



MACHAKOS UNIVERSITY

UNIVERSITY EXAMINATIONS 2024/2025

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF BUILDING AND CIVIL ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

ECV 507: GEOTECHNICAL ENGINEERING

Date:

Time :

INSTRUCTIONS

- *This paper comprises of **FIVE** questions. Answer **THREE** questions*
- *Question one is **Compulsory** and carries 30 marks*
- *Answer any other **TWO** questions*

QUESTION ONE

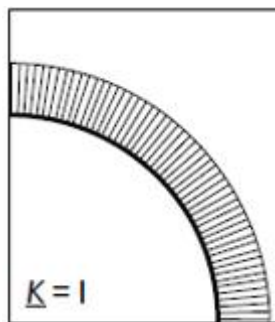
1. (i) Define the following terms
 - (a). Adit
 - (b). Tunnel Shaft
 - (c). RQD
 - (d). RMR classification system
 - (e). Q classification system
 - (f). Crown
 - (g). Invert
 - (h). Springline

- (i) Competent rock
- (j) dip/strike

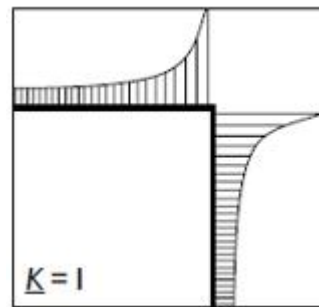
(10 Marks)

(ii). **Fig. Q1ii** shows stress distribution around circular tunnel opening and square tunnel opening. Compare and contrast the stress distribution in a & b. As an engineer which shape of the tunnel opening will you choose? Why?

(3 marks)



a circular tunnel opening



b square tunnel opening

Fig. Q1ii

(iii) **Fig. Q1iii** is a typical RQD borehole log information during a site investigation. Calculate the RQD, and Total Core Recovery, TCR Would you classify the rock as excellent, good, fair, poor, or very poor? Why?

(3 Marks)

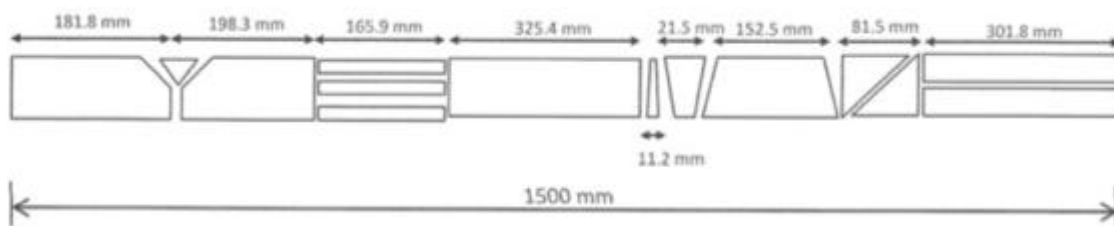


Fig. Q1iii

(iv) Assume that a road tunnel is 11 m in span and is excavated in a rock mass with a Q-value of 3.5. Find the Excavation Support Ratio (ESR) and the equivalent dimension (D_e). Also compute the bolt length, bolt spacing with and without shotcrete according to Barton and Grimstad (2014). Required tables are as attached

(3 Marks)

(v) Draw a sketch and label the key components of a Dam.

(5 Marks)

(vi) Rock bolts lead to less than 2% increase in post-excavation factor of safety, therefore rock bolting is not a very useful technique in enhancing rock strength. To what extent do you agree/disagree with this statement? Explain your answer. (2 marks)

(vii) What is the ground reaction curve? (2 marks)

(viii) Difference between safety and stability in rock tunneling. (2 marks)

QUESTION TWO

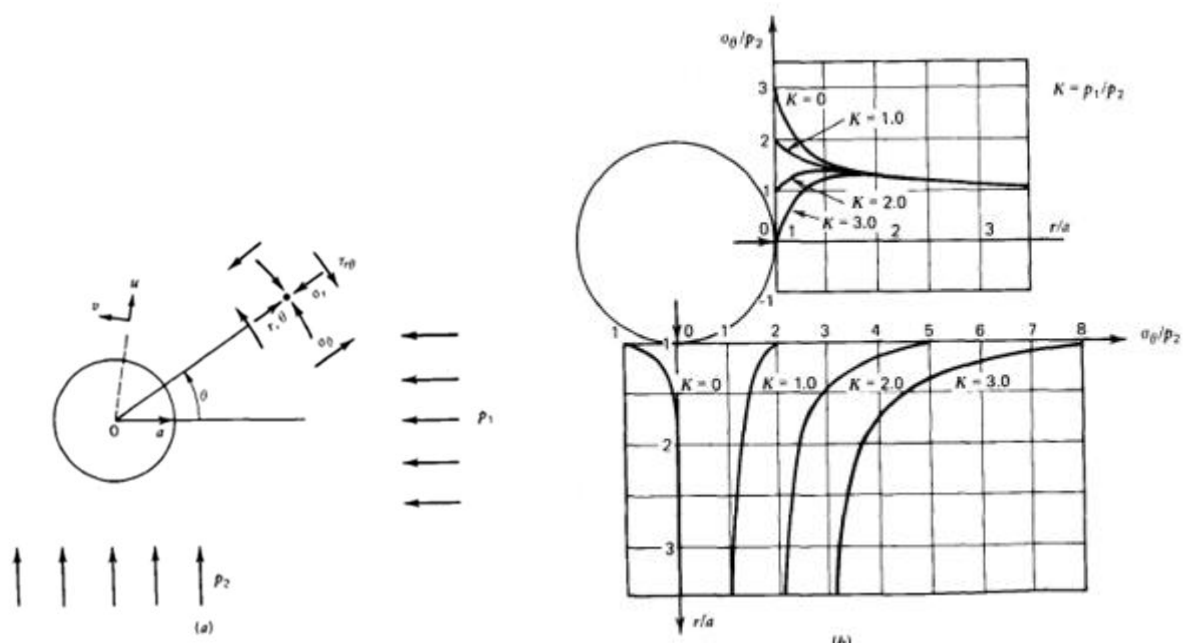
2. **Fig. Q2i**, shows stress distribution around a tunnel. Explain the curves and how they will help in deciding a bolting regime support around a tunnel. Based on these curves how far away may another tunnel of the same geometry be placed away from the first tunnel? (5 marks)

(ii) State and explain Five uses of a dam. (10 Marks)

(iii) In what direction should a tunnel be aligned? Under what conditions can this be defied? (2 marks)

(iii) Describe key input parameters for the Mohr-Coulomb model in PLAXIS, an application for computer-aided modeling in Geomechanics

(3 marks)



a Tunnel

b Stress distribution around the tunnel.

Fig. Q2i

QUESTION THREE

3. i) The rock recovered as indicated (**Fig.Q3i**) was recovered from a moist rock mass characterized by the following parameters: joint water pressure is nil: the point load index = 6 Mpa; the joint spacing is 800 mm. If the joints have slightly rough surfaces; an aperture less than 1 mm and consists of soft wall rock. Further, the rock consists of two minerals with sonic wave velocities of 4000m/s and 6000m/s respectively. If the sonic velocity of the insitu rock mass is 2033m/s. Find the porosity and classify the rock using the terminology of Fournaintraux as per the attached **Fig. Q3ii**. Also find the Total core recovery (TCR). (8 marks)
- (ii) Compare & contrast RMR & Q systems of rock classification (8marks)
- (iii) Squeezing ground is encountered at a depth of 350 m where yieldable steel arches are being considered for support instead of fixed steel sets for a tunnel 5 m wide by 5 m high. The rock mass is described as “squeezing rock, moderate depth,” so $H_p = (1.1 - 2.1)(B + H_t)$, say, $H_p = 1.5(5 + 5) = 15$ m, a substantial rock load. An arched back section will be used if steel sets are decided upon; a circular section would be used if yieldable arches are used. Determine the cross-sectional area of steel needed for the latter option. **Note symbols carry the usual meaning as learned in class** (4 marks)

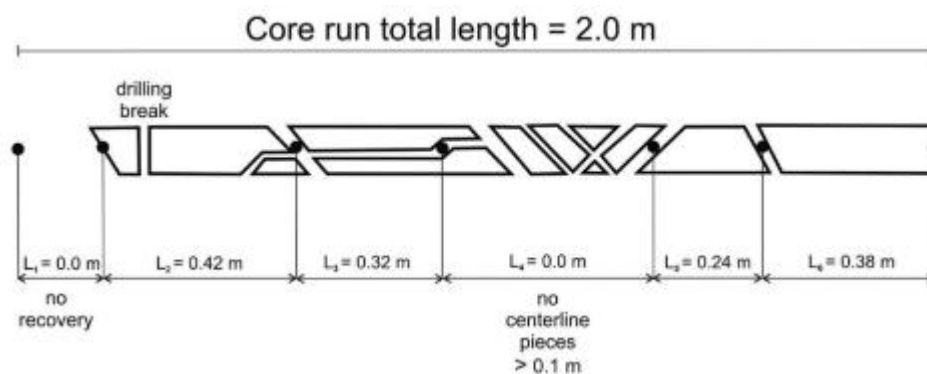


Fig. Q3i

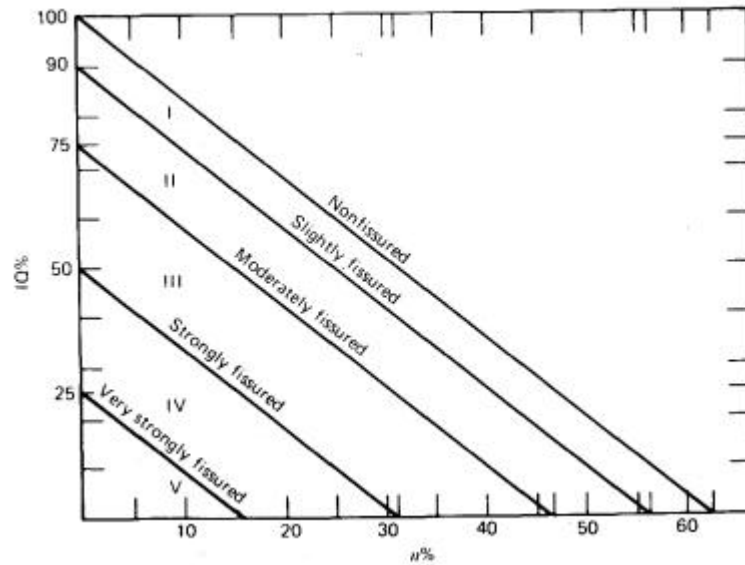


Fig. Q3ii

QUESTION FOUR

4. Determine the thickness and the P-wave velocity of the materials encountered. The results (**Fig Q4 & Table Q4**) obtained from a seismic study along a section of the centerline of a highway are shown below. Estimate the depths of the different strata of soil and suggest the type of soil in each stratum.

(20 marks)

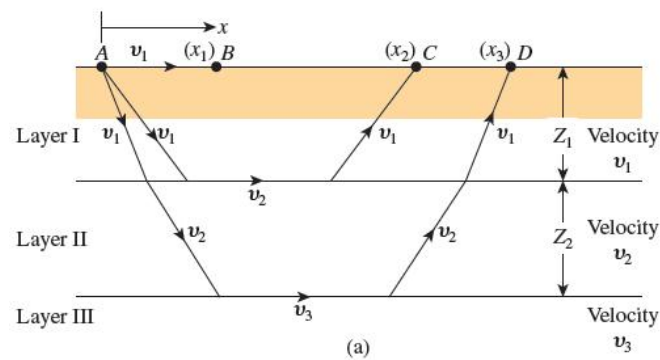


Fig. Q4i

$$Z_2 = \frac{1}{2} \left[T_{12} - 2Z_1 \frac{\sqrt{v_3^2 - v_1^2}}{v_3 v_1} \right] \frac{v_3 v_2}{\sqrt{v_3^2 - v_2^2}}$$

Table Q4.

<i>Distance of Impulse to Geophone (m)</i>	<i>Time for Wave Arrival (10^{-3} sec)</i>
7.5	20
15	40
22.50	60
30	68
37.5	74
45	82
52.50	84
60	86
67.50	88
75	90

QUESTION FIVE

5. (i) A moist rock mass is characterized by the following parameters: joint water pressure is nil; the point load index = 6 MPa; the joint spacing=200 mm and RQD=61%. If the joints have slightly rough surfaces; an aperture less than 1 mm and consists of soft wall rock. Using the attached tables in the appendix, provide an RMR rating for the rock justifying each step. Comment on the rock condition. (3 Marks)

- (ii) Consider a horizontal, rectangular opening that is 3 m high and 6 m wide and driven due north 1,524 m. Rock properties are (13 marks)

$$C_o = 163.5 \text{ MPa}, \quad T_o = 10.2 \text{ MPa}, \quad E = 36.48 \text{ GPa}, \\ \nu = 0.27, \quad \gamma = 25.34 \text{ kN/m}^3$$

The premining stress state relative to compass coordinates is

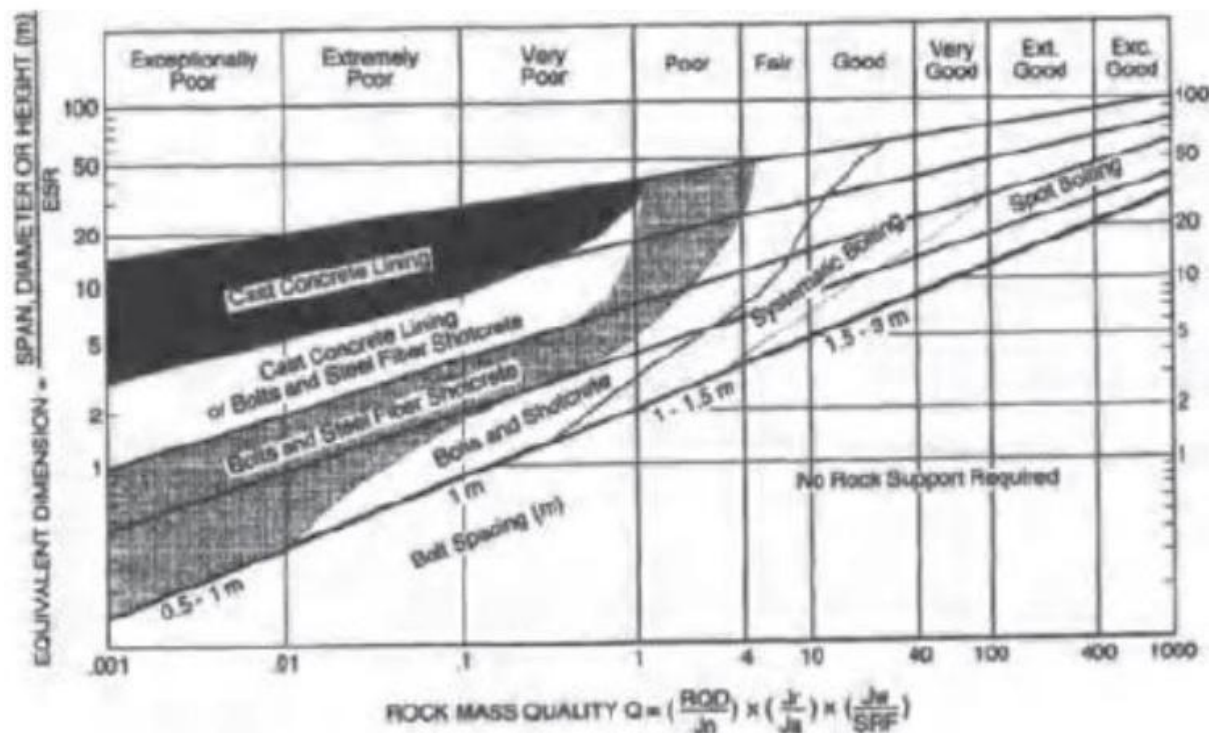
$$S_E = 2,414 + 4.53 h, \quad S_N = 2,897 + 7.92 h, \quad S_V = 25.34 h$$

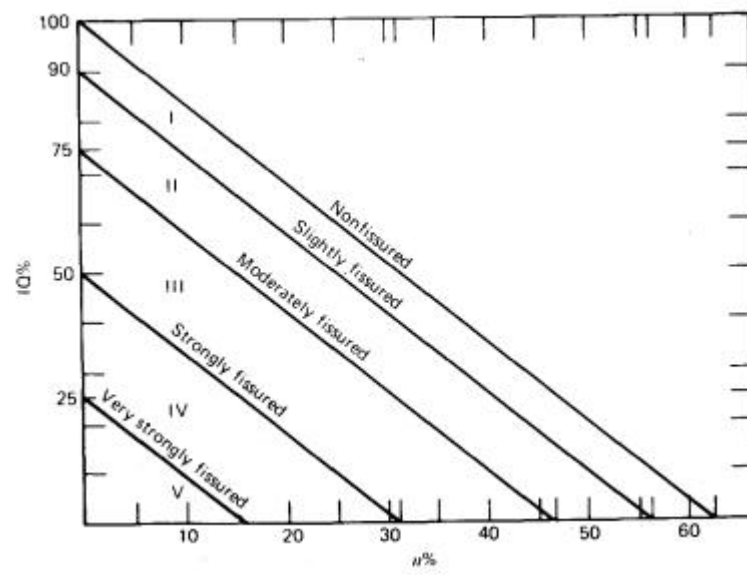
where stresses are in kPa, h =depth in m, E , N , V refer to compass coordinates (x =east, y =north, z =up) and compression is positive. Premining shear stresses are nil relative to compass coordinates. How wide can this opening be made before failure occurs at a depth of 533 m? Justify.

(iii) State and explain the uses of shafts.

(4 marks)

Excavation Category	ESR
A Temporary mine openings	3–5
B Permanent mine openings, water tunnels for hydropower (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 defense chambers, portal intersections	1.0
E Underground nuclear power stations, railway stations, sports and public facilities, factories	0.8





Parameter			Ranges of Values						
1	Strength of intact rock material	Point-load strength index (MPa)	>10	4-10	2-4	1-2	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength (MPa)	>250	100-250	50-100	25-50	5-25	1-5	<1
	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		>2m	0.6-2m	200-600mm	60-200mm	<60mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See Section E of Table)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation <1mm Slightly weathered walls	Slightly rough surfaces Separation <1mm Highly weathered wall	Slickensided surfaces or Gouge <5mm thick or Separation 1-5mm Continuous	Soft gouge >5mm thick or Separation >5mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (L/min)	None or _____	<10 or _____	10-25 or _____	25-125 or _____	>125 or _____		
		Joint water pressure Ratio: _____ Major principal stress	0 or _____	<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		

Course Description

Design and construction of Tunnels, shafts and dams. Rock mechanics: classification according to strength, stress analysis, mechanical testing. Determination of rock mass properties and rock support interaction. Use of Rock quality indices. Design of rock bolts support systems. In-situ bearing capacity tests:- plate bearing, Dynamic Cone Penetration and Pile Load tests. Geotechnical site investigations: boring and sampling, penetration tests, remote sensing, geophysical exploration. Numerical modelling in Geomechanics. Introduction to related computer software.