UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2011/2012

Januari 2012

EBS 417/3 – Geomechanics
[Geomekanik]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains ELEVEN printed pages and TWO pages APPENDIX before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEBELAS muka surat yang bercetak dan DUA muka surat LAMPIRAN sebelum anda memulakan peperiksaan ini.]

This paper consists of TWO questions from PART A and FIVE questions from PART B.
[Kertas soalan ini mengandungi DUA soalan dari BAHAGIAN A dan LIMA soalan dari BAHAGIAN B.]

Instruction: Answer **ALL** questions from PART A and **THREE** questions from PART B. If candidate answers more than five questions only the first five questions answered in the answer script would be examined.
*[**Arahan**: Jawab **SEMUA** soalan dari BAHAGIAN A dan **TIGA** soalan dari BAHAGIAN B. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

The answers to all questions must start on a new page.
[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]

You may answer a question either in Bahasa Malaysia or in English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

In the event of any discrepancies, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

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PART A:

***BAHAGIAN A*:**

1. [a] The results on sieve analysis on soil are:

Keputusan analisa saringan ke atas suatu tanah ialah:

Sieve size / *Saiz saringan (mm)*	Mass retained / *Jisim yang tertinggal (g)*
50.00	0
37.50	15.5
20.00	17.0
14.00	10.0
10.00	11.0
6.30	33.0
3.35	114.5
1.18	63.3
0.60	18.2
0.15	17.0
0.063	10.5

The total mass of the sample was 311 g, plot the particle size distribution curve and, from the inspection of this curve, determine the effective size and uniformity coefficient. Classify the soil based on the chart in Appendix 1.

Jumlah jisim sampel ialah 311 g, plotkan lengkungan taburan saiz zarah dan, daripada pemeriksaan lengkungan ini tentukan saiz keberkesanan dan pekali keseragaman. Kelaskan tanah ini berdasarkan carta di Lampiran 1.

(75 marks/*markah*)

[b] Please discuss the following:

(i) Porosity

(ii) Void Ratio

(iii) Well graded soil

(iv) Uniformly graded soil

(v) Gap graded soil

Sila bincangkan perkara berikut:

(i) Keliangan

(ii) Nisbah ruang

(iii) Tanah bergred rapi

(iv) Tanah bergred seragam

(v) Tanah bergred sela

(25 marks/*markah*)

2. [a] Please discuss the following:

(i) Q-system

(ii) *In-situ* stress

(iii) Discontinuities

(iv) Anisotropy

(v) Uniaxial Compressive Strength

Sila bincangkan mengenai perkara-perkara berikut

(i) Sistem-Q

(ii) Tegasan in-situ

(iii) Ketakselanjaran

(iv) Anisotropi

(v) Kekuatan mampatan unipaksi

(50 marks/*markah*)

[b] Nowadays, a variety of engineering activities require excavation of rock cuts. In mining, open pits mines account for the major portion of the world's mineral production. Write short notes about the common rock slope failures with the help of sketches of the slope and the stereographic projection of each failure.

Pelbagai aktiviti kejuruteraan pada hari ini memerlukan pemotongan permukaan cerun batuan. Di dalam perlombongan, lombong dedah memberi sumbangan yang besar kepada pengeluaran mineral dunia. Tulis secara ringkas mengenai kegagalan cerun batuan yang biasa berlaku dengan bantuan lakaran cerun dan unjuran stereografik untuk setiap kegagalan.

(50 marks/*markah*)

PART B:

***BAHAGIAN B*:**

3. [a] In pumping out test as shown in Figure 1, water is pumped out from a well at the rate of q and the height of water level at the first observation well at distance r1 from the center of the pumping well is h1 and the water level at the second observation well at r2 from the pumping well is h2. Derive the coefficient of permeability:

Dalam ujian pengepaman keluar seperti yang ditunjukkan dalam Rajah 1, air dipam keluar daripada sebuah telaga pada kadar alir q dan ketinggian paras air di telaga pemerhatian pertama dengan jarak r_1 daripada titik tengah telaga yang mengepam ialah h1 dan paras air di telaga pemerhatian kedua pada r2 dari telaga pengepaman ialah h2. Terbitkan pekali kebolehtelapan.

$$k \frac{2.3q \log_{10}\left(\frac{r_2}{r_1}\right)}{\pi(h_2^2 - h_1^2)}$$

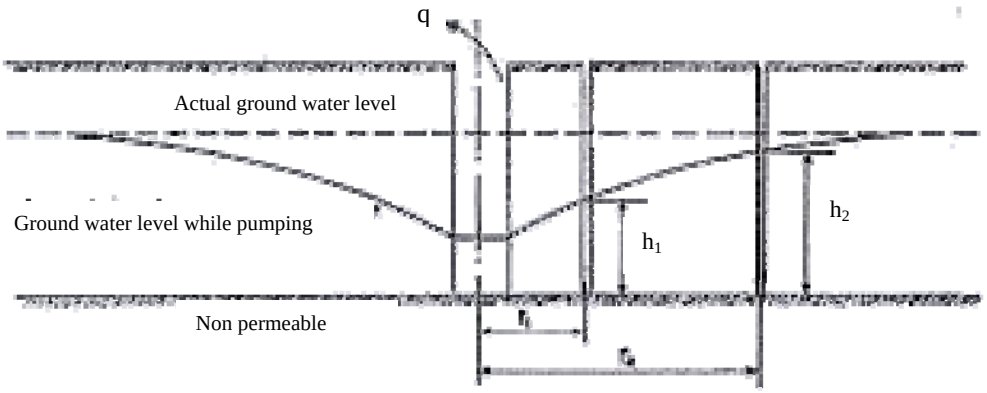


Figure 1: Pumping Out Test / *Rajah 1: Ujian Pengepaman Keluar*

(25 marks/*markah*)

[b] Slope failure indicates imperfection in our understanding of soil and rock behavior. Examine and discuss the corrective measures of soil failing slopes.

Kegagalan cerun menunjukkan ketidaksempurnaan pemahaman kita tentang tingkah laku tanah dan batuan. Kaji selidik dan bincangkan langkah pemulihan untuk cerun tanah yang gagal.

(75 marks/*markah*)

4. In mountainous terrain, the operation of highways and railways, power generation and transmission facilities, and the safety of residential and commercial developments often require stable slopes and control of rock falls. This applies to both excavated and natural slopes. In contrast, open pit mines activities can tolerate a certain degree of slope instability unless there is a hazard to the miners or a significant loss of production.

By considering the level of hazards and in term of economically justified, discuss five corrective measures for soil failing slopes.

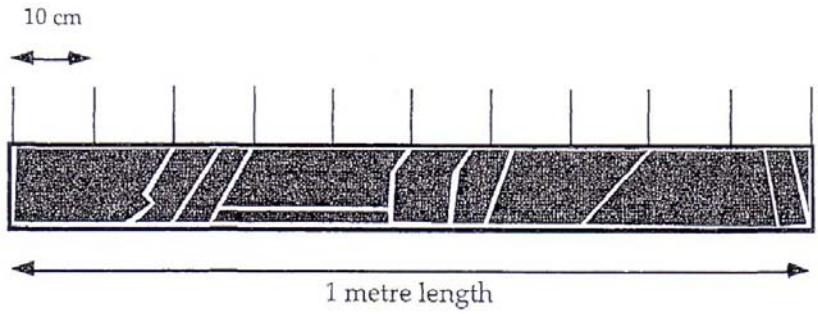
Di kawasan pergunungan, lebuhraya dan landasan keretapi yang beroperasi, stesen penjanaan kuasa, kawasan kemudahan penghantaran, dan keselamatan di kawasan perumahan dan kawasan komersil sering memerlukan keadaan cerun yang stabil dan jatuhan batuan yang terkawal. Ini adalah termasuk untuk cerun yang digali dan cerun semulajadi. Sebaliknya, aktiviti lombong dedah boleh bertolak-ansur dengan tahap tertentu ketidakstabilan cerun melainkan jika mendatangkan bahaya kepada pelombong atau menyebabkan pengurangan kepada jumlah pengeluaran.

Dengan mengambil kira tahap bahaya dan kos pembaikan, bincangkan lima langkah pembetulan kegagalan cerun tanah.

(100 marks/*markah*)

5. [a] For the following sketch, which shows a one meter long section of recovered drill core, what numerical estimate of Rock Quality Designation (RQD) for the core length and what rock quality would be associated with this rock?
Provide a brief description of the RQD classification technique.

Lakaran di bawah menunjukkan batuan dari lubang gerudi sepanjang 1 meter, apakah nilai jangkaan RQD bagi lubang gerudi tersebut dan apakah kualiti batuan yang boleh dikaitkan dengan batuan ini?
Sertakan penjelasan secara ringkas berkaitan teknik klasifikasi RQD.



(25 marks/*markah*)

[b] A mudstone rock mass at a depth of 200 m contains three discontinuity sets. One set comprises bedding planes; these are highly weathered, slightly rough surfaces, and are continuous with an orientation of 180/10. Another set is jointing; these are slightly weathered, slightly rough, and have an orientation of 185/75. The third set is also jointing; again, this is slightly weathered and slightly rough, and has an orientation of 090/80. The strength of the intact rock has been assessed as 55 Mpa, and values for the RQD and average discontinuity spacing are reported as 60% and 0.4 m, respectively.

Use the RMR (Appendix 1) system to classify this rock mass, and assess the stability of a 10 m wide excavation being driven from East to West.

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Jisim batu lumpur pada kedalaman 200 m mengandungi tiga jenis ketakselanjaran. Set pertama terdiri daripada satah perlapisan; sangat terluluhawa, sedikit kasar di permukaan, dan mempunyai selanjaran pada arah 180/10. Set kedua adalah kekar; sedikit terluluhawa, sedikit kasar dipermukaan dan mempunyai arah selanjaran pada 185/75. Set ketiga juga merupakan kekar; juga sedikit terluluhawa dan sedikit kasar, dan mempunyai selanjaran arah pada 090/80. Tegasan pada batuan utuh adalah 55 Mpa, nilai bagi RQD dan purata jarak ketakselanjaran adalah dilaporkan sebagai 60% dan 0.4 m.

Gunakan sistem klasifikasi RMR (Lampiran 1) untuk batuan ini, dan penilaian kestabilan bagi proses pengorekan selebar 10 m yang bakal dilakukan dari Timur ke Barat.

(75 marks/*markah*)

6. A 7 km motorway tunnel is to be built in a generally massive granitic rock with the rock mass is characterized by nine sets of major discontinuities (See table below). The angle of friction of all discontinuities is approximately $\phi = 30°$.

7 km terowong lebuh raya bakal dibina di dalam batuan granit yang secara amnya utuh dengan jisim batuan yang dikategorikan berdasarkan sembilan set ketakselanjaran utama (Lihat jadual di bawah). Sudut geseran ke semua ketakselanjaran adalah lebih kurang $\phi = 30$.

Joints / *Kekar*	**Dip direction / *Arah kemiringan***	**Dip / *Miring***
Plane 1 / *Satah 1*	120°	60°
Plane 2 / *Satah 2*	220°	50°
Plane 3 / *Satah 3*	250°	60°
Plane 4 / *Satah 4*	330°	40°
Plane 5 / *Satah 5*	030°	40°
Plane 6 / *Satah 6*	350°	70°
Plane 7 / *Satah 7*	270°	35°
Plane 8 / *Satah 8*	070°	50°
Plane 9 / *Satah 9*	170°	80°

[a] Plot the great circles of all planes and the small circle of ϕ using the stereonet (Appendix 2).

Plot bulatan besar bagi kesemua kekar dan bulatan kecil ϕ *menggunakan stereonet (Lampiran 2).*

(50 marks/*markah*)

[b] Identify the mode of failure of each potentially unstable wedge. In the case of a sliding failure, identify the direction of sliding. Give reasons why you think a wedge will move in a particular direction.

Kenalpasti jenis kegagalan untuk setiap baji yang berpotensi untuk tidak stabil. Sekiranya berlaku kes kegagalan gelinciran, kenalpasti arah gelinciran. Beri alasan mengapa anda fikir baji tersebut akan bergerak di dalam arah tertentu.

(50 marks/*markah*)

7. [a] Three lengths of rock core, of similar composition and all at 54 mm diameter have been subjected to point load failure testing. The failure forces applied for the three tests were found to be 28.5 kN, 29.6 kN and 31.4 kN. Of the following, which average Point Load Index (I_s) and calculated unconfined compressive strength (S_c) values best approximate the true strength parameters for this rock material (please justify your choice).

Tiga teras lubang gerudi, yang berkomposisi sama dan semuanya pada kepanjangan 54 mm telah dikenakan ujian kegagalan titik beban. Kuasa kegagalan yang dikenakan untuk ketiga-tiga ujian didapati pada 28.5 kN, 29.6 kN and 31.4 kN. Daripada yang disenaraikan, nilai purata Indek Beban Titik (I_s) dan kekuatan mampatan unipaksi (S_c) yang manakah yang paling mewakili kekuatan parameter untuk batuan tersebut (sila nyatakan sebab pemilihan).

(i) I_s = 10.05 MPa, S_c = 200.1 MPa

(ii) I_s = 10.05 MPa, S_c = 241.2 MPa

(iii) I_s = 10.85 MPa, S_c = 260.1 MPa

(iv) I_s = 10.85 MPa, S_c = 291.0 MPa

(30 marks/*markah*)

[b] In open pit mine operations, methods exist to stabilize sliding wedge failure through application of tensioned anchors across potential planes of sliding. Discuss one scenario under which placement of tensioned anchors might create a reduction in stability for a potential sliding wedge.

Dalam operasi lombong dedah, kaedah wujud untuk menstabilkan gelongsor oleh kegagalan baji melalui penggunaan penunjuk tuju yang ditegangkan keseluruhan satah yang berpotensi untuk gagal. Bincangkan satu senario di mana penggunaan penunjuk tuju-ditegangkan mungkin dapat mengurangkan potensi ketidakstabilan bagi kegagalan baji untuk berlaku.

(50 marks/*markah*)

[c] Discuss how rock mass characterization techniques can be used by mining engineers to influence excavation and support system design of mines during pre-development.

Bincangkan bagaimana teknik pencirian jisim batuan boleh digunakan oleh jurutera lombong di dalam mempengaruhi penggalian dan rekabentuk sistem sokongan lombong semasa pra-pembangunan lombong.

(20 marks/*markah*)

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Appendix 1 / *Lampiran 1*: Rock Mass Rating System (After Bieniawski, 1989)

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS									
Parameter			Range of values						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	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		> 2 m	0.6 - 2 . m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	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 DISCONTINUITY ORIENTATIONS (See F)						
Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS					
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 OF ROCK CLASSES					
Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)	> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)	> 45	35 - 45	25 - 35	15 - 25	< 15

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

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**			
Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 - 90°	Dip 20 - 45°
Very favourable	Favourable	Very unfavourable	Fair
Drive against dip - Dip 45-90°	Drive against dip - Dip 20-45°	Dip 0-20 - Irrespective of strike°	
Fair	Unfavourable	Fair	

* Some conditions are mutually exclusive . For example, if infilling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A.4 directly.

** Modified after Wickham et al (1972).

Appendix 2 / ***Lampiran 2*****:**