L-3/T-1/CE **Date: 30/03/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2021-2022

Sub: **CE 301** (Professional Practices & Communication)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.

1. (a) Name different most commonly used contract format. **(7)**

(b) Name different types of project delivery system, procurement method and contract types for payment. **(16)**

(c) What are project characteristics? **(9)**

(d) Name four (4) different ancient structural system. **(3)**

2. (a) Discuss 'Attributes' of Civil Engineer as a profession. **(15)**

(b) Name the most important aspects of inquiry conducted by surety companies before issuing bonds. **(7)**

(c) What are the eight (8) ways of dealing with contract risk? **(8)**

(d) Define "Civil Engineer" as per ASCE Body of Knowledge. **(5)**

3. (a) During pre-design phase of a project, what are **(20)**

   (i) Common client concerns

   (ii) Condition necessary for success

   (iii) Attributes of an effective brief.

(b) Compare the terminologies that are used for procurement of intellectual service as opposed to that of works and goods. **(15)**

4. Name the different methods of tendering for the procurement of works and goods with a brief description of their applicability, advantages and disadvantages. **(35)**

Contd P/2

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

5. As per ASCE Code of Ethics, answer the following: **(12+12+11=35)**

   (i) What kind of conduct or practice should the Engineer avoid?

   (ii) When will the Engineer engage or advise engaging specialists or experts?

   (iii) What principle should the Engineer uphold for compensating those engaged in engineering work?

6. (a) What are the three main elements of non-verbal communication? List the elements of body language. **(17)**

   (b) List the elements of human communication and describe them briefly. **(18)**

7. (a) List the steps for preparing an effective oral presentation. Also enumerate the steps for effective verbal delivery. **(17)**

   (b) Prepare a flow chart showing the steps for procurement of works. **(18)**

8. (a) A tender data sheet (TDS) is to be prepared for inviting a tender for construction of a 20 storied office building with an estimated cost of Tk. 80 crore and estimated project duration of three years. Prepare the following TDS items: **(5×5=25)**

   (i) required specific experience
   (ii) required general experience
   (iii) required turnover
   (iv) required tender security
   (v) required credit facility/liquid asset

   (b) List the conditions for which tender security of a bidder can be forfeited. **(10)**

L-3/T-1/CE **Date : 06/04/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **CE 311** (Structural Analysis)

Full Marks : 280 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

Assume reasonable values for any missing data.

1. (a) For the repair of the right abutment of a truss bridge, the truss shown in Fig. 1 had to be supported temporarily at joint **b** on a hydraulic jack. The gross reaction at **a** is 60 kip and at **c** is 40 kip. Compute the displacement at **b** caused by the jack to free the support at **c** and lift it (joint **c**) 1 inch above its normal position. Given, each member's cross-sectional area (A) = 4 in^2 and modulus of elasticity (E) = 29000 ksi. **(23$\frac{2}{3}$)**

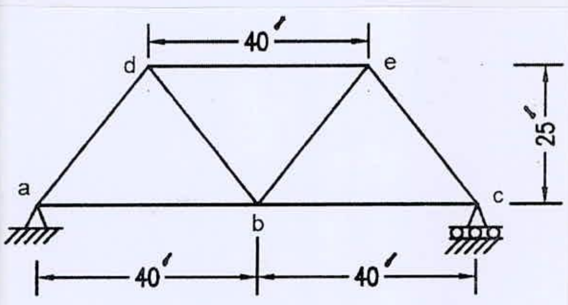

Fig. 1 for Ques 1a

(b) Plot a deflected shape of the loaded beam shown in Fig. 2 with the deflection value determined at point **a** and **c**. Use virtual work method. Consider that deflection of the beam is primarily caused by the bending strain energy. Given that E = 29000 ksi, I = 200 in^4, ϑ = 0.3. **(23)**

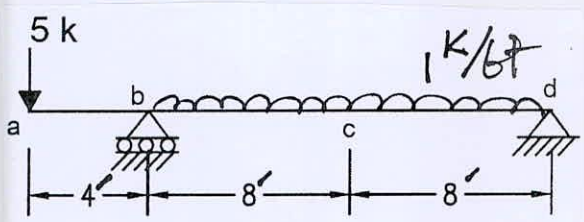

Fig. 2 for Ques 1b

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2. (a) Using the method of virtual work, find rotation at just left of internal hinge (at left of **e**) of the frame shown in Fig. 3. Consider that rotation of each member of the frame is primarily caused by the bending strain energy. Given that E = 29000 ksi, I = 3000 in^4, A = 30 in^2, ϑ = 0.3, and these material properties are same for all members of the frame. **(23)**

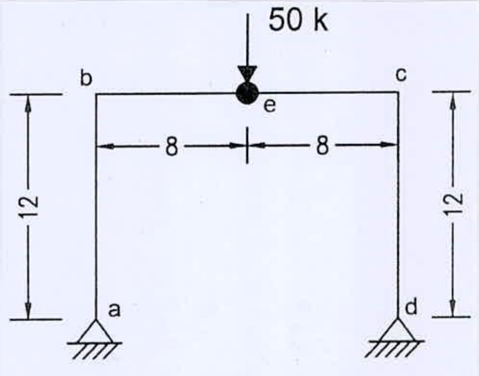

Fig. 3 for Ques 2a

(b) The stiffening truss shown in Fig. 4 is suspended from the parabolic cable in a suspension bridge. Determine the member force **a-c** of the truss (marked in the figure) when the structure is subjected to the loading shown in the figure. **(23⅔)**

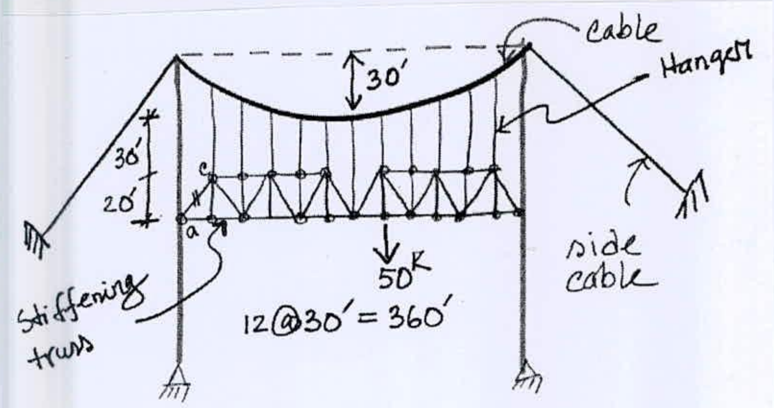

Fig. 4 for Ques 2b

3. (a) A 3 storied RC office building is located at Chittagong (Zone 3). Each story height of the building is 3 m, base to GF height is 1.5 m, site class is SB. Building plan dimension is 20 m × 20 m. Seismic zone coefficient (Z) = 0.28, importance factor (I) = 1.00, damping correction factor (η) = 1.2. Dead load including self-weight is 6 kN/m^2 and live load is 2.4 kN/m^2 for the typical floors and roof live load is 1 kN/m^2. Also given that self-weight of all pedestals is 100 kN. Assume that GF having an RC floor will occupy typical floor loads. Determine appropriate structural system of the building, seismic design category (SDC), earthquake base shear and story force at Level 2. Follow BNBC 2020. Use Tables 1-3. Use following equations for calculating Normalized Acceleration Response Spectrum. **(30⅔)**

$$C_s = S\left(1+\frac{T}{T_B}(2.5\eta-1)\right) \text{ for } 0 \le T \le T_B \qquad C_s = 2.5S\eta \text{ for } T_B \le T \le T_C$$

$$C_s = 2.5S\eta\left(\frac{T_C}{T}\right) \text{ for } T_C \le T \le T_D \qquad C_s = 2.5S\eta\left(\frac{T_C T_D}{T^2}\right) \text{ for } T_D \le T \le 4 \text{ sec}$$

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Contd ... Q. No. 3

(b) A one-storied RC office building has a plan dimension of 40 ft × 40 ft. The openings in the windward, leeward and side walls of the building are shown in Fig. 5. Determine whether the building is an ENCLOSED, PARTIALLY ENCLOSED or OPEN according to BNBC 2020. **(16)**

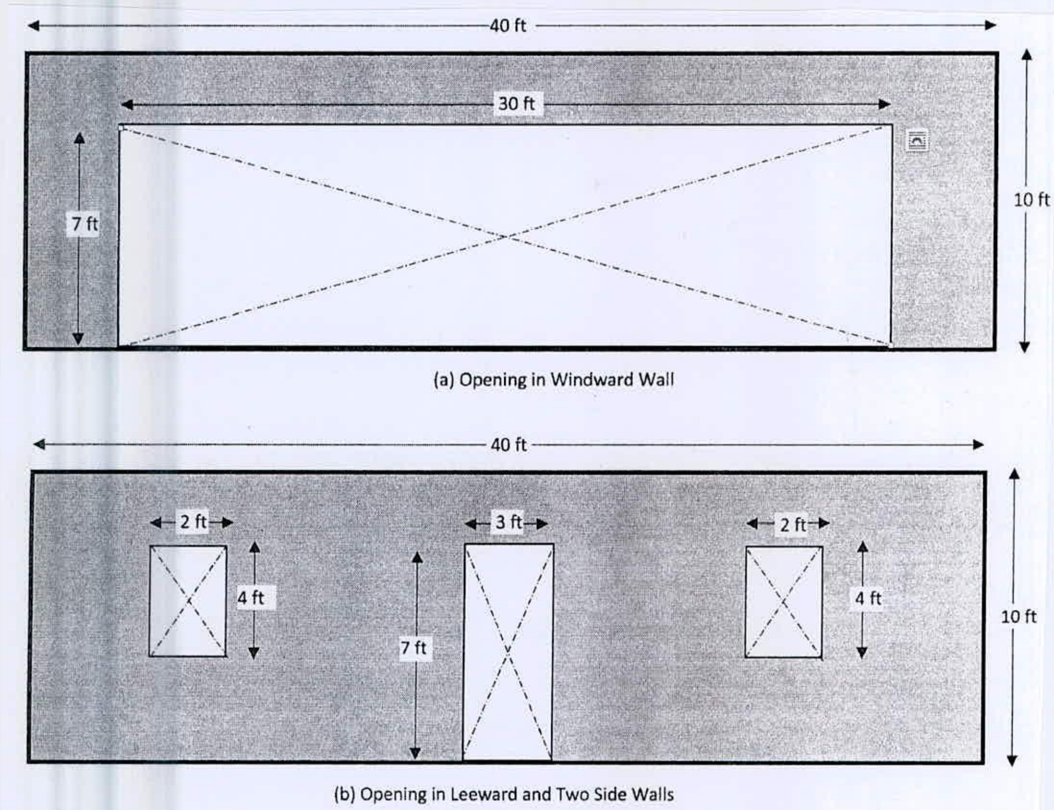

Fig. 5 for Ques 3b

4. (a) A six storied RC residential building shown in Fig. 6 is located on a 2-D escarpment. Find the topographic factor at the top of the building. Given, exposure is C and occupancy category is II. Assume that building's site conditions and locations of the structure meet the first two conditions of wind speed up effect. Use Table 4. Given $K_2 = \left(1 - \dfrac{|x|}{\mu L_h}\right)$; $K_3 = e^{-\gamma z/L_h}$. **($16\frac{2}{3}$)**

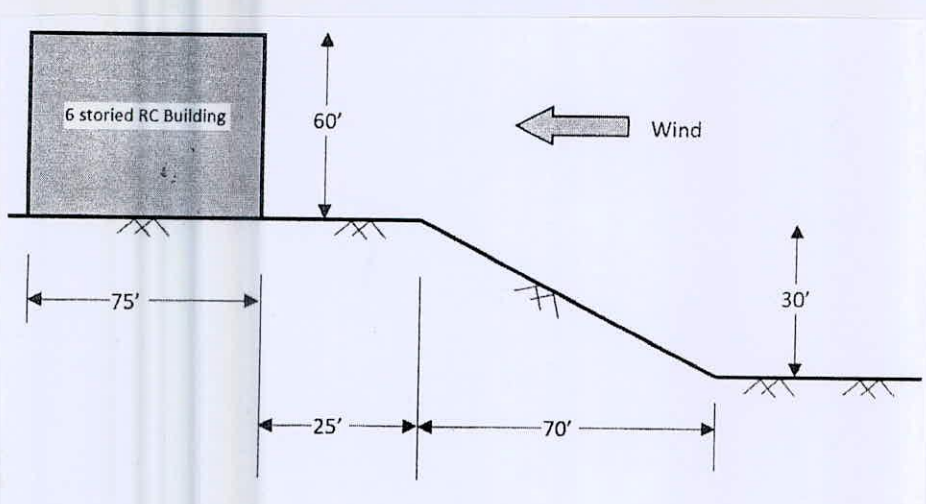

Fig. 6 for Ques 4a

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(b) For the beam with internal hinges at **C** and **D** shown in Fig. 7, draw influence lines for (i) reaction at E, (ii) shear just left of B, (iii) moment at H. **(12)**

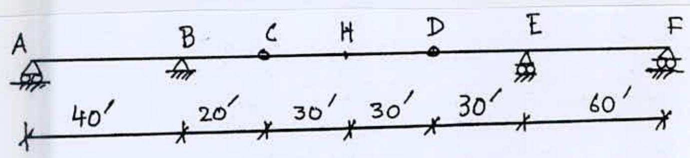

Fig. 7 for Ques 4b

(c) A typical three storied RC residential building is located in a flat open country of Comilla. The building plan dimension is 40 m by 40 m. The overall height of the building is 12 m. Given that the roof is flat, the building classification is enclosed, occupancy category is II. Basic wind speed of Comilla is 61.4 m/s. Determine velocity pressure for each floor of the building using analytical procedure of BNBC 2020. Equations of velocity pressure exposure coefficient are given below. **(18)**

$$K_z = 2.01\left(\frac{z}{z_g}\right)^{2/\alpha} \text{ for } 4.57\ m \le z \le z_g;\ z_g = 274.32\ m$$

$$K_z = 2.01\left(\frac{4.57}{z_g}\right)^{2/\alpha} \text{ for } z < 4.57\ m$$

SECTION – B

There are **Seven** questions in this section. Answer any **FIVE**.

5. Analyze the frame as shown in Fig. 8 and draw shear force and bending moment diagram. Consider internal hinge at C. **(28)**

6. Shear force diagram of columns of a frame for lateral loads P_1 and P_2, is shown in Fig. 9. Evaluate the value of P_1 and P_2 using Portal Method. Furthermore, draw bending moment diagram, and axial force diagram of columns. Also, draw bending moment diagram, shear force diagram and axial force diagram of beams. **(28)**

7. Determine the member force of AC, AD, CD, DE, CE, FD, EG and GF of the indeterminate truss as shown in Fig. 10. Assume the diagonals can support either tensile or compressive forces. **(28)**

Contd P/5

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8. For the truss shown in Fig. 11, draw influence lines for force in member U_3U_4 and L_3U_4. Note that, there are floor beams over the bottom chord member. **(28)**

9. A uniform live load of 2 kip/ft and single concentrated live load of 10 kip are placed on floor beams system as shown in Fig. 12. Draw influence lines for **(28)**

   (i) FBR_a, FBR_b

   (ii) R_a

   (iii) V_{ab}, V_{bc}

   (iv) M_c

   Also, calculate maximum positive shear for V_{bc} and maximum positive moment for M_c.

10. Compute maximum shear at one-third point from left support of a simply supported beam of 72 ft due to the wheel loads shown in Fig. 13. **(28)**

11. Using Cantilever Method, analyze the frame as shown in Fig. 14 and draw (a) axial force diagram of columns, (b) bending moment diagram of columns, (c) bending moment diagram of beams, (d) shear force diagram of beams. **(28)**

    Note: Numbers beside the column indicate their cross sectional area in inch^2.

=6=

Chart 1 for Ques 1 and 2: Integration Chart

Table for Evaluating $\int_0^L m\, m'\, dx$

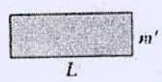
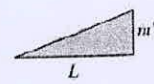
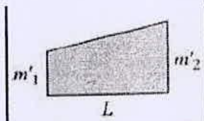
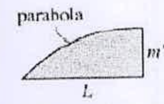
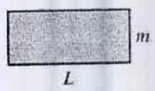
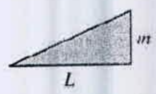
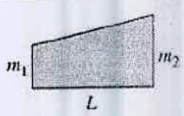
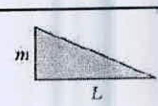
$\int_0^L m m' \, dx$				
	$mm'L$	$\frac{1}{2}mm'L$	$\frac{1}{2}m(m'_1 + m'_2)L$	$\frac{2}{3}mm'L$
	$\frac{1}{2}mm'L$	$\frac{1}{3}mm'L$	$\frac{1}{6}m(m'_1 + 2m'_2)L$	$\frac{5}{12}mm'L$
	$\frac{1}{2}m'(m_1 + m_2)L$	$\frac{1}{6}m'(m_1 + 2m_2)L$	$\frac{1}{6}[m'_1(2m_1 + m_2) + m'_2(m_1 + 2m_2)]L$	$\frac{1}{12}[m'(3m_1 + 5m_2)]L$
	$\frac{1}{2}mm'L$	$\frac{1}{6}mm'(L + a)$	$\frac{1}{6}m[m'_1(L + b) + m'_2(L + a)]$	$\frac{1}{12}mm'\left(3 + \frac{3a}{L} - \frac{a^2}{L^2}\right)L$
	$\frac{1}{2}mm'L$	$\frac{1}{6}mm'L$	$\frac{1}{6}m(2m'_1 + m'_2)L$	$\frac{1}{4}mm'L$

Table 1 for Ques 3a

Seismic Force–Resisting System	Response Reduction Factor, R	System Overstrength Factor, Ω_o	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category D
				Height limit (m)		
4. Special reinforced concrete moment frames	8	3	5.5	NL	NL	NL
5. Intermediate reinforced concrete moment frames	5	3	4.5	NL	NL	NP
5. Ordinary reinforced concrete moment frames	3	3	2.5	NL	NP	NP

Table 2 for Ques 3a

Table 6.2.18: Seismic Design Category of Buildings

Site Class	Occupancy Category I, II and III				Occupancy Category IV			
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
SA	B	C	C	D	C	D	D	D
SB	B	C	D	D	C	D	D	D
SC	B	C	D	D	C	D	D	D
SD	C	D	D	D	D	D	D	D
SE, S_1, S_2	D	D	D	D	D	D	D	D

Table 3 for Ques 3a

Table 6.2.16: Site Dependent Soil Factor and Other Parameters Defining Elastic Response Spectrum

Soil type	S	T_B(s)	T_C(s)	T_D(s)
SA	1.0	0.15	0.40	2.0
SB	1.2	0.15	0.50	2.0
SC	1.15	0.20	0.60	2.0
SD	1.35	0.20	0.80	2.0
SE	1.4	0.15	0.50	2.0

Table 4 for Ques 4a

Topographic factor, K_{zt} - Method 2

Parameters for Speed-Up Over Hills and Escarpments						
Hill Shape	$K_1/(H/L_h)$			γ	μ	
	Exposure A	Exposure B	Exposure C		Upwind of crest	Downwind of Crest
2-dimensional ridges (or valleys with negative H in $K_1/(H/L_h)$)	1.30	1.45	1.55	3	1.5	1.5
2-dimensional escarpments	0.75	0.85	0.95	2.5	1.5	4
3-dimensional axisym. Hill	0.95	1.05	1.15	4	1.5	1.5

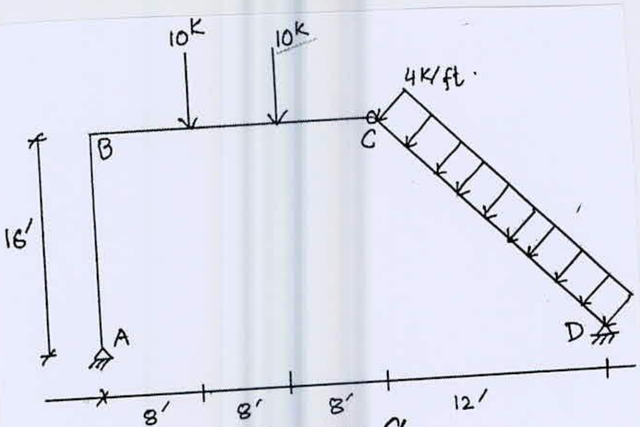


Fig. ~~1~~ 8

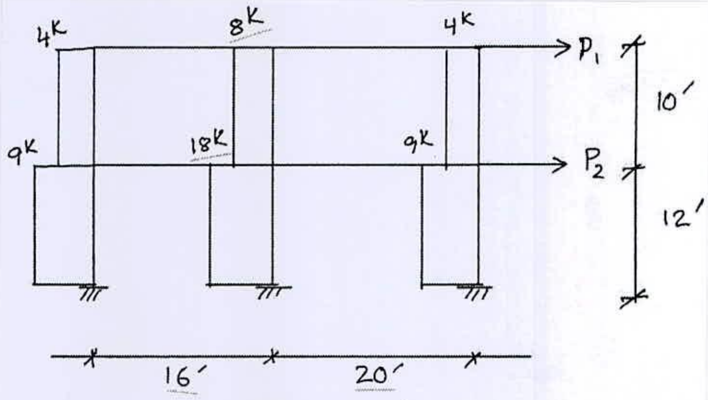


Fig. ~~2~~ 9

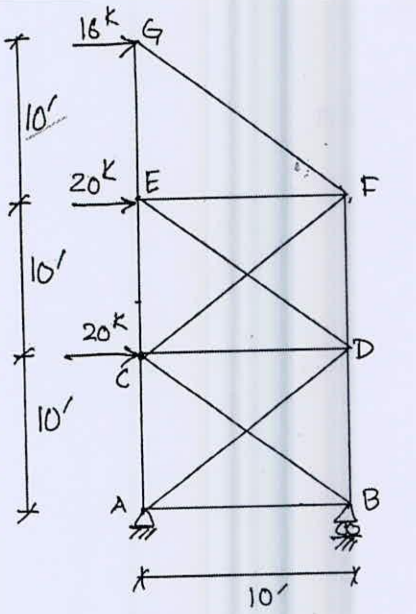


Fig. ~~3~~ 10

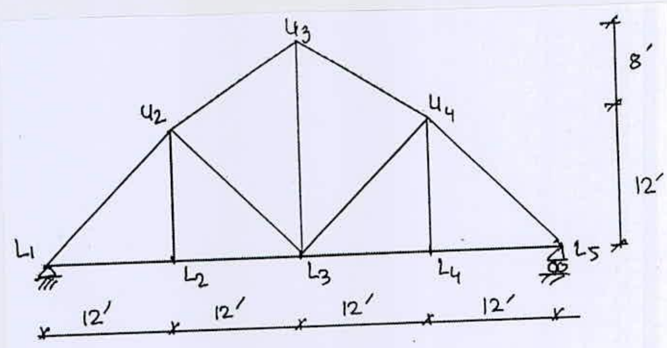


Fig. ~~4~~ 11

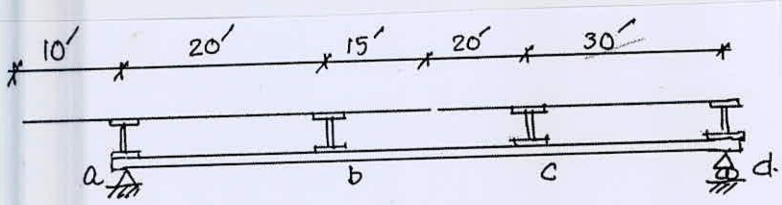


Fig. ~~5~~ 12

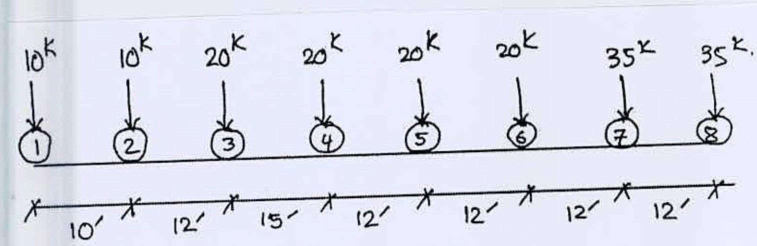


Fig. ~~6~~ 13

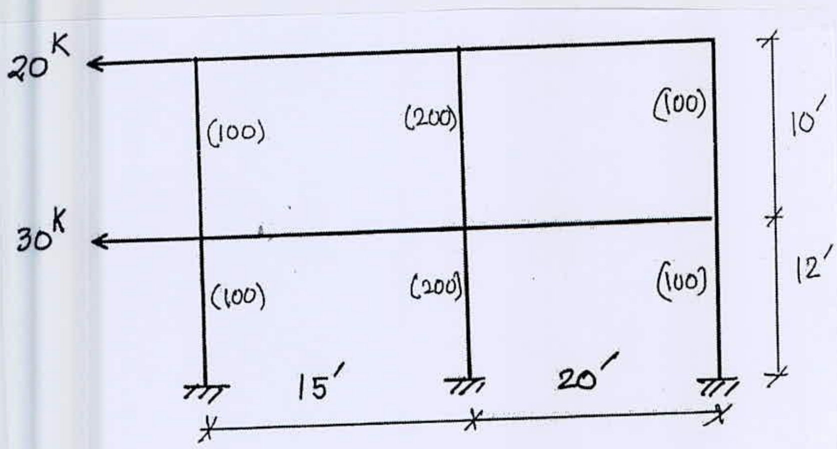


Fig. ~~7~~ 14

L-3/T-1/CE **Date: 07/05/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2021-2022

Sub: **CE 315** (Design of Concrete Structures I)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.
Use USD Method of Design if not mentioned otherwise.
Assume reasonable value for any missing data.

1. (a) A 14 ft clear span one way slab with an overhanging cantilever span of 5 ft on both sides as shown in Fig. 1 is to be designed. The slab supports live load 100 psf in addition to its own weight. Assume partition wall (pw) load 60 psf and Floor Finish (FF) load 30 psf. Design the slab for maximum positive and negative moments considering live load can occupy any position in the slab. Show reinforcement details in neat sketches. Material strengths are: $f_c' = 3.5$ ksi and $f_y = 60$ ksi. **(25)**

   (b) Discuss why and how temperature and shrinkage reinforcement is provided in one-way slab. **(10)**

2. (a) Design a slab of panel 20 ft by 25 ft to support a uniform live load of 80 psf. The panel is a corner panel of a group. Consider partition wall load 60 psf ; floor finish load 40 psf in addition to self-weight of slab. Material strengths are: $f_c' = 3.0$ ksi and $f_y = 60$ ksi. Use ACI moment co-efficients from supplied tables. Show the slab reinforcements with neat sketch. **(23)**

   (b) What are the sources of uncertainties in RC design? Explain. **(6)**

   (c) Explain briefly the class A and class B splices in tension rebars. **(6)**

3. (a) Design the stirrups for the beam shown in Fig. 2. Use $f_c' = 4$ ksi and $f_y = 60$ ksi. Calculate stirrups with 3 sets of spacing. Show the stirrups in a neat sketch. **(20)**

   (b) What are the maximum spacing of stirrups in shear design for the following cases: **(8)**

   i) when $V_S \le 4\sqrt{f_c'}\, b_w d$

   ii) when $V_S > 4\sqrt{f_c'}\, b_w d$

   (c) What do you understand by the term "serviceability" in RC design? **(7)**

4. (a) Design a singly reinforced beam for the loads shown in Fig. 3. All loads are factored. Assume $f_c' = 3500$ psi ; $f_y = 60{,}000$ psi; b = 12" and $\rho = 0.6\, \rho_{max}$. **(20)**

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(b) Discuss briefly the factors that influence development length of a reinforcing bar. **(7)**

(c) Describe with neat sketches five reinforced concrete floor systems commonly used in Bangladesh. **(8)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.
Assume reasonable value for any missing data.
Use USD method if not mentioned otherwise

5. (a) Discuss the behavior of RC rectangular beam in flexure under increasing load by drawing neat sketches for strain and stress distribution of uncracked, cracked and ultimate conditions. **(7)**

(b) A rectangular beam made using concrete with $f'_c = 4.0$ ksi and steel with $f_y = 60$ ksi has a width b = 14 in., an effective depth of d = 17.5 in., and a total depth of h = 20 in. The concrete modulus of rupture $f_r = 474$ psi. The elastic moduli of the concrete and steel are respectively, $E_c = 3600$ ksi and $E_s = 29000$ ksi. The tensile steel consists of four No. 9 bars.

(i) Determine the cracking moment M_{cr}. **(8)**

(ii) Determine steel stresses and strains just before the cracking. **(4)**

(iii) Find the maximum service load moment that can be resisted without stressing the concrete above $0.45 f'_c$ or the steel above $0.4 f_y$. **(8)**

(iv) What is the maximum moment that can be carried by this beam before failure? Find steel strain at this moment. **(8)**

6. (a) Explain the differences between USD and WSD methods of design with particular emphasis on how safety is ensured in both the design methods. **(7)**

(b) Derive equation for finding ρ_{max} and discuss how a minimum tensile strain (ε_t = 0.004) at failure is ensured by not exceeding maximum reinforcement ratio. Also discuss the variation of φ with ε_t as given in ACI/BNBC code. **(8)**

(c) A beam section is limited to width b = 14 in. and total depth h = 28 in. Calculate the required reinforcement if the beam has to resist a factored moment M_u = 700 kip-ft. Assume two layer tensile reinforcement with d = 24 in. and d_t = 25.5 in. Also, assume d′ = 2.5 in. if compression steel is required. Given: $f'_c = 4.0$ ksi and $f_y = 60$ ksi. **(20)**

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CE 315

7. (a) A floor system consists of a 6 in. slab supported by continuous beams with 30 ft span and centre to centre spacings of 12 ft. 6 in. as shown in Figure 4. Slab and beam are monolithically cast. Beam web width b_w = 12 in and effective depth = 24 in. At mid span of the beam, there are 3#9 bars at the bottom. What is the nominal and design positive moment capacity of the beam at mid span? Check ε_t. **(17)**

Given: $f'_c = 4.0$ ksi, $f_y = 60$ ksi.

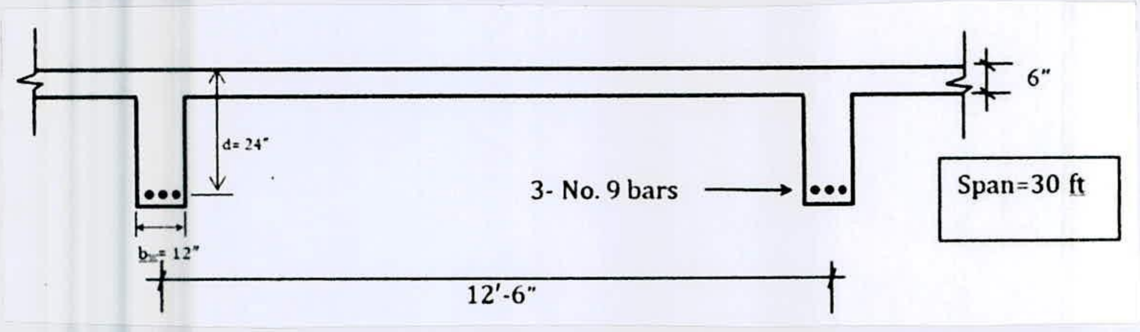

Figure 4: Section at mid span

(b) For the same floor system, as in Question 7(a), at the support there are 6#7 bars in two rows at the top as shown in Figure 5. Assume d = 24.0", d_t = 25.5" as shown in detail in Figure 6. What is the nominal and design negative moment capacity of the beam at the support? Check ε_t. **(18)**

Given: $f'_c = 4.0$ ksi, $f_y = 60$ ksi.

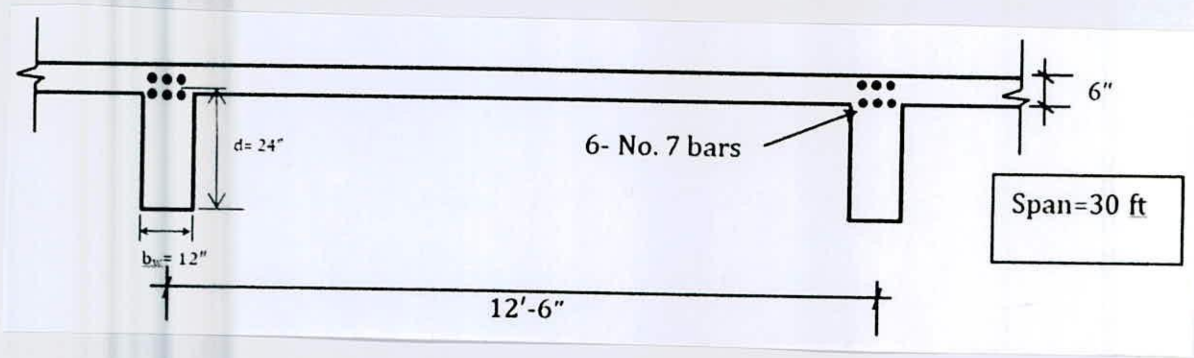

Figure 5: Section at support

CE 315

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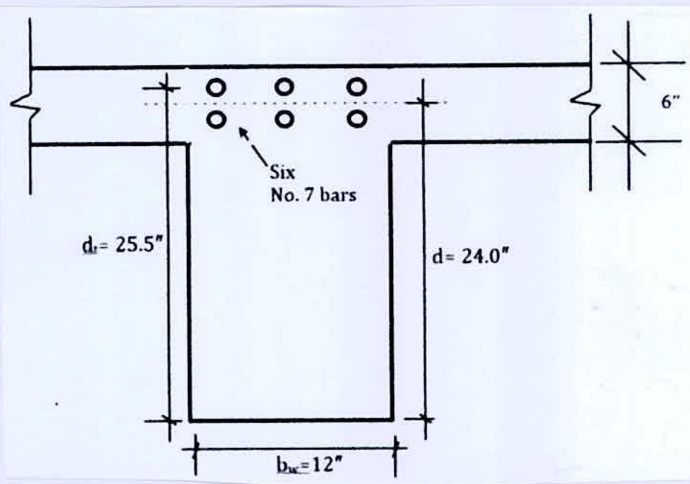


Figure 6: Beam Section at support in detail

8. (a) A rectangular RC beam as shown in Figure 7 measures 14 in. wide and has an effective depth of 23 in. Tension steel consists of eight No. 8 bars in two layers (d = 23 in., d_t = 24.5 in.) and compression steel consists of four No. 8 bars is located 2.5 in. from the compression face. What is the design moment capacity of the beam according to ACI/ BNBC code? **(18)**

Given: $f_c' = 5.0$ ksi, $f_y = 60$ ksi.

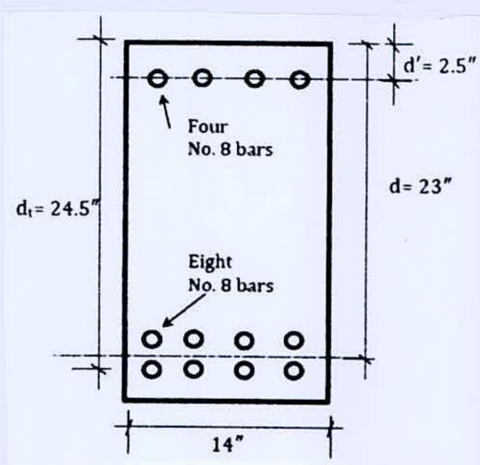


Figure 7

(b) A rectangular beam carries a service live load (unfactored) of 2.0 kip/ft and an unfactored superimposed dead load of 1.5 kip/ft (in addition to self-weight of beam) on a 25 ft simple span. The beam will have a cross-section of 14" × 28" for architectural reason. Design the beam for flexure **(17)**

Given: $f_c' = 4.0$ ksi, $f_y = 60$ ksi.

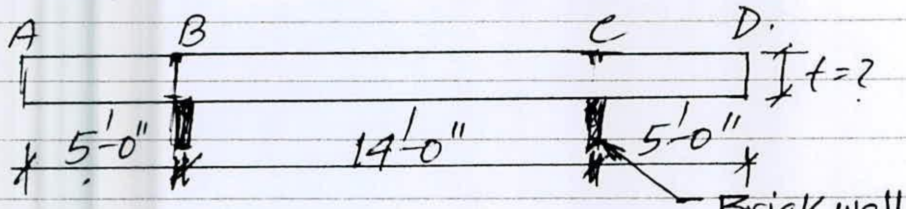


Fig. 1

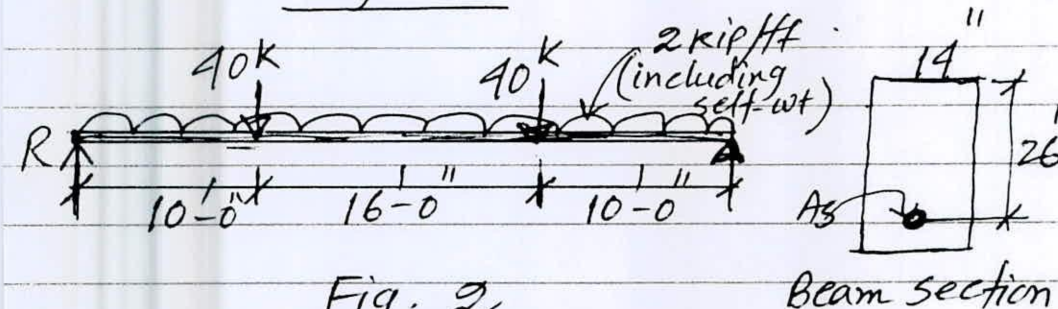
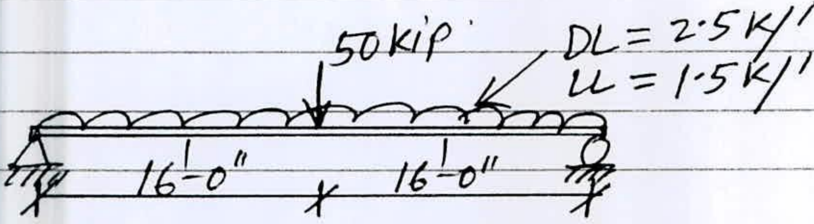


Fig. 2

ALL LOADS ARE FACTORED.



All Loads are factored.
Dead load includes self wt of beam.

Fig. 3

Table 1: Co-efficients for **Negative Moments** in Slabs

$M_{a,(negative)} = C_{a,(negative)} w L_a^2$; $M_{b,(negative)} = C_{b,(negative)} w L_b^2$; where w = total uniform dead plus live load

Ratio $\frac{L_a}{L_b}$	Co-efficient	Case **1**	Case **2**	Case **3**	Case **4**	Case **5**	Case **6**	Case **7**	Case **8**	Case **9**
1.00	$C_{a,(negative)}$	---	0.045	---	0.05	0.075	0.071	---	0.033	0.061
	$C_{b,(negative)}$	---	0.045	0.076	0.05	---	---	0.071	0.061	0.033
0.95	$C_{a,(negative)}$	---	0.05	---	0.055	0.079	0.075	---	0.038	0.065
	$C_{b,(negative)}$	---	0.041	0.072	0.045	---	---	0.067	0.056	0.029
0.90	$C_{a,(negative)}$	---	0.055	---	0.06	0.08	0.079	---	0.043	0.068
	$C_{b,(negative)}$	---	0.037	0.07	0.04	---	---	0.062	0.053	0.025
0.85	$C_{a,(negative)}$	---	0.06	---	0.066	0.082	0.083	---	0.049	0.072
	$C_{b,(negative)}$	---	0.031	0.065	0.034	---	---	0.057	0.046	0.021
0.80	$C_{a,(negative)}$	---	0.065	---	0.071	0.083	0.086	---	0.055	0.075
	$C_{b,(negative)}$	---	0.027	0.061	0.029	---	---	0.051	0.041	0.017
0.75	$C_{a,(negative)}$	---	0.069	---	0.076	0.085	0.088	---	0.061	0.078
	$C_{b,(negative)}$	---	0.022	0.056	0.024	---	---	0.044	0.036	0.014
0.70	$C_{a,(negative)}$	---	0.074	---	0.081	0.086	0.091	---	0.068	0.081
	$C_{b,(negative)}$	---	0.017	0.05	0.019			0.038	0.029	0.011
0.65	$C_{a,(negative)}$	---	0.077	---	0.085	0.087	0.093	---	0.074	0.083
	$C_{b,(negative)}$	---	0.014	0.043	0.015	---	---	0.031	0.024	0.008
0.60	$C_{a,(negative)}$	---	0.081	---	0.089	0.088	0.095	---	0.08	0.085
	$C_{b,(negative)}$	---	0.01	0.035	0.011	---	---	0.024	0.018	0.006
0.55	$C_{a,(negative)}$	---	0.084	---	0.092	0.089	0.096	---	0.085	0.086
	$C_{b,(negative)}$	---	0.007	0.028	0.008	---	---	0.019	0.014	0.005
0.50	$C_{a,(negative)}$	---	0.086	---	0.094	0.09	0.097	---	0.089	0.088
	$C_{b,(negative)}$	---	0.006	0.022	0.006	---	---	0.014	0.01	0.003

*A crosshatched edge indicates that the slab continues across or is fixed at the support; an unmarked edge indicates a support at which torsional resistance is negligible.

Table 2: Co-efficients for **Dead Load Positive Moments** in Slabs

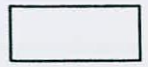
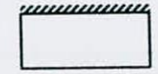
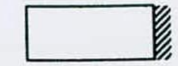
$M_{a,(positive),DL} = C_{a,(positive)} w_{DL} L_a^2$; $M_{b,(positive),DL} = C_{b,(positive)} w_{DL} L_b^2$; where w_{DL} = total uniform dead load

Ratio $\frac{L_a}{L_b}$	Co-efficient	Case **1**	Case **2**	Case **3**	Case **4**	Case **5**	Case **6**	Case **7**	Case **8**	Case **9**
1.00	$C_{a,(positive)}$	0.036	0.018	0.018	0.027	0.027	0.033	0.027	0.02	0.023
	$C_{b,(positive)}$	0.036	0.018	0.027	0.027	0.018	0.027	0.033	0.023	0.02
0.95	$C_{a,(positive)}$	0.040	0.02	0.021	0.03	0.028	0.036	0.031	0.022	0.024
	$C_{b,(positive)}$	0.033	0.016	0.025	0.024	0.015	0.024	0.031	0.021	0.017
0.90	$C_{a,(positive)}$	0.045	0.022	0.025	0.033	0.029	0.039	0.035	0.025	0.026
	$C_{b,(positive)}$	0.029	0.014	0.024	0.022	0.013	0.021	0.028	0.019	0.015
0.85	$C_{a,(positive)}$	0.050	0.024	0.029	0.036	0.031	0.042	0.04	0.029	0.028
	$C_{b,(positive)}$	0.026	0.012	0.022	0.019	0.011	0.017	0.025	0.017	0.013
0.80	$C_{a,(positive)}$	0.056	0.026	0.034	0.039	0.032	0.045	0.045	0.032	0.029
	$C_{b,(positive)}$	0.023	0.011	0.02	0.016	0.009	0.015	0.022	0.015	0.01
0.75	$C_{a,(positive)}$	0.061	0.028	0.04	0.043	0.033	0.048	0.051	0.036	0.031
	$C_{b,(positive)}$	0.019	0.009	0.018	0.013	0.007	0.012	0.02	0.013	0.007
0.70	$C_{a,(positive)}$	0.068	0.03	0.046	0.046	0.035	0.051	0.058	0.04	0.033
	$C_{b,(positive)}$	0.016	0.007	0.016	0.011	0.005	0.009	0.017	0.011	0.006
0.65	$C_{a,(positive)}$	0.074	0.032	0.054	0.05	0.036	0.054	0.065	0.044	0.034
	$C_{b,(positive)}$	0.013	0.006	0.014	0.009	0.004	0.007	0.014	0.009	0.005
0.60	$C_{a,(positive)}$	0.081	0.034	0.062	0.053	0.037	0.056	0.073	0.048	0.036
	$C_{b,(positive)}$	0.010	0.004	0.011	0.007	0.003	0.006	0.012	0.007	0.004
0.55	$C_{a,(positive)}$	0.088	0.035	0.071	0.056	0.038	0.058	0.081	0.052	0.037
	$C_{b,(positive)}$	0.008	0.003	0.009	0.005	0.002	0.004	0.009	0.005	0.003
0.50	$C_{a,(positive)}$	0.095	0.037	0.08	0.059	0.039	0.061	0.089	0.056	0.038
	$C_{b,(positive)}$	0.006	0.002	0.007	0.004	0.001	0.003	0.007	0.004	0.002

*A crosshatched edge indicates that the slab continues across or is fixed at the support; an unmarked edge indicates a support at which torsional resistance is negligible.

Table 3: Co-efficients for **Live Load Positive Moments** in Slabs

$M_{a,(positive),LL} = C_{a,(positive)} w_{LL} L_a^2$; $M_{b,(positive),LL} = C_{b,(positive)} w_{LL} L_b^2$; where w_{LL} = total uniform live load

Ratio $\frac{L_a}{L_b}$	Co-efficient	Case **1** 	Case **2** 	Case **3** 	Case **4** 	Case **5** 	Case **6** 	Case **7** 	Case **8** 	Case **9** 
1.00	$C_{a,(positive)}$	0.036	0.027	0.027	0.032	0.032	0.035	0.032	0.028	0.03
	$C_{b,(positive)}$	0.036	0.027	0.032	0.032	0.027	0.032	0.035	0.03	0.028
0.95	$C_{a,(positive)}$	0.040	0.03	0.031	0.035	0.034	0.038	0.036	0.031	0.032
	$C_{b,(positive)}$	0.033	0.025	0.029	0.029	0.024	0.029	0.032	0.027	0.025
0.90	$C_{a,(positive)}$	0.045	0.034	0.035	0.039	0.037	0.042	0.04	0.035	0.036
	$C_{b,(positive)}$	0.029	0.022	0.027	0.026	0.021	0.025	0.029	0.024	0.022
0.85	$C_{a,(positive)}$	0.050	0.037	0.04	0.043	0.041	0.046	0.045	0.04	0.039
	$C_{b,(positive)}$	0.026	0.019	0.024	0.023	0.019	0.022	0.026	0.022	0.02
0.80	$C_{a,(positive)}$	0.056	0.041	0.045	0.048	0.044	0.051	0.051	0.044	0.042
	$C_{b,(positive)}$	0.023	0.017	0.022	0.02	0.016	0.019	0.023	0.019	0.017
0.75	$C_{a,(positive)}$	0.061	0.045	0.051	0.052	0.047	0.055	0.056	0.049	0.046
	$C_{b,(positive)}$	0.019	0.014	0.019	0.016	0.013	0.016	0.02	0.016	0.013
0.70	$C_{a,(positive)}$	0.068	0.049	0.057	0.057	0.051	0.06	0.063	0.054	0.05
	$C_{b,(positive)}$	0.016	0.012	0.016	0.014	0.011	0.013	0.017	0.014	0.011
0.65	$C_{a,(positive)}$	0.074	0.053	0.064	0.062	0.055	0.064	0.07	0.059	0.054
	$C_{b,(positive)}$	0.013	0.01	0.014	0.011	0.009	0.01	0.014	0.011	0.009
0.60	$C_{a,(positive)}$	0.081	0.058	0.071	0.067	0.059	0.068	0.077	0.065	0.059
	$C_{b,(positive)}$	0.010	0.007	0.011	0.009	0.007	0.008	0.011	0.009	0.007
0.55	$C_{a,(positive)}$	0.088	0.062	0.08	0.072	0.063	0.073	0.085	0.07	0.063
	$C_{b,(positive)}$	0.008	0.006	0.009	0.007	0.005	0.006	0.009	0.007	0.006
0.50	$C_{a,(positive)}$	0.095	0.066	0.088	0.077	0.067	0.078	0.092	0.076	0.067
	$C_{b,(positive)}$	0.006	0.004	0.007	0.005	0.004	0.005	0.007	0.005	0.004

*A crosshatched edge indicates that the slab continues across or is fixed at the support; an unmarked edge indicates a support at which torsional resistance is negligible.

L-3/T-1/CE **Date: 13/04/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2021-2022

Sub: **CE 331** (Environmental Engineering I)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.

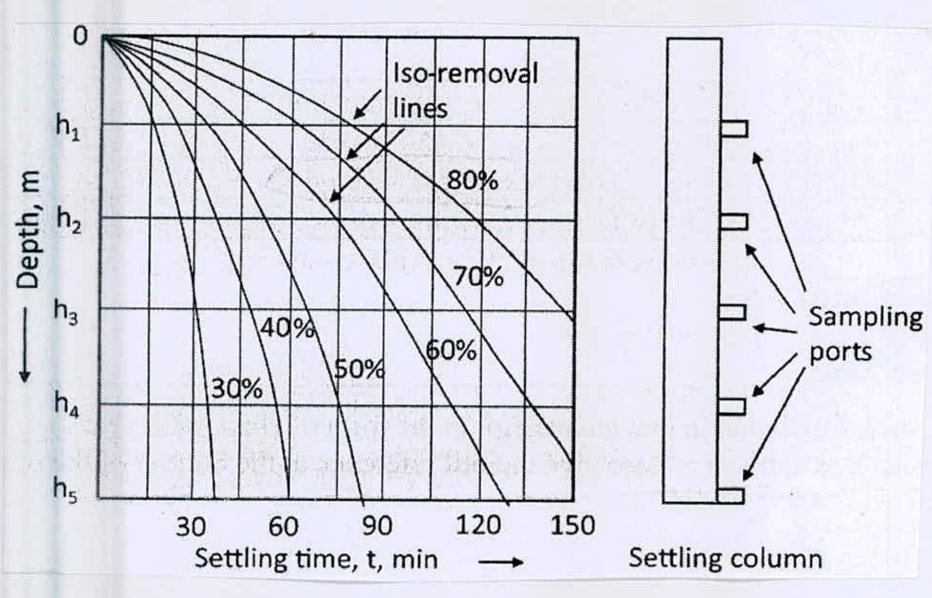
1. (a) "Bangladesh has achieved a wide coverage in the water supply sector but there still remains a wide gap" – Explain this statement with examples. **(7)**

(b) State the problems associated with water supply and potential options to mitigate those for the following areas: (i) coastal region, (ii) haor region, (iii) arsenic problem areas **(10)**

(c) How are 'Priming' and 'Cavitation' avoided in a centrifugal submersible pump? Explain. A submersible pump is installed in an underground reservoir located at 15 ft below the ground level to deliver 750,000 litres of water per day to an elevated water tank which is 80 ft high from the ground level. The height of underground reservoir and elevated water tank are 8 ft and 15 ft respectively. If the pumping duration is 9 hours per day, velocity of water is 12 ft/sec and the horizontal length of the pipe is 200 ft, then determine the water power and input power produced by the pump if the friction factor is .01 and pump efficiency is 70% (neglect minor losses). **(18)**

2. (a) Briefly describe the 7 steps of developing a water safety plan. Illustrate the water treatment flow diagrams of surfacewater and groundwater and show the differences. **(21)**

(b) A settling column analysis of a flocculating suspension is being performed. The initial suspended solids concentration is 250 mg/L and column depth is 3m. The resulting removal fractions with iso-removal lines are shown in the figure below. The sampling ports are located at 0.5m intervals. What will be overall efficiency of suspended solids removal of a settling basin having 3m depth with a detention time of 60 and 105 minutes? **(14)**



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3. (a) Describe straining and non-straining mechanisms in filtration. Describe the theory and criteria of Mn and As removal. **(15)**

   (b) Write short notes (with illustrations, if needed) on **(20)**

   (i) Surface overflow rate

   (ii) Reduction of surface potential by double-layer compression

   (iii) Split Treatment

   (iv) Ion Exchange for demineralization

4. (a) What amount of Lime and/or soda ash is required to soften the water with the following composition (a) for selective calcium removal (b) upto practical solubility limits. Draw the bar diagrams of finished water in both cases. **(13)**

Compound	Concentration, mg/L as $CaCO_3$
CO_2	4.6
Ca^{2+}	257.9
Mg^{2+}	22.2
HCO_3^-	248.0
SO_4^{2-}	32.1

   (b) Describe the effect of coagulant dosage with colloid concentration with diagrams. How would you apply alum dose for water having (i) low turbidity, high alkalinity (ii) low turbidity, low alkalinity? **(14)**

   (c) What are the characteristics of an ideal disinfectant? **(8)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Name the factors to be considered in percapita water consumption. State the ways in which these factors influence water consumption. **(20)**

   (b) State the methods of population prediction. Which method do you consider best for population estimation in Uttara 3rd phase (Newly built area)? Explain. **(15)**

6. (a) Discuss briefly the essential elements for designing a water supply system. **(15)**

   (b) Deduce a mathematical expression for the yield of a well in an unconfined aquifer. Determine the flow of 300 mm diameter well having a depth of 100 m below the level of water table, drawdown is 20 m when the well is pumped. The coefficient of permeability is 40.5 m^3/m^2/day and radius of circle of influence is 1000 m. **(20)**

Contd P/3

CE 331

7. (a) Write short notes on **(12)**

(i) Hydrologic cycle, (ii) Cone of depression and (iii) Water Hammer.

(b) Describe the various layouts of water distribution system. **(16)**

(c) Differentiate between Dry intake and wet intake with sketches. **(7)**

8. (a) What are the roles of an Environmental Engineer in the context of present situation of the world? Explain. **(8)**

(b) Describe the energy situation of Bangladesh. Show the relationship between Energy use and water consumption with examples. **(12)**

(c) A 7-storied residential building has a roof area of 2340 m^2. The annual rainfall is recorded in that area is 2918 mm. The owner of that building is planning to adopt rainwater harvesting system. The historical rainfall distribution is as below: **(15)**

Month	Jan	Feb	March	Apr.	May	June	July	Aug	Sept	Oct	Nov.	Dec.
Rainfall mm	5.6	24.4	54.7	147.4	298.6	607.3	727	530	259.3	184.4	67.5	11.9

What rainwater storage tank size would you recommend for the building? (Assume any reasonable data required).

L-3/T-1/CE **Date: 02/05/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2021-2022

Sub: **CE 341** (Principles of Soil Mechanics)

Full Marks: 280 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.
Assume appropriate values of missing data, if necessary.

1. (a) Using phase diagram of soil establish an expression of γ_d in terms of S, w, G_s and γ_w. The symbles have their usual meanings. **(12)**

(b) After construction of a building, it underwent a settlement of 40 mm in 100 days due to consolidation of a 4 m thick underlying clay layer. If the total consolidation settlement of the clay layer is 200 mm, find the time for 100 mm consolidation settlement. Assume two way drainage of the clay layer. Time factor T_v for various degree of consolidation are given in the following Table. **(14)**

Values of T_v for different U%

U%	T_v	U%	T_v
10	0.008	60	0.287
20	0.031	70	0.403
30	0.071	80	0.567
40	0.126	90	0.848
50	0.197	100	∞

(c) A foundation (Fig. 1) is loaded with a uniform pressure of 150 kPa. Determine the vertical stress at a point P at a depth of 5 m from the foundation base. Use Newmarks's influence chart (attached). **(15)**

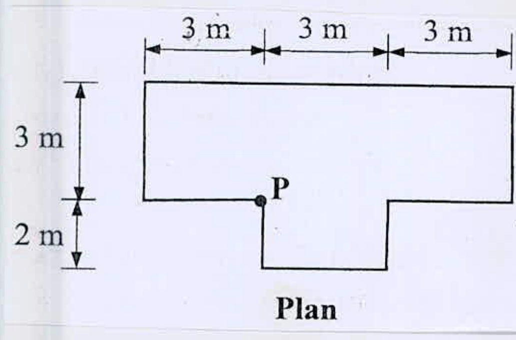


Fig.1 for Q.No.1(c) and Q.No.2(c)

Contd P/2

CE 341
Contd... Q. No. 1

(d) State the types of rollers that you will suggest to compact different soil types. **(5 $\frac{2}{3}$)**

2. (a) Describe the effect of sampling disturbance on e-log(p) curve obtained from laboratory test. Also state the procedure for establishment of field e - log(p) curve for NC clay of low to mediun plasticity. **(4+10=14)**

(b) For construction of a building foundation at a site, excavation is to be made to a depth of 9 m. The subsoil at the site consist of 12 m thick clay layer (saturated unit weight 18.5 kN/m^3) extending from the ground surface and is underlain by a sand layer. Water table is at the ground surface. It is considered that, as excavation continues, water level will be always kept to the bottom of excavation by pumping. Carry out the relevant analysis and comment whether excavation will be possible without lowering the water table surrounding the excavation. **(20)**

(c) Consider the foundations as shown in Fig. 1. If it transmits a uniform pressure of 200 kPa at its base, determine the stress at point **P** at a depth of 5 m using Fadum's chart for Newmark's influence coefficient (attached). **(12$\frac{2}{3}$)**

3. (a) The subsoil condition at a site is shown in the Fig. 2. The water table is at the ground surface. The entire site (large area) is raised by 5 m fill of soil with average unit weight of 20 kN/m^3. Estimate the consolidation settlement due to the landfill. **(20)**

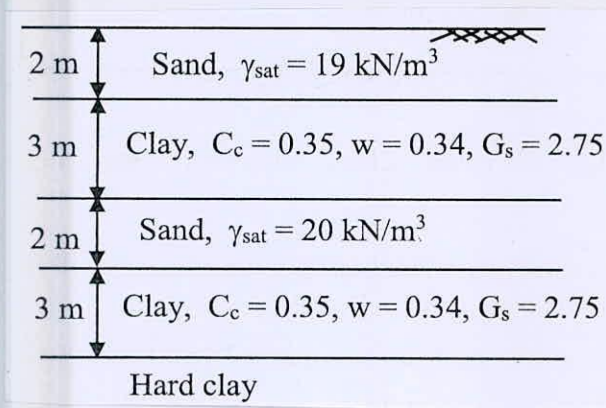


Fig.2 for Q. No. 3(a)

(b) Write short notes on: **(16)**

(i) Secondary consolidation settlement

(ii) Critical hydraulic gradient

(iii) Zero air void curve

(iv) Field compaction control

(c) A compacted fill of volume 20,000 m^3 is to be constructed at a dry density of 18.6 kN/m^3 using the soil from a nearby borrow area. The soil in the borrow area has a void ratio of 0.95 and specific graity of 2.70. Determine the total amount to be paid to the owner of the borrow area at the rate of Tk. 500 per cum. **(10$\frac{2}{3}$)**

Contd P/3

4. (a) Two column footings, each 1.2 m × 1.2 m in plan, are spaced 5.0 m apart center to center. Each footing transmits 300 kN of load to a sand stratum at 1.5 m below the ground surface (Fig. 3). The sand stratum is 6.0 m thick below which exists a 8.0 m thick compressible clay layer which is underlain by a stiff impervious stratum. Water Table is 3 m below the ground surface. Considering the column loads as point loads acting at the center of the footings, determine the stress increase at the mid height of the clay layer and vertically below the center of any one of the footings. **(15)**

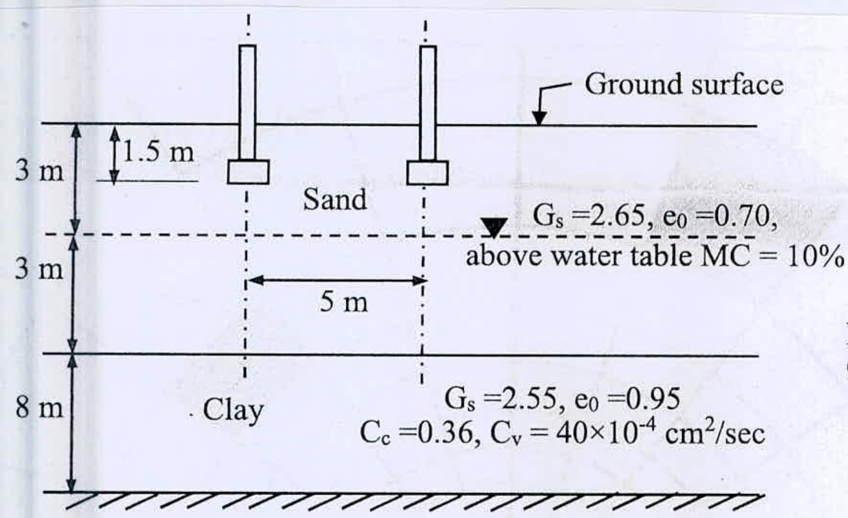


Fig. 3 for Q.No.4(a)

Boussinesque equation for point load is given by $\sigma_z = \dfrac{3Q}{2\pi z^2}\dfrac{1}{[1+(r/z)^2]^{5/2}}$

(b) State the method of determining field density of soils using Sand Cone Method. **($11\frac{2}{3}$)**

(c) Fig. 4 shows the section of a dam. For the underlying soil $k_x = 5 \times 10^{-5}$ mm/s and $k_z = 5 \times 10^{-5}$ mm/s. Draw a flow net and calculate the rate of seepage below the dam. The dam is 25 m long. **(20)**

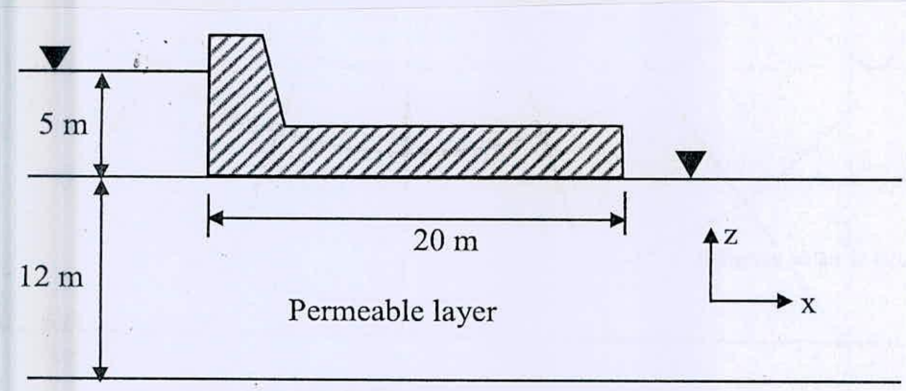


Fig.4 for Q.No. 4(c)

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

Assume reasonable value of missing data, if any. Use attached Charts where necessary

5. (a) Define shrinkage limit. Derive an expression for shrinkage limit of soil having known specific gravity of soil solids (G_s). **($8\frac{2}{3}$)**

(b) A cone penetration test was performed on a silty clay sample and the following results were obtained: **(17)**

Trial No.	1	2	3	4
Cone Penetration (mm)	16	18	22	25
Weight of Wet Soil (gm)	193.8	190.7	186.5	181.3
Weight of Oven-dry Soil (gm)	145.6	136.0	121.2	111.4

Determine the liquid limit of the soil and also check the result for a single point method using a relevant data.

(c) Classify different types of soils based on particle size according to ASTM D422. **(7)**

(d) A specimen of saturated normally consolidated clay sample was fully consolidated in the triaxial cell under a cell pressure of 200 kN/m^2. Pore pressure within the specimen at the end of consolidation was zero. Deviator stress was then applied under undrained condition and increased until failure took place. The values of deviator stress and pore pressure at failure were found to be 115 kN/m^2 and 125 kN/m^2, respectively. A second specimen of the same sample was fully consolidated in the triaxial cell under a cell pressure of 400 kN/m^2. Pore pressure within this specimen at the end of consolidation was zero. Deviator stress was then applied under undrained condition and increased until failure took place. Determine the following analytically. **(14)**

(i) Values of ϕ' and ϕ_u of the sample.

(ii) Values of pore pressure at failure (u_f) and the pore pressure parameters A at failure (A_f) of the second specimen.

6. (a) Define various types of soil structure for coarse and fine-grained soil with neat sketches. Mention the differences between flocculated and dispersed structure. **(9+4=13)**

(b) For an inorganic soil, the following grain-size analysis was obtained. **($13\frac{2}{3}$)**

Sieve No.	Percent Passing
4	100
10	90
20	64
40	38
80	18
200	13

Contd P/5

CE 341
Contd... Q. No. 6(b)

For this soil, Liquid Limit (LL) = 23 and Plastic Limit (PL) = 19. Classify the soil according to the following:

(i) AASHTO Soil Classification System (Use Table 1)

(ii) Unified Soil Classification System (Use Table 2 and Chart 1).

Give the group name and group symbol of each classification.

(c) Describe the importance of earth retaining structures and name four commonly encountered earth retaining structures. Briefly discuss about the fundamental differences between Rankine's and Coulomb's earth pressure theories. **(6+6=12)**

(d) What are the advantages of triaxial test over direct shear test? Also show with neat sketches two examples of unconsolidated undrained (UU) analyses in clays. **(4+4=8)**

7. (a) The following results were obtained in a consolidated drained (CD) direct shear test carried out on a clay sample: **($15\frac{2}{3}$)**

Specimen No.	Normal Load (kg)	Peak Shear Force (N)
1	16	80.5
2	32	159.6
3	64	309.3

Diameter and height of each specimen were 63.5 mm and 25 mm, respectively. Draw the failure envelope in a plain graph paper and determine the values of effective shear strength parameters (c' and ϕ') from it. Also comment on the stress history of the sample.

(b) With a neat sketch show the variation of the magnitude of lateral earth pressure with tilt of wall. Mention the principal factors that influence the field value of K_0. **(5+5=10)**

(c) The following results were obtained at failure in consolidated undrained (CU) triaxial compression tests performed on two specimens of a compacted clay sample: **(14)**

Specimen No.	Cell Pressure (kN/m^2)	Deviator Stress (kN/m^2)	Pore Pressure (kN/m^2)
1	70	230	-20
2	350	550	90

Draw Mohr Circles in terms of effective stresses in a plain graph paper. Draw the Mohr-Coulomb failure envelope and hence determine the values of effective shear strength parameters (c' and ϕ') from it. Also write down the Mohr-Coulomb failure equation for the effective stress failure envelope. **(14)**

Contd P/6

CE 341
Contd... Q. No. 7

(d) A vane, 100 mm height and 50 mm diameter was pressed into a clay deposit at the bottom of a borehole and the bottom of the vane is flush with the surface of the clay. Torque was applied and its value at failure was found to be 15 N-m. Assuming uniform mobilization of end shear, calculate the in-situ undrained shear strength of the clay. If the values of liquid limit and plastic limit of the clay are 56 and 20, respectively, what will be the design value of undrained shear strength of the clay? **(7)**

8. (a) A clay sample (liquid limit = 58%, plastic limit = 27% and natural moisture content = 45%) was collected from a depth of 10 m below the existing ground level. Water table is at the existing ground level and saturated unit weight of the sample is 20 kN/m^3. From a laboratory one-dimensional consolidation test, the preconsolidation pressure of the sample was found to be 510 kN/m^2. Estimate the value of undrained shear strength of the sample at that depth. **(10)**

(b) Draw the following qualitative curves: **(12)**

(i) Pore pressure versus axial strain for saturated samples of normally consolidated, lightly overconsolidated and heavily overconsolidated clays in consolidated (with back pressure) undrained triaxial compression tests.

(ii) Volumetric strain versus shear displacement for saturated samples of loose sand and dense sand in consolidated drained direct shear tests.

(iii) Skempton's pore pressure coefficient B versus degree of saturation.

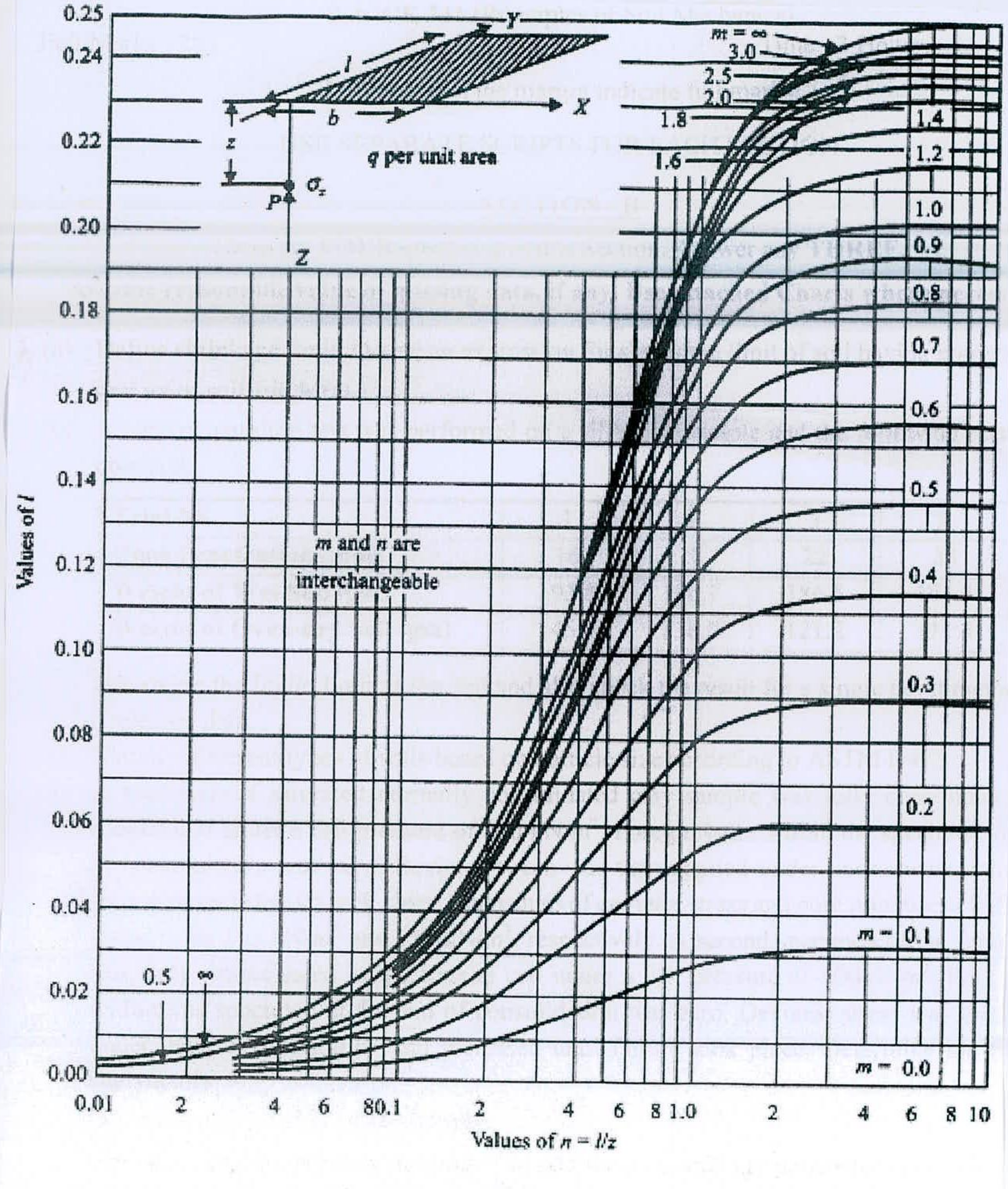
(c) A 5-m high retaining wall with a vertical back face retains a homogeneous saturated soft clay. A surcharge pressure of 11 kN/m^2 is applied on top of the backfill. The saturated unit weight of the clay is 21 kN/m^3. The undrained shear strength of the soft clay soil is 17 kN/m^2. **($24\frac{2}{3}$)**

(i) Draw the variation of Rankine's active pressure on the wall with depth.

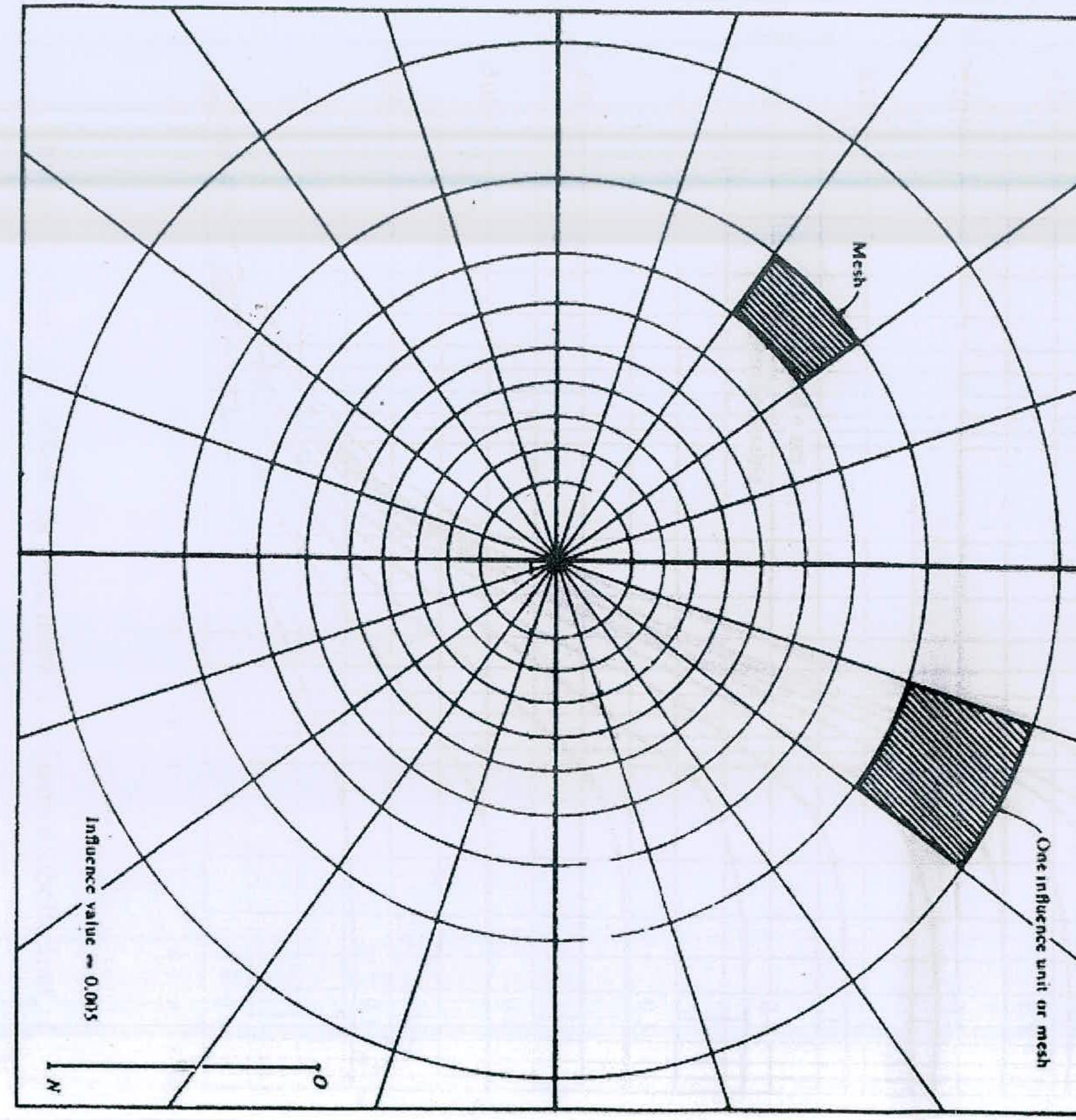
(ii) Find the depth up to which tensile crack can occur.

(iii) Determine the total active force per unit length of the wall and the location of the resultant before the tensile crack occurs.

(iv) Determine the total active force per unit length of the wall and the location of the resultant after the tensile crack occurs.



Fadum's chart for obtaining Newmark's influence coefficient, I



Newmark's influence chart

=7=

=8=

Table 1

General classification	Granular materials (35% or less of total sample passing No. 200)						
	A-1			A-2			
Group classification	**A-1-a**	**A-1-b**	**A-3**	**A-2-4**	**A-2-5**	**A-2-6**	**A-2-7**
Sieve analysis (percentage passing)							
No. 10	50 max.						
No. 40	30 max.	50 max.	51 min.				
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.
Characteristics of fraction passing No. 40							
Liquid limit				40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		NP	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Stone fragments, gravel, and sand		Fine sand	Silty or clayey gravel and sand			
General subgrade rating	Excellent to good						

General classification	Silt-clay materials (more than 35% of total sample passing No. 200)			
Group classification	**A-4**	**A-5**	**A-6**	**A-7** **A-7-5**[a] **A-7-6**[b]
Sieve analysis (percentage passing)				
No. 10				
No. 40				
No. 200	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40				
Liquid limit	40 max.	41 min.	40 max.	41 min.
Plasticity index	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Silty soils		Clayey soils	
General subgrade rating	Fair to poor			

[a]For A-7-5, $PI \le LL - 30$

[b]For A-7-6, $PI > LL - 30$

Table 2

Criteria for assigning group symbols				Group symbol
Coarse-grained soils More than 50% of retained on No. 200 sieve	**Gravels** More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[a]	$C_u \ge 4$ and $1 \le C_c \le 3$[c]	GW
			$C_u < 4$ and/or $C_c < 1$ or $C_c > 3$[c]	GP
		Gravels with Fines More than 12% fines[a,d]	$PI < 4$ or plots below "A" line (Figure 5.3)	GM
			$PI > 7$ and plots on or above "A" line (Figure 5.3)	GC
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[b]	$C_u \ge 6$ and $1 \le C_c \le 3$[c]	SW
			$C_u < 6$ and/or $C_c < 1$ or $C_c > 3$[c]	SP
		Sands with Fines More than 12% fines[b,d]	$PI < 4$ or plots below "A" line (Figure 5.3)	SM
			$PI > 7$ and plots on or above "A" line (Figure 5.3)	SC
Fine-grained soils 50% or more passes No. 200 sieve	**Silts and clays** Liquid limit less than 50	Inorganic	$PI > 7$ and plots on or above "A" line (Figure 5.3)[e]	CL
			$PI < 4$ or plots below "A" line (Figure 5.3)[e]	ML
		Organic	$\frac{\text{Liquid limit—oven dried}}{\text{Liquid limit—not dried}} < 0.75$; see Figure 5.3; OL zone	OL
	Silts and clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line (Figure 5.3)	CH
			PI plots below "A" line (Figure 5.3)	MH
		Organic	$\frac{\text{Liquid limit—oven dried}}{\text{Liquid limit—not dried}} < 0.75$; see Figure 5.3; OH zone	OH
Highly organic soils	Primarily organic matter, dark in color, and organic odor			Pt

[a]Gravels with 5 to 12% fine require dual symbols: GW-GM, GW-GC, GP-GM, GP-GC.

[b]Sands with 5 to 12% fines require dual symbols: SW-SM, SW-SC, SP-SM, SP-SC.

[c]$C_u = \dfrac{D_{60}}{D_{10}}$; $C_c = \dfrac{(D_{30})^2}{D_{60} \times D_{10}}$

[d]If $4 \le PI \le 7$ and plots in the hatched area in Figure 5.3, use dual symbol GC-GM or SC-SM.

[e]If $4 \le PI \le 7$ and plots in the hatched area in Figure 5.3, use dual symbol CL-ML.

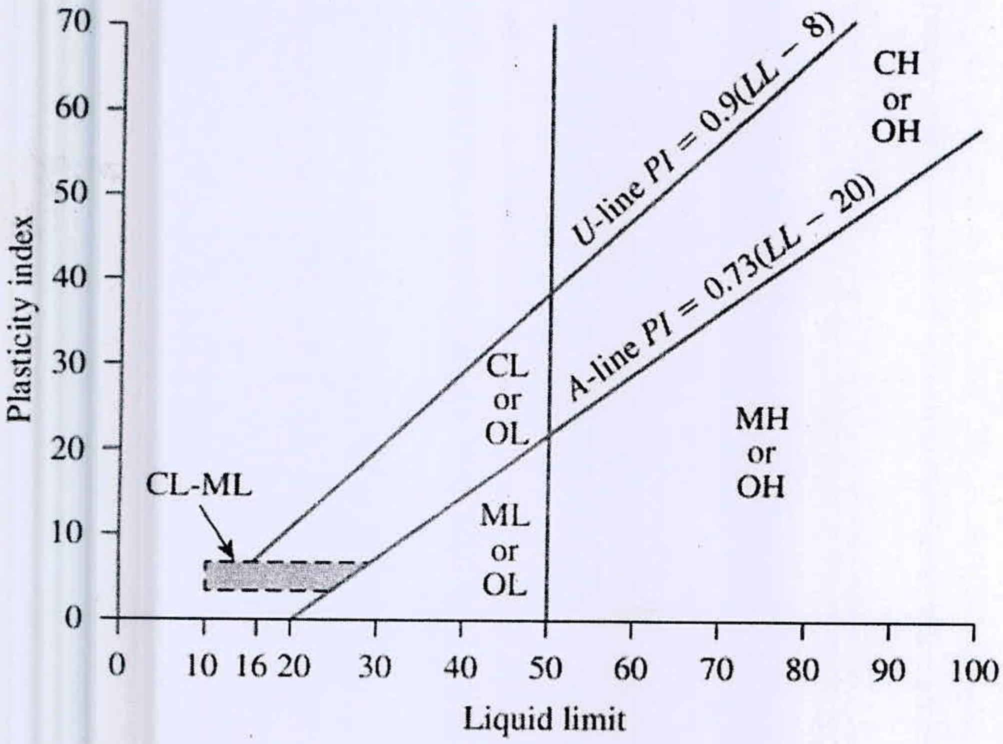


Chart 1

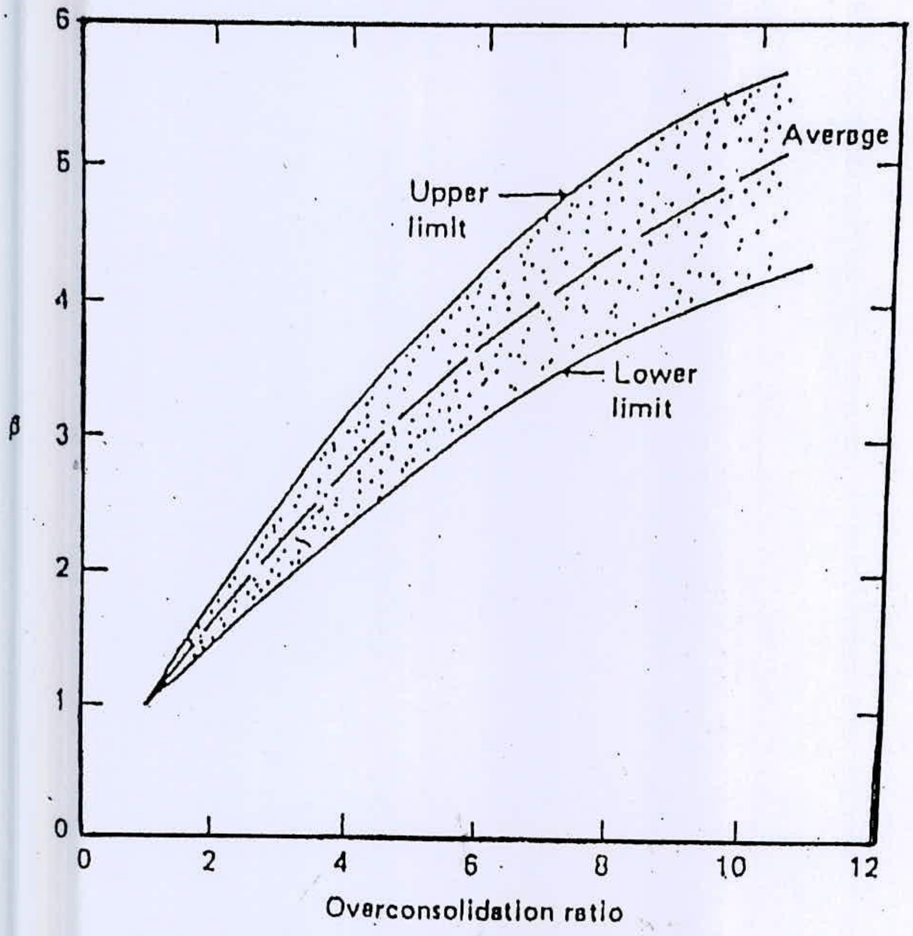


Chart 2 Plot of β versus Overconsolidation Ratio