPa	<1MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality RQD		90%-100%	75%-90%	50%-75%	25%-50%	<25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		>2mm	0.6-2mm	200-600mm	60-200mm	<60mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces. Not continous. No separation. Unweathered wall rock.	Slightly rough surfaces. Separation <1mm. Slightly weathered walls.	Slightly rough surfaces. Separtion < 1 mm. Highly weathered walls.	Slickensided surfaces or Gouge<5 mm thick or Separtion 1-5 mm continous.	Soft gouge>5 mm thick or Separtion>5mm continous.		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	<10m	10-25	25-125	>125		
		(Joint water press)/ (Major principal)	0	<0.1	0.1-0.2	0.2-0.5	>0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITIY ORIENTATION (SEE F)

Strike and dip orientations		Very favourable	Favourable	Fair	Unfavorable	Very Unfavorable
Rating	Tunnels and mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	0

C. ROCK MASS CLASSES

Rating	100-81	80-61	60-41	40-21	<21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING ROCK CLASSES

Class number	I	II	III	IV	V
Average stand-up time	20 years for 15 m span.	1 year for 10 m span.	1 week for 5 m span	10 hours for 2.5 m span	30 minutes for 1 m span
Cohesion of rock mass (kPa)	>400	300-400	200-300	100-200	<100
Friction angle of rock mass (degree)	>45	35-45	25-35	15-25	<15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS * (1) IS RATING

Discontinuity length (persistence)	<1m 6	1-3m 4	3-10m 2	10-20m 1	>20 m 0
Separation (aperture)	None 6	<0.1mm 5	0.1-1.0 mm 4	1-5 mm 1	>5 mm 0
Roughness	Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge)	None 6	Hard filling <5mm 4	Hard filling >5mm 2	Soft filling<2 mm 2	Soft filling 5mm 0
Weathering	Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELING

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip- 45°-90°	Drive with dip- 20°-45°	Dip 45°-90°	Dip 20°-45°
Very favourable	Favourable	Very unfavourable	Fair
Drive against dip- 45°-90°	Drive against dip-20°-45°	Dip 0°-20° –Irrespective of strike	
Fair	Unfavourable	Fair	

FIGURE Q2(c) : Rock Mass Rating System (After Bieniawski, 1989)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	Parameter		Ranges of values						
1	Strength of intact rock material	Point-load strength index	>10MPa	4-10MPa	2-4MPa	1-2MPa	For this low range-uniaxial compressive test is preferred		
		Uniaxial Compression strength	>250MPa	100-250MPa	50-100MPa	25-50MPa	5-25MPa	1-5MPa	<1MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality RQD		90%-100%	75%-90%	50%-75%	25%-50%	<25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		>2mm	0.6-2mm	200-600mm	60-200mm	<60mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces. Not continous. No separation. Unweathered wall rock.	Slightly rough surfaces. Separation <1mm. Slightly weathered walls.	Slightly rough surfaces. Separtion < 1 mm. Highly weathered walls.	Slickensided surfaces or Gouge<5 mm thick or Separtion 1-5 mm continous.	Soft gouge>5 mm thick or Separtion>5mm continous.		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	<10m	10-25	25-125	>125		
		(Joint water press)/ (Major principal)	0	<0.1	0.1-0.2	0.2-0.5	>0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITIY ORIENTATION (SEE F)

Strike and dip orientations		Very favourable	Favourable	Fair	Unfavorable	Very Unfavorable
Rating	Tunnels and mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	0

C. ROCK MASS CLASSES

Rating	100-81	80-61	60-41	40-21	<21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING ROCK CLASSES

Class number	I	II	III	IV	V
Average stand-up time	20 years for 15 m span.	1 year for 10 m span.	1 week for 5 m span	10 hours for 2.5 m span	30 minutes for 1 m span
Cohesion of rock mass (kPa)	>400	300-400	200-300	100-200	<100
Friction angle of rock mass (degree)	>45	35-45	25-35	15-25	<15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS * (1) IS RATING

Discontinuity length (persistence)	<1m 6	1-3m 4	3-10m 2	10-20m 1	>20 m 0
Separation (aperture)	None 6	<0.1mm 5	0.1-1.0 mm 4	1-5 mm 1	>5 mm 0
Roughness	Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge)	None 6	Hard filling <5mm 4	Hard filling >5mm 2	Soft filling<2 mm 2	Soft filling 5mm 0
Weathering	Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELING

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip- 45°-90°	Drive with dip- 20°-45°	Dip 45°-90°	Dip 20°-45°
Very favourable	Favourable	Very unfavourable	Fair
Drive against dip- 45°-90°	Drive against dip-20°-45°	Dip 0°-20° –Irrespective of strike	
Fair	Unfavourable	Fair	

FIGURE Q2(c) : Rock Mass Rating System (After Bieniawski, 1989)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010
SUBJECT : GEOLOGI KEJURUTERAAN

COURSE : 2 BFF
SUBJECT CODE : BFC 3013

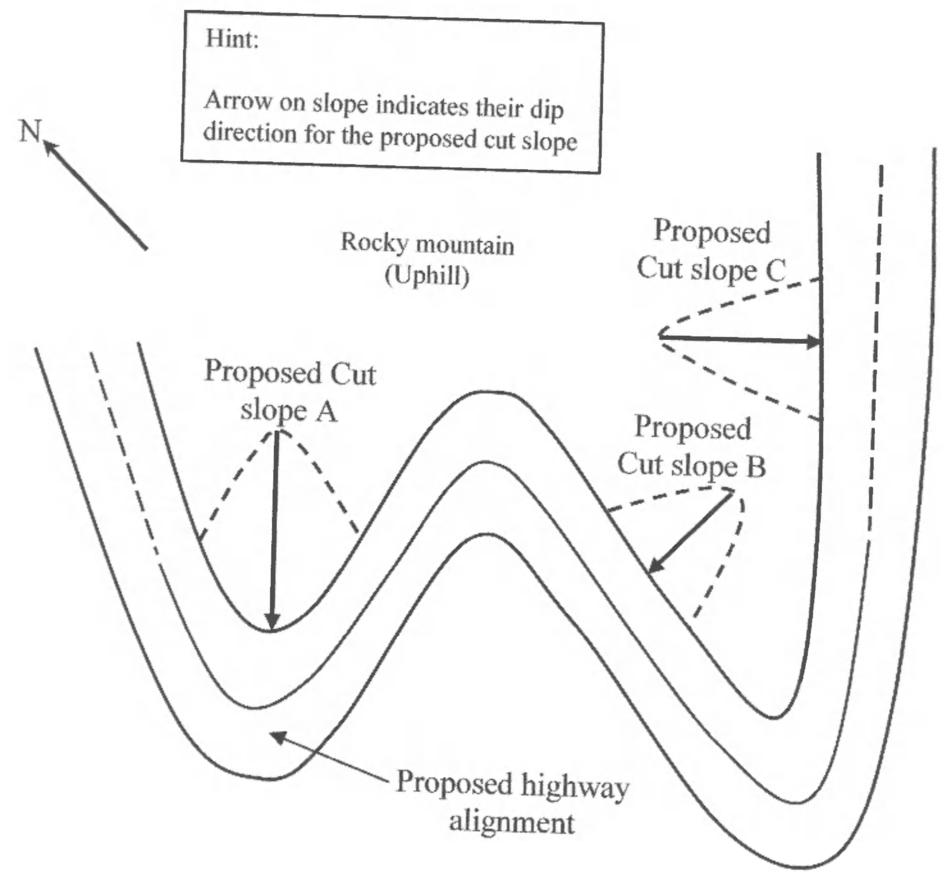


FIGURE Q3(a) : Proposed road alignment and the box cut of rock slope A side and B side from plan view

(Drawing: Not to Scale)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010
SUBJECT : GEOLOGI KEJURUTERAAN

COURSE : 2 BFF
SUBJECT CODE : BFC 3013

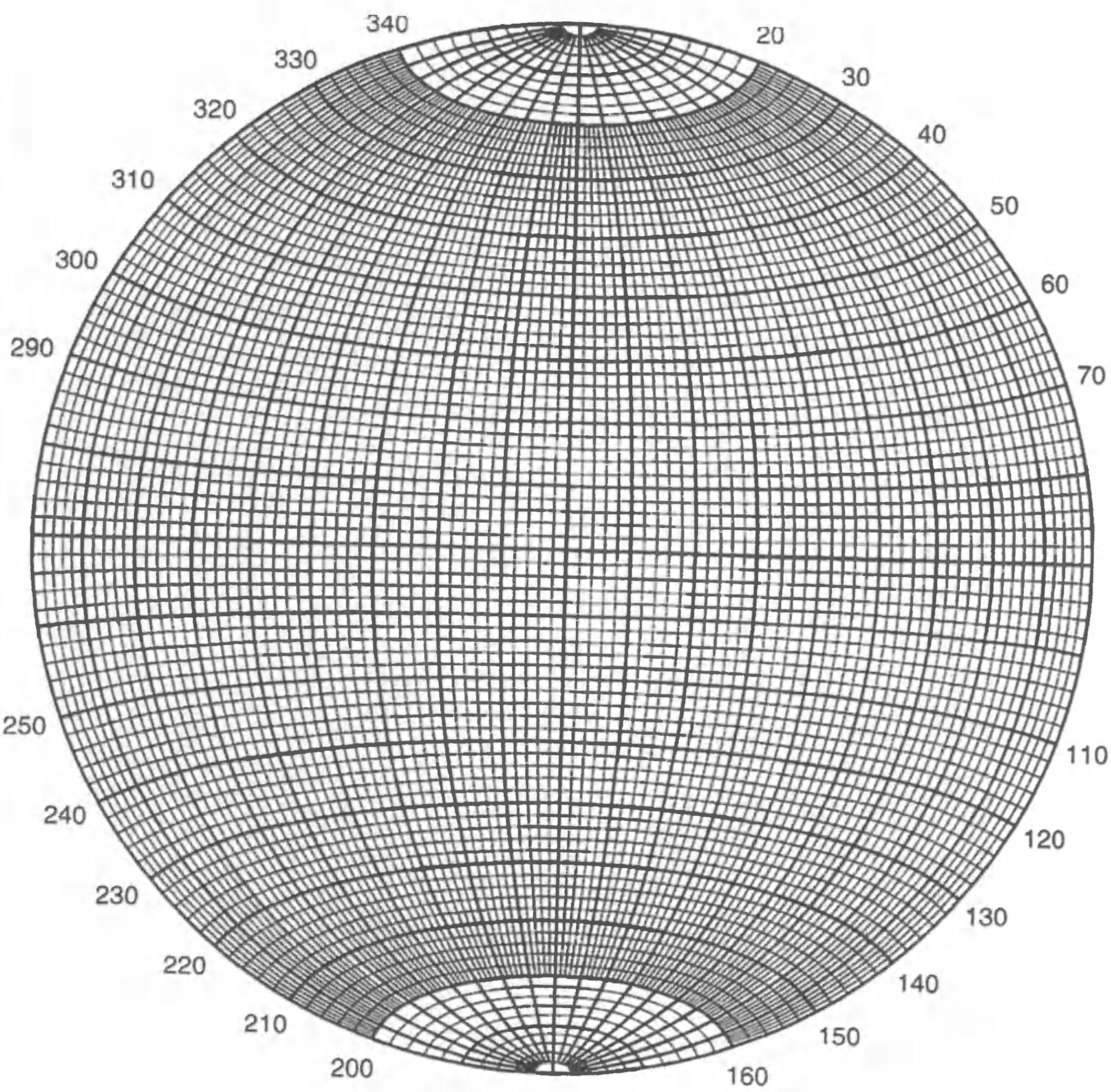


FIGURE Q3(b) : **Equal-area equatorial net for plotting poles and great circles**
(DO NOT CHANGE THE SIZE)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013

Joint set	Dip direction, ° N	Dip angle, °
J1		
J2		
J3		

FIGURE Q3(c)

Slope	Strike, ° N	Dip direction, ° N
A		
B		
C		

FIGURE Q3(d)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010
SUBJECT : GEOLOGI KEJURUTERAAN

COURSE : 2 BFF
SUBJECT CODE : BFC 3013

Slope	Mode of failure	Joint set and data	Criteria	Stability
A	Plane			
A	Wedge			
A	Toppling			
B	Plane			
B	Wedge			
B	Toppling			

FIGURE Q3(e)

FINAL EXAMINATION

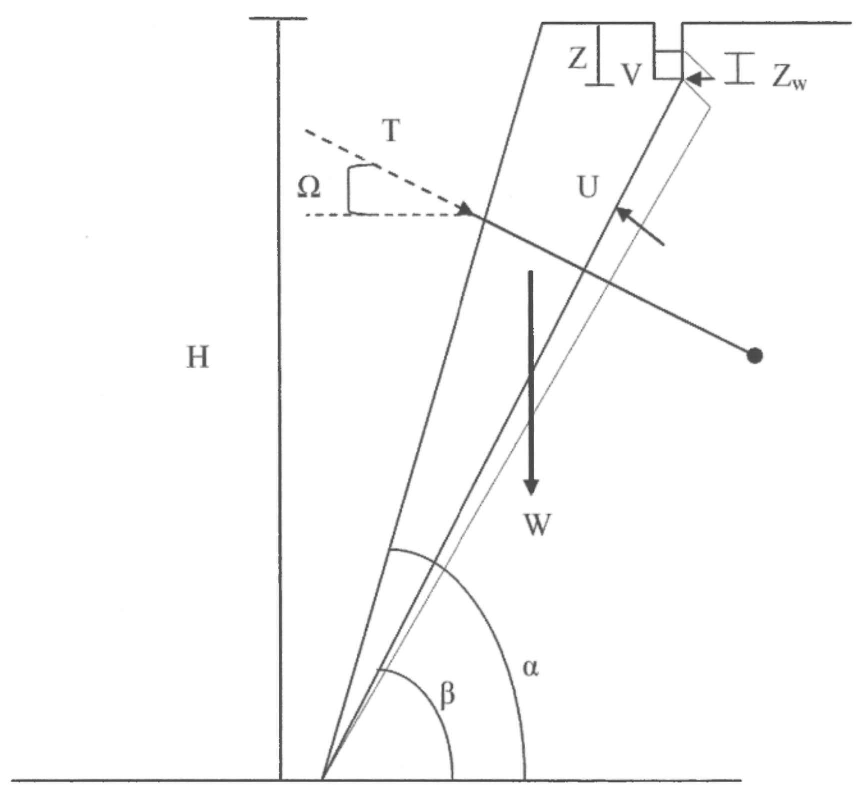
SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013

Slope	Mode of failure	Joint set and data	Criteria	Stability
C	Plane			
C	Wedge			
C	Toppling			

FIGURE Q3(e) continued

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013



Given:

$$\mathbf{FOS} = \frac{cA + (W\cos\beta - U - V\sin\beta + T\sin(\Omega+\beta))\tan\phi}{W\sin\beta + V\cos\beta - T\cos(\Omega+\beta)}$$

$A = (H\text{-}Z).\text{cosec}\,\beta$

$W = \frac{1}{2}\gamma_r.\,H^2\,[(1-(Z/H)^2)\cot\beta - \cot\alpha]$

$U = \frac{1}{2}\gamma_w.Z_w\,.(H\text{-}Z).\text{cosec}\,\beta$

$V = \frac{1}{2}\gamma_w.Z_w$

cosec = 1/sin sec=1/cos cot=1/tan

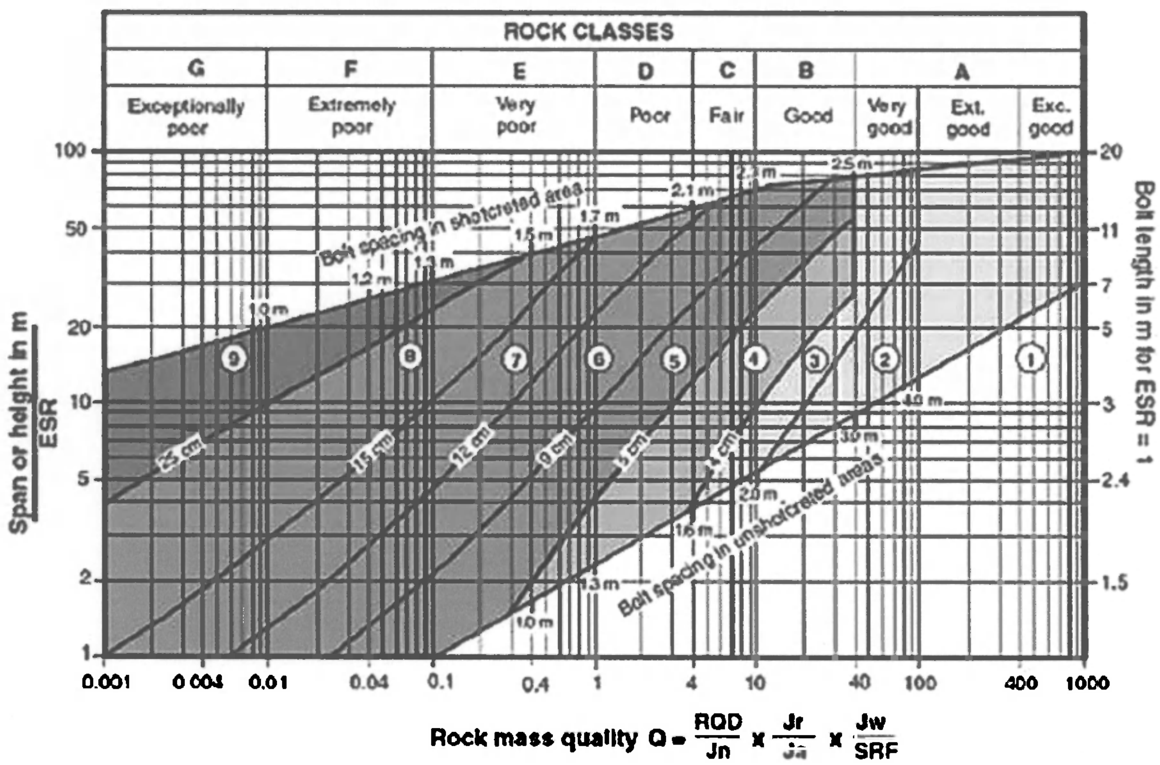
FIGURE Q4(a)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013

RQD (%)	Descriptions Rock Quality
0-25	Very Poor
25-50	Poor
50-75	Moderate
75-90	Good
90-100	Very Good

FIGURE Q4(b) Measurement identify rock quality (Source: Deere, 1989)



REINFORCEMENT CATEGORIES:

1) Unsupported
2) Spot bolting
3) Systematic bolting
4) Systematic bolting, (and unreinforced shotcrete
5) Fibre reinforced shotcrete and bolting, 5 - 9 cm
6) Fibre reinforced shotcrete and bolting, 9 - 12 cm
7) Fibre reinforced shotcrete and bolting, 12 - 15 cm
8) Fibre reinforced shotcrete, > 15 cm, reinforced ribs of shotcrete and bolting
9) Cast concrete lining

FIGURE Q4(c) : Estimated support categories based on the tunneling quality index, *Q* (After Grimstad and Barton, 1993, reproduced from Palmstrom and Broch, 2006)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010
SUBJECT : GEOLOGI KEJURUTERAAN

COURSE : 2 BFF
SUBJECT CODE : BFC 3013

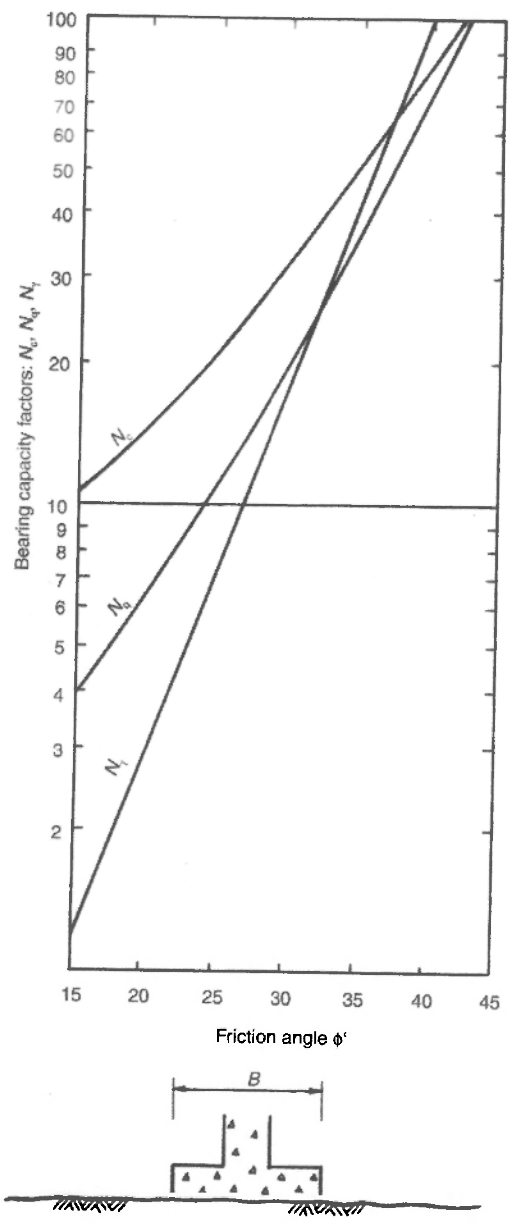


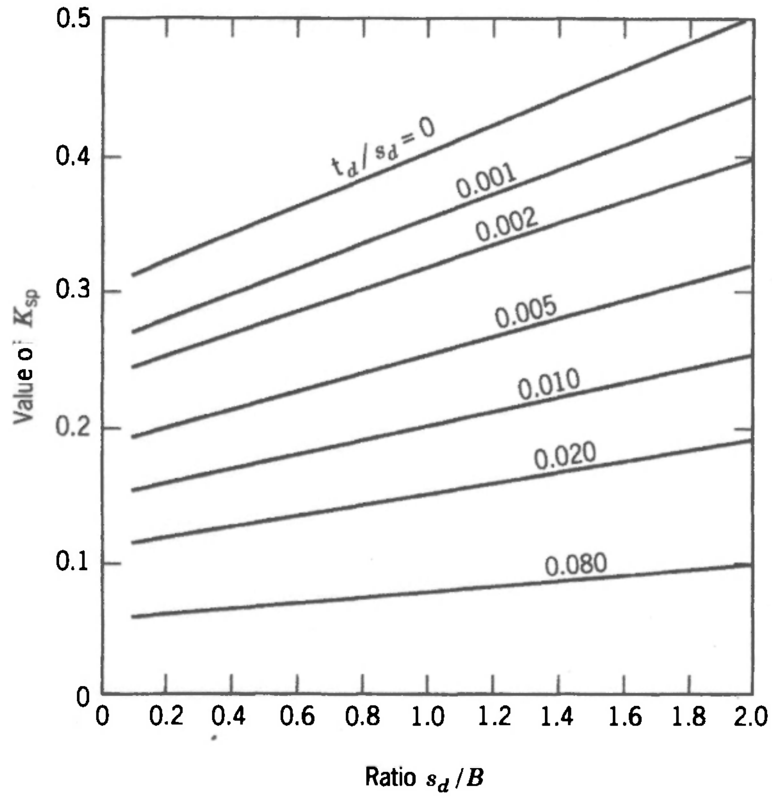
FIGURE Q4(d): Bearing capacity factor for footings located on horizontal ground surface (US Dept. of Navy, 1982)

Foundation shape	C_{f1}	C_{f2}
Strip ($L/B > 6$)	1.0	1.0
Rectangular		
$L/B = 2$	1.12	0.9
$L/B = 5$	1.05	0.95
Square	1.25	0.85
Circular	1.2	0.7

FIGURE Q4(e) : Correlation factor for foundation shapes (L= length, B = width)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 | COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN | SUBJECT CODE : BFC 3013



$$K_{sp} = \frac{3 + s_d/B}{10\sqrt{1 + 300\, t_d/s_d}}$$

s_d = spacing of discontinuities
t_d = thickness of discontinuities
B = Pile width or diameter

FIGURE Q5(a) : Values of empirical coefficient, Ksp. The coefficient Ksp takes into account the size effect and presence of discontinuities and contains a nominal factor of safety of three against general foundation failure. (Canadian Foundation Engineering Manual, 1985)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2009/2010 COURSE : 2 BFF
SUBJECT : GEOLOGI KEJURUTERAAN SUBJECT CODE : BFC 3013

Rock Mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	"Steel sets"
I-Very good rock RMR:81-100	Full face, 3 m advance	Generally no support required except spot bolting		
II-Good rock RMR:61-80	Full face, 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh	50 mm in crown where required.	None
III-Fair rock RMR:41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face	Systematic bolts 4 m long, spaced 1.5-2m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None
IV-Poor rock RMR:21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4 m long, spaced 1-1.5m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V-Very poor rock RMR<20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and fore poling if required. Close invert.

FIGURE Q5(b) : Guidelines for excavation and support of 10 m span rock tunnels in accordance with the RMR system (After Bieniawski, 1989)