



MACHAKOS UNIVERSITY

University Examinations for 2022/2023

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF BUILDING AND CIVIL ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION

BACHELOR OF SCIENCE (CIVIL ENGINEERING)

ECV 507 GEOTECHNICAL ENGINEERING

DATE:

TIME:

INSTRUCTIONS

. You should have the following for this Examination,
Battery-powered calculator

. This paper consist of **Five Questions**
. Attempt Question **One** and **Any other Two**.

. Question **One** carries **30** Marks and is **COMPULSORY**.
The rest are **20 Marks** Each.

1. a) Define the following terms
 - i) Adit
 - ii) Tunnel Shaft
 - iii) RQD
 - iv) RMR classification system
 - v) Q classification system (10 marks)
- b) Fig. 1 is a typical RQD borehole log information during a site investigation. Calculate the RQD. Would you classify the rock as excellent, good, fair, poor, or very poor? Why? (5 marks)

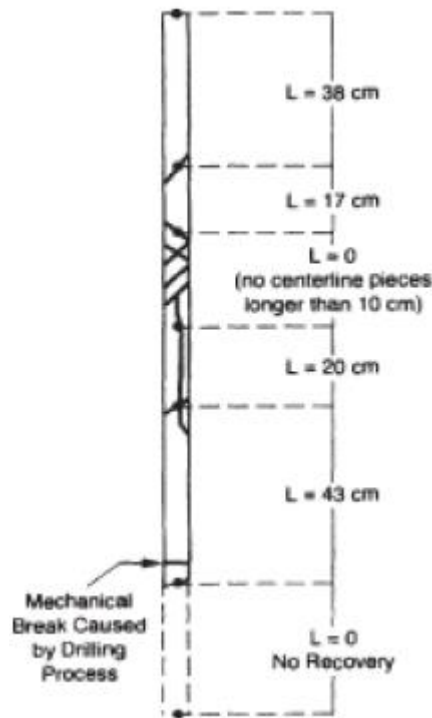


Fig. 1

- c) A moist rock mass is characterized by the following parameters: joint water pressure is nil: the point load index = 3 Mpa; the joint spacing=0.5 m and RQD=55%. If the joints have slightly rough surfaces; an aperture less than 1 mm and consists of soft wall rock. Using a well-reasoned approach (tables attached), justifying each step, provide an RMR rating for the rock. and comment on the rock condition. (8 marks)
- d) For the rock being considered in (iii) above. Assume it has two joint sets and the wall rock is filled with stiff clay. Given the rock is loose with open discontinuities, rate the rock and classify it according to the Q system. (7 marks)
2. With the aid of well-labeled sketches, and necessary mathematical formulations (if applicable), discuss the various modes of failure of grouted rock bolts. (20 marks)
3. (i) Highlight various mechanisms through which rock bolts are normally designed to effectively carry their loads in tunnels. (10 Marks)
- (ii) Discuss various failure modes of in-situ rockmass. Also, state clearly under what conditions such failure may occur. (10 Marks)

4. (i) A shaft of internal diameter 3 m, is to be embedded 20 m deep in rock as an opening to send supplies to the tunnel boring machine(TBM). The shaft is to be made of concrete with an ultimate strength of 20 N/mm². Given the shaft has to resist a moment of 40,000kNm. If the thickness of the shaft is 200mm. Check the suitability of this design to carry the bending moment above. (6 marks)
- (ii) Other than the functions of the tunnel shaft mentioned in 4(i) above, discuss other tunnel shaft uses. (4 marks)
- (iii) For the tunnel shown below P=100kN/m, R= 4m, Young's modulus of the soil on site is 200 MPa,Poisson's ratio of the soil =0.25, Poisson's ratio of concrete liner =0.22. Compute $\frac{\Delta D}{D}$ and a suitable liner Young's modulus (E_i), if liner thickness (t) is 0.15m. Use the Peck, Hendron, and Mohraz (PHM) method. Also determine the compressibility (C) and Flexibility (F) ratios, (necessary formulae are as attached).

(10 marks)

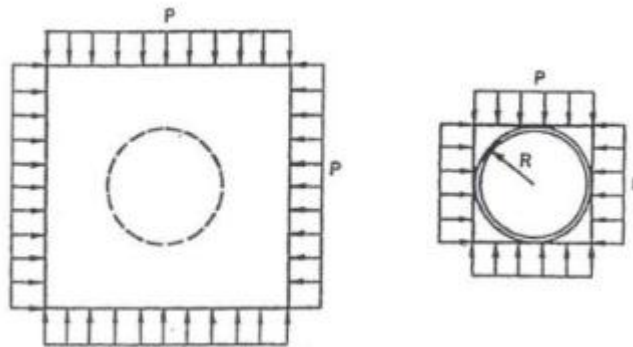


Fig. 1

5. The results of a refraction survey (Figure 2 shown) at a site are given in the following Table 1. Determine the thickness and the P-wave velocity of the materials encountered.

(20 marks)

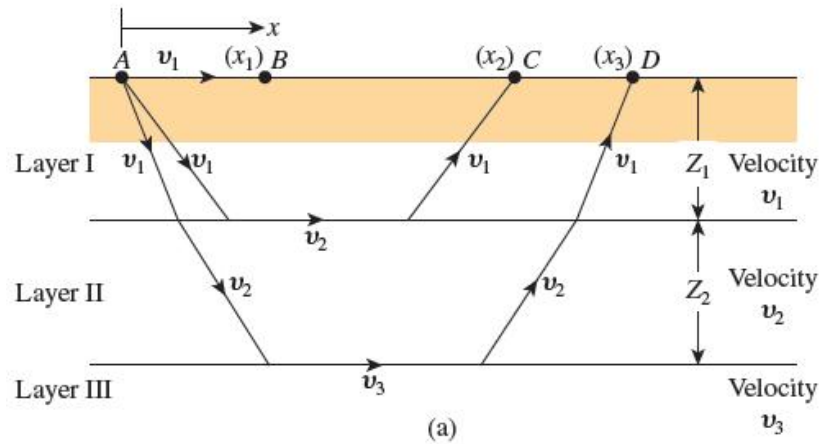


Fig. 2

$$Z_2 = \frac{1}{2} \left[T_{i2} - 2Z_1 \frac{\sqrt{v_3^2 - v_1^2}}{v_3 v_1} \right] \frac{v_3 v_2}{\sqrt{v_3^2 - v_2^2}}$$

Table 1.

Distance from the source of disturbance (m)	Time of first arrival of P waves (s × 10 ³)
2.5	5.08
5.0	10.16
7.5	15.24
10.0	17.01
15.0	20.02
20.0	24.2
25.0	27.1
30.0	28.0
40.0	31.1
50.0	33.9

Table 2.10 Rock Mass Rating Increments for Compressive Strength of the Rock

Point Load Index (MPa)	OR	Unconfined Compressive Strength (MPa)	Rating
>10		>250	15
4-10		100-250	12
2-4		50-100	7
1-2		25-50	4
Don't use		10-25	2
Don't use		3-10	1
Don't use		<3	0

Table 2.11 Rock Mass Rating Increments for Drill Core Quality

RQD (%)	Rating
90-100	20
75-90	17
50-75	13
25-50	8
<25	3

Table 2.12 Increments of Rock Mass Rating for Spacing of Joints of Most Influential Set

Joint Spacing (m)	Rating
>2.0	20
0.6-2.0	15
0.2-.6	10
0.06-	
0.2	8
<0.06	5

Table 2.13 Rock Mass Rating Increments for Joint Condition

Description	Rating
Very rough surfaces of limited extent; hard wall rock	30
Slightly rough surfaces; aperture less than 1 mm; hard wall rock	25
Slightly rough surfaces; aperture less than 1 mm; soft wall rock	20
Smooth surfaces, OR gouge filling 1-5 mm thick, OR aperture of 1-5 mm; joints extend more than several meters	10
Open joints filled with more than 5 mm of gouge, OR open more than 5 mm; joints extend more than several meters	0

Table 2.14 Increments of Rock Mass Rating Due to Groundwater Condition

Inflow per 10 m Tunnel Length (L/min)	OR	Joint Water Pressure Divided by Major Principal Stress	OR	General Condition	Rating
None		0		Completely dry	15
<10		0.0-0.1		Damp	10
10-25		0.1-0.2		Wet	7
25-125		0.2-0.5		Dripping	4
>125		>0.5		Flowing	0

Table 2.17 Values of the Parameters in the Q System

Number of Sets of Discontinuities	J_n
Massive	0.5
One set	2.0
Two sets	4.0
Three sets	9.0
Four or more sets	15.0
Crushed rock	20.0
Roughness of Discontinuities	J_r^*
Noncontinuous joints	4.0
Rough, wavy	3.0
Smooth, wavy	2.0
Rough, planar	1.5
Smooth, planar	1.0
Slick, planar	0.5
"Filled" discontinuities	1.0
*Add 1.0 if mean joint spacing exceeds 3 m	

Filling and Wall Rock Alteration	J_a
Essentially unfilled	
Healed	0.75
Staining only; no alteration	1.0
Silty or sandy coatings	3.0
Clay coatings	4.0
Filled	
Sand or crushed rock filling	4.0
Stiff clay filling <5 mm thick	6.0
Soft clay filling <5 mm thick	8.0
Swelling clay filling <5 mm thick	12.0
Stiff clay filling >5 mm thick	10.0
Soft clay filling >5 mm thick	15.0
Swelling clay filling >5 mm thick	20.0
Water Conditions	J_w
Dry	1.0
Medium water inflow	0.66
Large inflow with unfilled joints	0.5
Large inflow with filled joints that wash out	0.33
High transient inflow	0.2–0.1
High continuous inflow	0.1–0.05
Stress Reduction Class	SRF*
Loose rock with clay-filled discontinuities	10.0
Loose rock with open discontinuities	5.0
Rock at shallow depth (<50 m) with clay-filled discontinuities	2.5
Rock with tight, unfilled discontinuities under medium stress	1.0
* Barton et al. also define SRF values corresponding to degrees of bursting, squeezing, and swelling rock conditions.	

Compressibility ratio

Ground

$$\frac{\Delta D}{D} = \varepsilon_m = \frac{P}{E} (1 + \nu)(1 - 2\nu); \frac{\Delta D}{D} = \frac{E}{(1+\nu)(1-2\nu)}$$

Liner

$$\frac{\Delta D}{D} = \frac{PR}{E_l t'} \cdot \frac{P}{D} = \frac{E_l t}{R(1-\nu_l^2)}$$

Compressibility ratio

$$C = \frac{E R}{E_l t} \frac{(1-\nu_l^2)}{(1+\nu)(1-2\nu)}$$

Flexibility ratio

Ground

$$\frac{\Delta D}{D} = \frac{P}{E} (1 + \nu); \frac{P}{D} = \frac{E}{(1+\nu)(1-2\nu)}$$

Liner

$$\frac{\Delta D}{D} = \frac{PR^3}{6E_l I_l'}; \frac{P}{D} = \frac{6E_l I_l}{R^3 (1-\nu_l^2)}$$

Flexibility ratio

$$F = \frac{2E}{E_l} \left(\frac{R}{t}\right)^3 \frac{(1-\nu_l^2)}{(1+\nu)}$$

Ground

$$\frac{\Delta D}{D} = \frac{P}{E} (1 + \nu); \frac{P}{D} = \frac{E}{(1+\nu)(1-2\nu)}$$

Liner

$$\frac{\Delta D}{D} = \frac{PR^3}{6E_l I_l'}; \frac{P}{D} = \frac{6E_l I_l}{R^3 (1-\nu_l^2)}$$

Flexibility ratio

$$F = \frac{2E}{E_l} \left(\frac{R}{t}\right)^3 \frac{(1-\nu_l^2)}{(1+\nu)}$$