00223

THE OPENUNIVERSITY OF SRI LANKA
Department of Civil Engineering
Bachelor of Technology (Civil) - Level 5

CEX5232 – Engineering Geology

FINAL EXAMINATION – 2015/2016

Time Allowed: Three (03) Hours

Date: 17-11-2016 (Thursday) Time: 0930- 1230 hrs.

Answer five (5) out of eight (8) questions.

Q1. Geological structures play a major role in the geotechnical engineering performance of underlying bedrocks.

(a). Draw a neatly sketched diagram of a **fault** showing all the structural parameters. (10 marks)

(b). Differentiate between **Reverse faults** and **Normal faults**, with the help of neatly sketched labelled diagrams (5 marks)

(c). Differentiate between **Angular unconformity** and **Non-conformity**, with the help of neatly sketched labelled diagrams. (5 marks)

Q2. Behavior of groundwater in hard rock formations greatly depend on the their textures and structures.

(a). State and describe **five** different types of textures that can be identifiedin an **igneous rocks**. (5 marks)

(b). State and describe **four** different types of textures that can be identified in a **clastic sedimentaryrocks**. (4 marks)

(c). Discuss the Aquifer Potential of a **sedimentary rock** and how it relates with the answer given in Q2 (b). (7 marks)

(d). A limestone formation is having a coefficient of permeability (k) of 4×10^{-2}m/day. If the particular rock is having an aquifer of saturated thickness 15m, determine the **transmissibility** of the aquifer. (4 marks)

Q3. Write Short Notes on Following.

(a). Failure and destruction process of reservoir slopes. (5 marks)

(b). Erosion process of rivers. (5 marks)

(c). Valley widening process in formation of river valleys. (5 marks)

(d) Stabilizing of boreholes to avoid collapsing (5 marks)

(e) Piston type soil samplers (5 marks)

Q4. The information shown in Table Q4 (1) were reported during a site investigation program for a hydropower tunnel construction along a section of a proposed tunnel axis.

Table Q4 (1)

Item No.	Rock Mass Parameter Description		Rock Mass Parameter
01	Drill quality of rock mass		Core Recovery= 89% Rock Quality Designation= 64% Fracture Index= 17/m
02	Discontinuity spacing		1.0m
03	Discontinuity condition	Length	3.45m
		Separation	0.65mm
		Roughness	Slickensided
		Infilling	Hard >5mm
		Weathering	Slightly weathered
04	Groundwater condition		Wet
05	Average Uniaxial Compressive Strength of rock cores		125MPa

Special Note:
It has been further revealed that the discontinuity planes are in striking parallel to the proposed tunnel axis and their dip direction is towards the direction of tunnel drive with an average dip angle of 65^0.

With the above given information in Table Q4 (1) and with the help of attached Table Q4 (2) to Table Q4 (7), answer following questions.

(a). Determine the Rock Mass Rating (RMR) value of the rock mass for the particular section of the tunnel. (15 marks)

(b). Propose range of values to **angle of internal friction** and **cohesion** to the given rock mass. (5 marks)

Q5. Four boreholes (BH-A 01, BH-A 02, BH-B 01 and BH-B 02) hasbeen carried out in two proposed narrow valley locations (location A and location B) for a reservoir dam. The details obtained from those are given in Table Q5(1).

Table Q5 (1)

Borehole	Purpose	Depth from existing ground level (m)	Layer description
BH-A 01	Side Slopes of valley area for dam abutting	0.00-3.40 3.40-5.90 5.90-30.00	Very dense residual with rock boulders Highly weathered rock Fresh Charnokitic Gneiss rock; bedding and joint planes are dipping at 70^0towards up stream area of the dam axis and striking parallel to dam axis
BH-A 02	Bottom of valley area for dam founding	0.00-2.80 2.80-4.20 4.20-5.80 5.80-16.70 16.70-50.00	Loose fine sand Very soft alluvial clay Highly weathered rock Fresh Quratzo feldspathic Gneiss rock-interbedded with quartzite dikes; bedding and joint planes are dipping at 43^0 towards up stream area of the dam Fresh Charnokitic Gneiss rock; bedding and joint palnes are dipping at 50^0 towards up stream area of the dam.
BH-B 01	Side Slopes of valley area for dam abutting	0.00-2.10 2.10-6.30 6.30-30.00	Very dense residual with rock boulders Slightly weathered Granitic Gneiss rock interbedded with weathered marble bands varying from 0.20m-1.30m thickness. Fresh Charnokitic Garnet Biotite Gneiss rock; bedding and joint planes are dipping at 45^0 towards down stream area of the dam and striking parallel to dam axis

BH-B 02	Bottom of valley area for dam founding	0.00-4.70 4.70-5.90 4.20-5.80 5.80-30.00	Very dense sandy gravel accompanied with cobbles and boulders Highly weathered Biotite Gneiss rock Biotite Mica layer dipping 15^0 towards down stream area of the dam. Fresh Feldspathic Biotite Gneiss rock-with >90% of Orthoclase Feldspar; bedding and joint planes are dipping at 60^0 towards down stream area of the dam.

Critically evaluate the suitability of;

(a) **Location A** and

(b) **Location B** for the construction of proposed dam based on the given information in Table Q5(01), taking into consideration of weathering potential and orientation of discontinuities of underlying formations. (8marks each)

(c). Propose the most suitable location for the construction of proposed dam based on the answers to questions Q5(a) and Q5(b). (4 marks)

Q6. The map shown in Figure Q(6) indicates five (05) borehole locations, conducted as a part of the geotechnical investigation program for construction of a tunnel. Results obtained havereported following information.

- A Quartzite bed has been observed from the collar level (top surface) of BH-A. This Quartzite stratum strikes in East-West Direction and Dips exactly towards south at an angle of 45^o.

- A Marble layer has been observed in BH-B, BH-C and BH-D during the drilling and this Marble layer was encountered at 20m, 40m and 50m depths at the respective boreholes.

Considering above information and details in give in Figure Q(6);

a) Compile the **outcrop pattern** of the Quartzite layer in the same Figure Q(6), considering that this layer dips at a constant angle with no change in dip direction. (8 marks)

b) Determine the **strike direction** of Marble layer. (4 marks)

c) Determine the **Dip angle** and the **Dip Direction** of the Marble layer. (4 marks)

d) Determine the possible **depth** of Marble layer that can be expected to be encountered during the drilling in borehole BH-E location. (4 marks)

Q7. A rock slope has been created due to an excavation for a road cut to a height of 12m at a face angle of 60^0. The rock which this cut has been made contains a weak **planer**foliation plane which dips at an angle of $35^0$and dips towards the slope face and strikes parallel to it. During a rainy season, a 4.35m deep tension crack has been created at a distance of 4.0m behind the crest and is filled with water to a height of 3.0m above the weak foliation plane (i.e sliding surface). The strength parameters of sliding surface are; cohesion (c) =25kPa and angle of internal friction (ø) = 37^0. The unit weight of rock mass material is $26kN/m^3$ and the unit weight of water can be assumed as $9.81kN/m^3$.

(a). Draw a neatly sketched diagram showing all the slope geometrical parameters pertaining to above mentioned information. (2 marks)

(b). Mark all the forces affecting the stability of the slope concerned in the same diagram drawn in Q(5)(a) (3 marks)

(c). Calculate the factor of safety of the slope under above mentioned conditions. (10 marks)

(d). Comment on the stability of the slope if the crest area is fully flooded due to overland flow. (5 marks)

Q8. Following information was revealed in a borehole carried out during a geotechnical investigations program for a new highway project at its feasibility assessment stage. The borehole was carried out in design of both embankment and a bridge pier.

Table Q8 (1)

Depth (m)	Layer Description	Additional remarks
0.00-2.10	Silty sandy clay with high content of organic matter	Very soft soil
2.10-9.60	Peat with partly decayed wooden material	Very soft, high moisture content soil
9.60-17.20	Organic clay with some sand	Stiff to very stiff soil
17.20-22.80	Medium to coarse sand with mica	Medium dense to very dense
22.80-26.40	Calcareous limestone interbedded with sandstone layers	Excessive amount of water loss observed during drilling, rock core samples reports very low core recovery values
26.40-33.40	Calcareous limestone	Moderate amount of water loss observed during drilling in upper part of the layer, rock core samples reports appreciable core recovery values

(a). Based on the information given in Table Q8 (1) briefly discuss about the geotechnical engineering properties and their possible impacts on the proposed structures that can be expected fromthe formations mentioned. (6 marks)

(b). Develop a subsurface exploratory drilling program that should be performed for the **detailed design** of aforementioned structures in the same area. In your answer following aspects should be clearly mentioned.

(i) Drilling methodology and frequency of exploratory locations

(ii) In-situ tests that will need to be performed with reasons for performing the test.

(iii) Depth of exploration. (iv) Methods of sampling. (8 marks)

(c). Formulate a laboratory testing program that should be performed for the same site with reasoning.

(6 marks)

Table Q4 (2). Classification Parameters and Ratings

PARAMETER			RANGES OF VALUES						
1	Strengh 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 compressive 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**	**6**	**3**		
3	Spacing of discontinuities		>2m	0.6-2m	200-600mm	60-200mm	<60mm		
	Rating		**20**	**15**	**10**	**8**	**5**		
4	Condition of discontinuities (see E for details)		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 > 5mmThick OR Separation >5 mm Continuous		
	Rating		**30**	**25**	**20**	**10**	**0**		
5	Group Water	Inflow per 10 m tunnel length	None OR	<10 liters/mm OR	10-25 liters/mm OR	25-125 liters/mm OR	>125 liters/mm OR		
		Ratio = Joint water pressure / Major principal stress(σ)	0 OR	0.0-0.1 OR	0.1-0.2 OR	0.2-0.5 OR	>0.5 OR		
		General Conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		**15**	**10**	**7**	**4**	**0**		

Table Q4 (3). Rating adjustments for discontinuity Orientations (see Table Q4 (7))

Strike and dip Orientation of joins		Very favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Rating	Tunnels	0	-2	-5	-10	-12
	Foundation	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

Table Q4 (4). Rook Mass Classes determined from Total Ratings

Rating	100-81	80-61	60-41	40-21	<21
Class No.	I	II	III	IV	V
Description	Very good Rock	Good rock	Fair Rock	Poor Rock	Very Poor Rock

Table Q4 (5). Meaning of rock mass classes

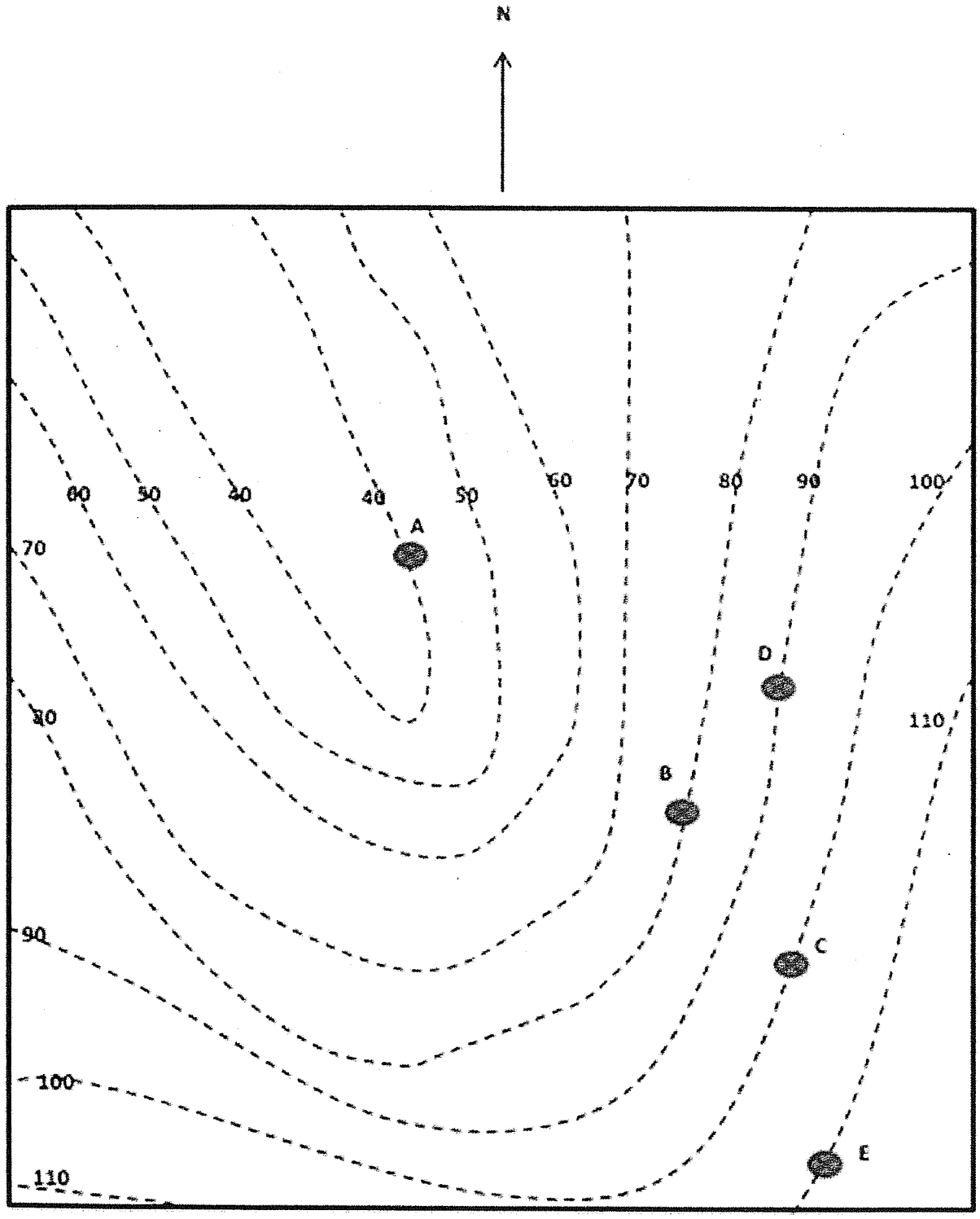
Class No	I	II	III	IV	V
Average stand-up time	20 years for 15m span	1 year for 10m span	1 week for 5m span	10 hours for 2.5m span	30 minutes for 1m span
Cohesion of the rock mass	>400kPa	300-400kPa	200-300kPa	100-200kPa	<100kPa
Friction angle of the rock mass	>45°	35 ° -45 °	25 ° -35 °	15 ° -25 °	<15 °

Table Q4 (6). Guidelines for Classification of Discontinuity Conditions

Discontinuity Length (persistence)	<1m	1-3m	3-10m	10-20m	>20m
Rating	6	4	2	1	0
Separation (aperture)	None	<0.1mm	0.1-1.0mm	1-5mm	>5mm
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<5mm	Hard filling>5mm	Soft filling<5mm	Soft filling>5mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Rating	6	5	3	1	0

Table Q4 (7). Effect of discontinuity strike and dip orientation on Rock Mass Rating values for tunnels

Strike **Perpendicular** to tunnel axis		Strike **Parallel** to tunnel axis	
Drive **with** Dip with beds dip 45^0-90^0	Drive **with** Dip with beds dip 20^0-45^0	Beds dip 45^0-90^0	Beds dip 20^0-45^0
Very Favorable	**Favorable**	**Very Unfavorable**	**Fair**
Drive **against** Dip with beds dip 45^0-90^0	Drive **against** Dip with beds dip 20^0-45^0	Beds dip 0^0-20^0 Irrespective of strike	
Fair	**Unfavorable**	**Fair**	



Scale of the map- 1:1000

Contour Intervals- 10m

Contours in meters

Figure Q (06)