L-3/T-2/CE **Date: 06/05/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2020-2021

Sub: **CE 317** (Design of Concrete Structures II)

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.

Use USD Method of Design and ACI 318/BNBC 2020 Codes.

1. (a) Design a square tied column of a flyover pier with about 2% reinforcement to support working unfactored loads: P_{DL} = 1700 kip and P_{LL} = 900 kip. Also, design the ties required. Given: $f'_c = 6.0$ ksi and f_y = 72.5 ksi. **(10)**

(b) A 14 × 26 inch column is reinforced with Eight No. 10 bars as shown in Fig. 1. Construct the nominal strength interaction diagram for the column by calculating five points corresponding to **(25)**

(i) pure axial load,

(ii) pure bending,

(iii) balanced condition $\varepsilon_s = \varepsilon_y$,

(iv) $\varepsilon_s = 0$ and

(v) $\varepsilon_s = 0.006$ (tensile).

Given: $f'_c = 4$ ksi and f_y = 60 ksi, $E_s = 29\times10^3$ ksi.

Also find corresponding ϕ for the above points. Assume bending about Y-Y axis.

2. (a) A ground floor column of a multistoried building is to be designed for the following three load combinations (axial force and uniaxial bending)- **(15)**

Gravity load condition	P_u = 700 kip, M_u = 80 kip-ft
Lateral load combination 1	P_u = 546 kip, M_u = 341 kip-ft
Lateral load combination 2	P_u = 455 kip, M_u = 322 kip-ft

Architectural considerations require that a rectangular column with b = 14 in. and h = 25 in. is to be used. Material strengths are $f'_c = 4$ ksi and f_y = 60 ksi.

Find the required column reinforcement (longitudinal and tie) and show in sketch. Use supplied design chart (A.7) assuming reinforcement distributed along the perimeter.

(b) A shear wall of a 16-storey building is subjected to following factored loads at the base: **(15)**

P_u = 600 kip

V_u = 500 kip

M_u = 4000 kip-ft

Contd P/2

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Contd.... for Q. No. 2(b)

The wall is 15 ft long, 160 ft high and 14 inch thick. Design the shear wall at the base with $f'_c = 4$ ksi and $f_y = 60$ ksi. Ignore axial force as it is less than balanced load of the section.

Note: Design moment capacity of wall section with uniformly distributed reinforcement is

$$\varphi M_n = \varphi\left[0.5\, A_{st} f_y l_w \left(1 - \frac{z}{l_w}\right)\right]$$

Where,

$$\frac{z}{l_w} = \frac{1}{2 + \dfrac{0.85\, \beta_1 l_w h f'_c}{A_{st} f_y}}$$

(c) Discuss possible failure modes of high-rise shear walls. **(5)**

3. (a) A 25 × 25 inch column is to be designed with reinforcement arranged around the column perimeter. Material strengths are $f'_c = 4.0$ ksi and $f_y = 60$ ksi. Design the short column using Load Contour method for the load combination: **(21)**

$$P_u = 500 \text{ kip},\ M_{ux} = 400 \text{ kip-ft},\ M_{uy} = 350 \text{ kip-ft}$$

Use supplied design chart (A.7). Start the trial with 2% reinforcement and adjust as required. Show longitudinal and tie (not seismic) reinforcements in sketch.

(b) Design tie for the above column considering seismic provisions of an IMRF system. Clear height of the column is 10 ft. Show arrangements in cross and long-sections. **(8)**

(c) What is a slender column? As per ACI/BNBC code, slenderness effects can be neglected if slenderness ratio of a column is below certain limits, write these limits for columns of sway and non-sway frames. **(6)**

4. (a) A flat plate floor has thickness h = 8″ and is supported by 18″ × 18″ columns spaced 20 ft on centers each way. The floor will carry a DL = 180 psf including self-weight and a live load of 100 psf. Check the adequacy of the slab in resisting punching shear. If inadequate, design the punching shear reinforcement using bent bar arrangement. Consider, d = 6.5″; f'_c = 3,500 psi and f_y = 60000 psi. **(16)**

(b) A prestressed concrete rectangular beam 20 inch by 28 inch has a simple span of 30 ft and is loaded by a uniform load of 3 k/ft including its own weight as shown in Fig. 2. The prestress tendon produces an effective prestress of 350 k. Compute the extreme fiber stresses in the concrete at the midspan section. Use **second concept** for calculation. **(14)**

(c) Explain the Seismic design philosophy under different levels of earthquakes. **(5)**

Contd P/3

SECTION – B

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

Assume reasonable values for any missing data.

5. (a) An interior column (30″×30″) supports a dead load, DL = 500 kip and a live load, LL = 400 kip. The allowable bearing pressure, q_a = 5 kip/ft^2 at the level of the bottom of the footing, which is 4 ft below the grade. Design a footing for this column using $f_c' = 4{,}000$ psi and f_y = 60000 psi. Also, check the provision for development length. **(17)**

(b) An exterior and an interior column are to be supported by a combined rectangular footing whose outer end cannot protrude beyond the outer facing of the exterior column. Column sizes and their respective loads are shown in Fig. 3. The bottom of the footing is 6.0 *ft* below the grade where net allowable bearing pressure after deducing soil load, self wt. of the footing and other surcharges is 4000 *psf*. Determine size of the footing. If d = 18 inch, check the adequacy against punching. Also, design the transverse beam. **(18)**

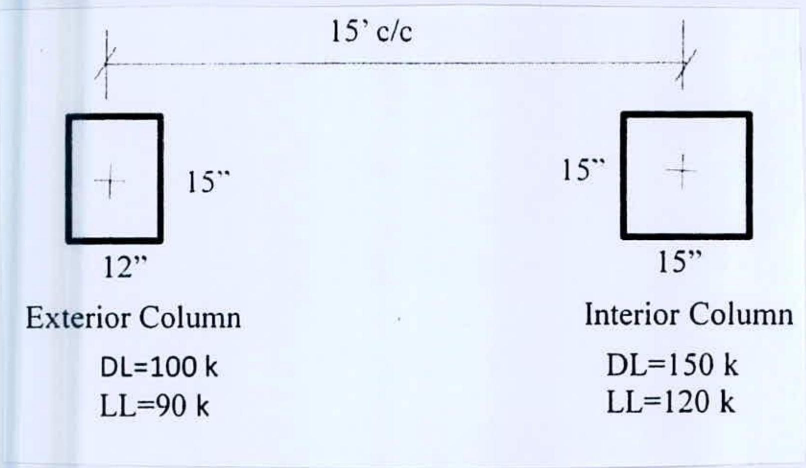


Fig. 3

6. (a) A residential building is to be designed using flat plate floor system. The interior columns are 24″×24″ and they are spaced 22 ft c/c in one direction and 24 ft c/c in other direction. Design the interior panel (22′×24′) and show reinforcement in long direction only with neat sketches. Assume slab thickness of 8″. Specified live load = 40 psf; Floor finish and partition wall load = 60 psf in addition to the self weight of floor slab. $f_c' = 3{,}500$ psi and f_y = 60000 psi. **(25)**

(b) What are the limitations of Direct Design Method for the analysis of two way slab? **(10)**

Contd P/4

7. (a) Describe briefly the different states (including sub stages) of loadings that should be considered for design and/or analysis of prestressed concrete members. **(10)**

(b) Write down the sources of loss of prestress. **(5)**

(c) Make a preliminary design for section of prestressed concrete beam to resist a total moment M_T = 330 kip-ft and girder moment M_G = 44 kip-ft. Total depth of the section is given as 38 inch. The effective prestress for steel, f_{sc} = 124000 psi and allowable compressive stress for concrete under working load f_c = 1750 psi. **(20)**

8. (a) A posttensioned simple beam as shown in Fig. 4 has an initial prestress of 138000 *psi*, reducing to 118000 *psi* after deducting all losses and assuming no bending of the beam. The parabolic cable has an area of 2.5 sq in., n = 6. The beam carries superimposed dead load of 800 *plf* in addition to its own weight of 375 *plf*. Compute the stresses in the steel at midspan, assuming: **(18)**

   (i) the steel is bonded by grouting
   (ii) the steel is unbonded and free to slip.

(b) For the beam shown in Fig. 4 compute the total dead and live uniform load that can be carried by the beam, **(17)**

   (i) For zero tensile stress at bottom fiber
   (ii) For cracking at the bottom fiber at a modulus of rupture of 600 *psi*.

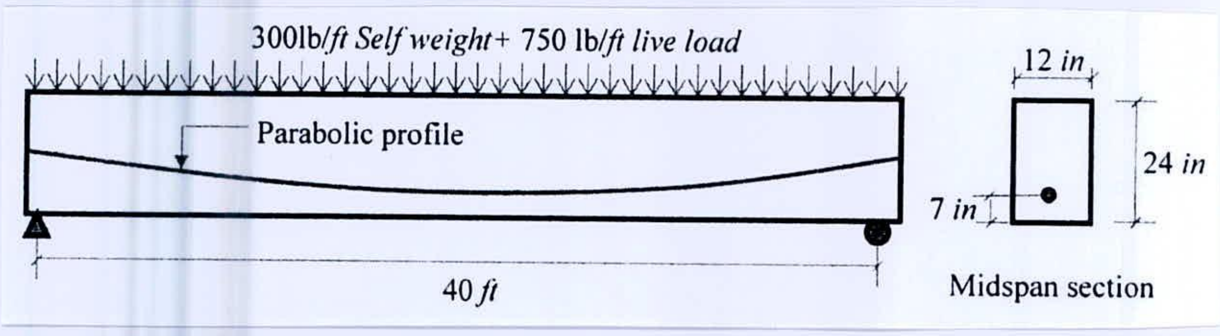
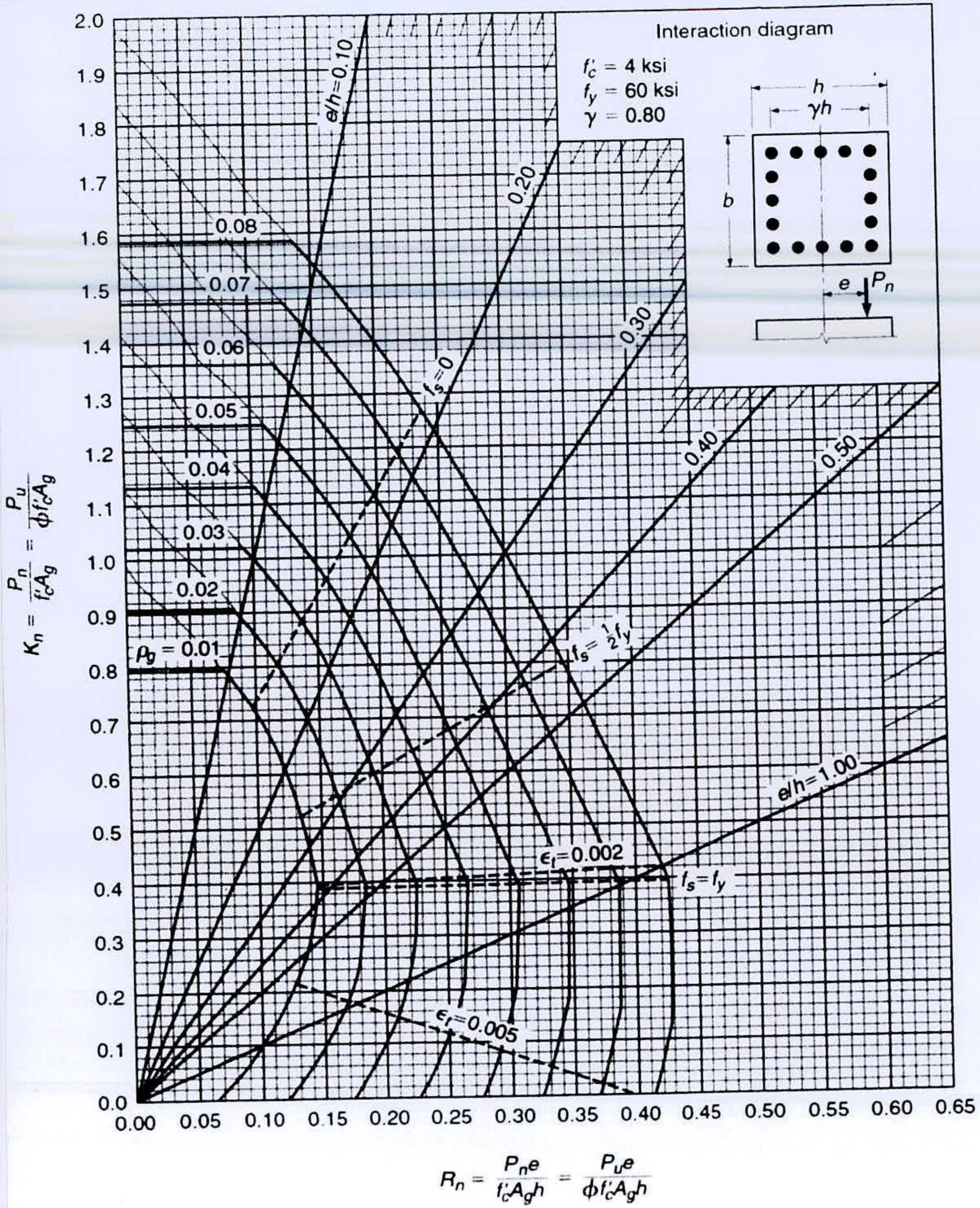


Fig. 4



GRAPH A.7
Column strength interaction diagram for rectangular section with bars on four faces and $\gamma = 0.80$.

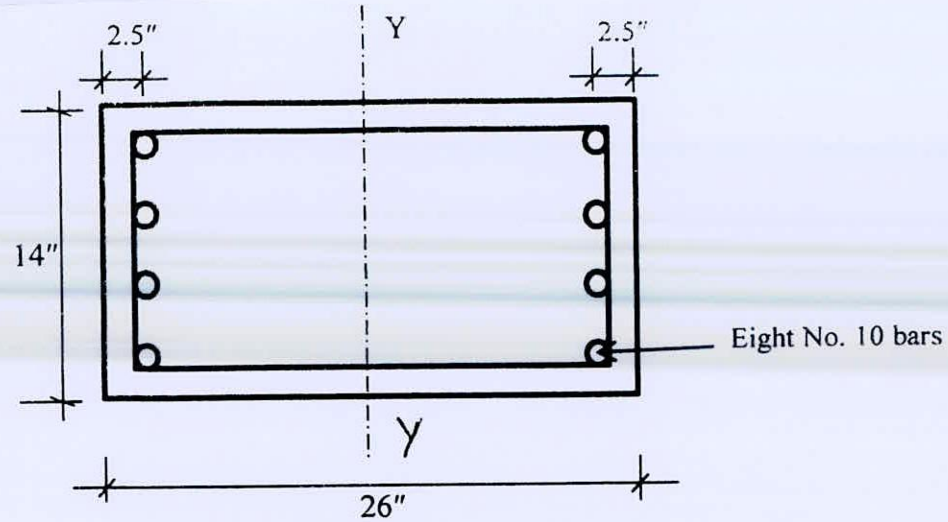


Fig. 1

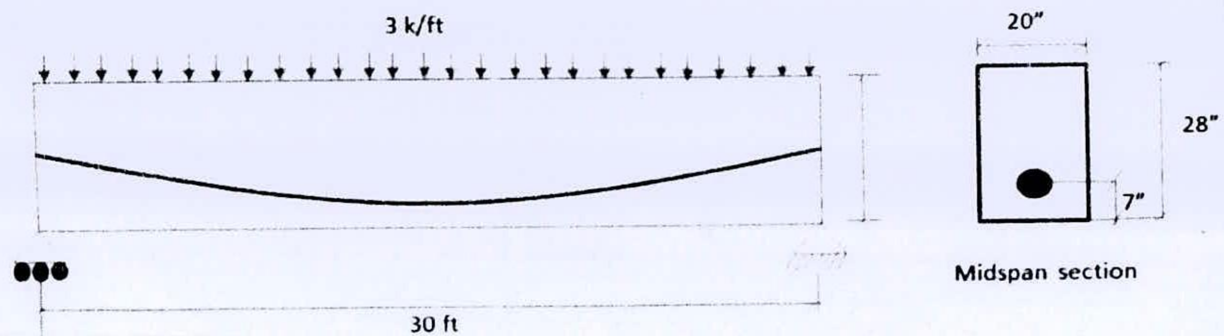


Fig. 2

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L-3/T-2/CE **Date: 12/04/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2020-2021

Sub: **CE 319** (Design of Steel Structures)

Full Marks: 210 Time: 3 Hours

USE SEPARATE

SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

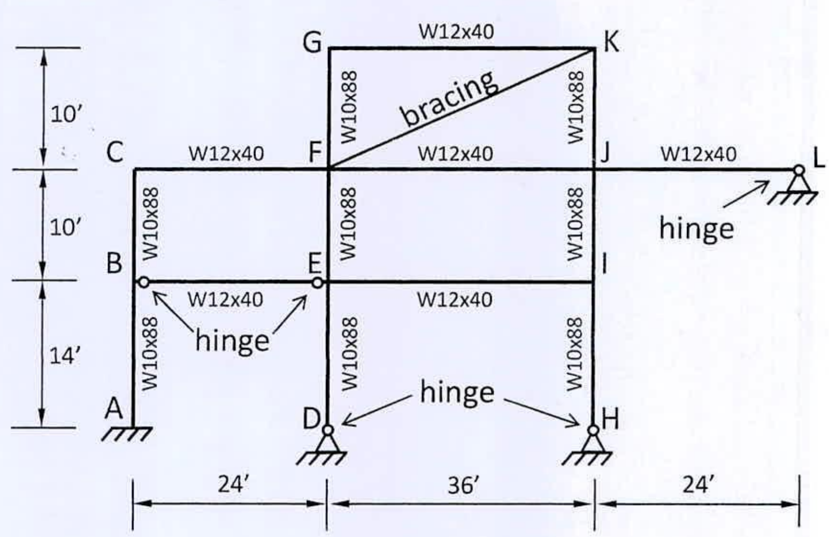
There are **FOUR** questions in this section. Answer any **THREE** questions.

1. (a) Briefly discuss, with the help of graphs/illustrations, the effect of temperature on properties of mild steel such as yield strength, tensile strength, modulus of elasticity and fracture toughness. **(10)**

(b) A W21 × 93 beam (A572 Gr. 50, F_y = 50 ksi, F_u = 65 ksi) has to transfer 85 k-ft dead load and 150 k-ft live load moment on to a W21 × 201 (A572 Gr. 50) column on its strong axis through an extended end plate type connection. Chose a suitable end-plate connection with four or six bolts type and determine the bolt diameter and thickness of end plate (A572 Gr. 50) considering thick end-plate behavior. Use ASTM A325 bolts (F_y = 90 ksi, F_u = 120 ksi). Show the end plate and bolt location details with dimensions on a neat sketch. **(25)**

2. (a) Determine the effective length factor K for the columns AB, DE, FG, HI and IJ as shown in plane frame of Fig. 1 below. Assume that all frame members are loaded in their strong axis bending. **(17)**

Fig. 1



(b) For the bolted bracket shown in Fig. 2, determine the maximum bolt shear force. **(18)**

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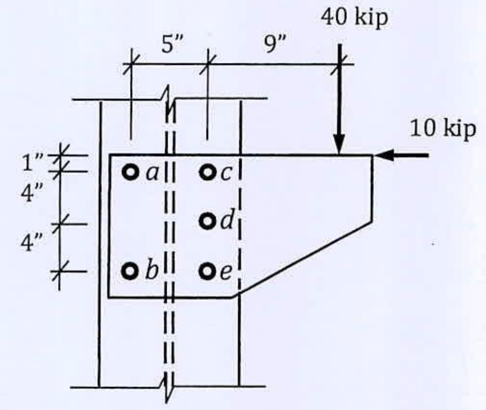
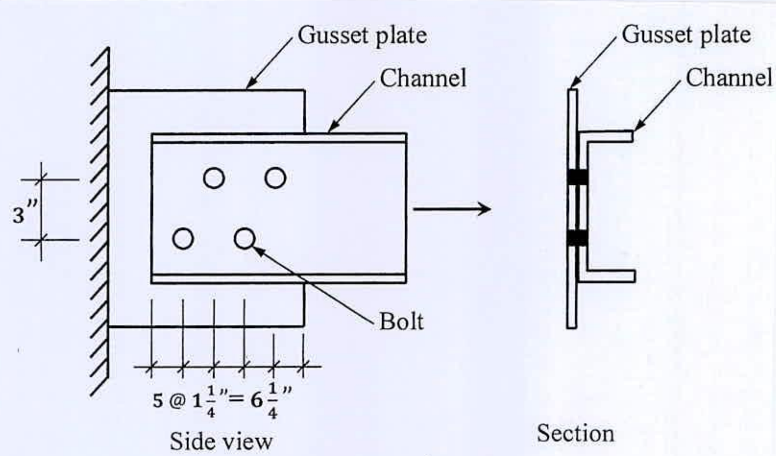
Contd… Q. No. 2(b)

Fig. 2



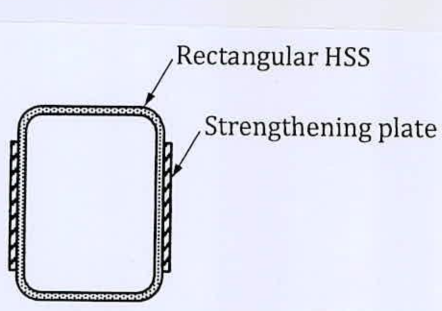
3. (a) A C8 × 18.7 channel section of A572 Grade 50 steel (F_y = 50 ksi, F_u = 65 ksi) is attached to a gusset plate of thickness ½-in. and A36 material (F_y = 36 ksi, F_u = 58 ksi) using four A325 bolts (F_y = 90 ksi, F_u = 120 ksi) in bearing type connection as shown in Fig. 3. Determine the design tension capacity of the connection based on bolt limit states. Follow LRFD principle. **(18)**

Fig. 3



(b) A column section consists of a rectangular HSS 8 × 6 × ½ which is further strengthened by symmetrically attaching 4 × ½ plate sections on the outside of only the long sides of the HSS as shown in Fig. 4. The height of the column is 18-ft and both ends are hinged in all directions. All the material is A36 (F_y = 36 ksi, F_u = 58 ksi). Determine the axial compression capacity, ϕP_n, of the built-up column following LRFD principle. **(17)**

Fig.4



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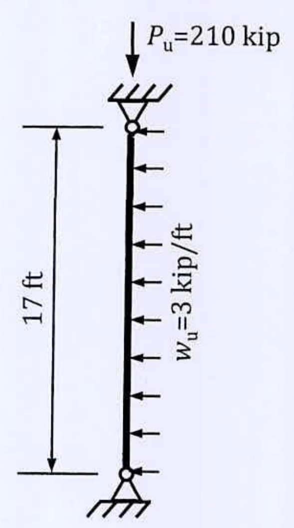
4. (a) By solving the differential equation of a axially loaded crooked column, derive the expression for moment amplification factor B as, **(10)**

$$B = \frac{1}{1 - \frac{P}{P_e}}$$

(b) The beam-column shown in the Fig. 5 is pinned at both ends and is subjected to the loads shown. Bending is about the strong axis. The column is a W10 × 49 section with A992 steel (F_y = 50 ksi, F_u = 65 ksi). Determine whether this member satisfies the appropriate AISC Specification interaction equation. Follow LRFD approach and consider P-δ effect. The column is not braced except at the ends. Take C_b = 1.14 for flexure. **(25)**

Fig. 5



SECTION – B

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

Assume any reasonable value of missing data.

5. (a) What do you mean by "Residual stress"? Write down the main sources of residual stress. **(2+4=6)**

(b) The tension member is a PL 3/8×5 ½ of A242 steel (F_y = 50 ksi, F_u = 70 ksi). It is connected to a 3/8-in. thick gusset plate, also of A242 steel, with 3/4-inch diameter bolts as show in Figure 6. Determine the design capacity of the tension member considering all types of tension limit states. Use AISC LRFD method. **(29)**

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Contd... Q. No. 5(b)

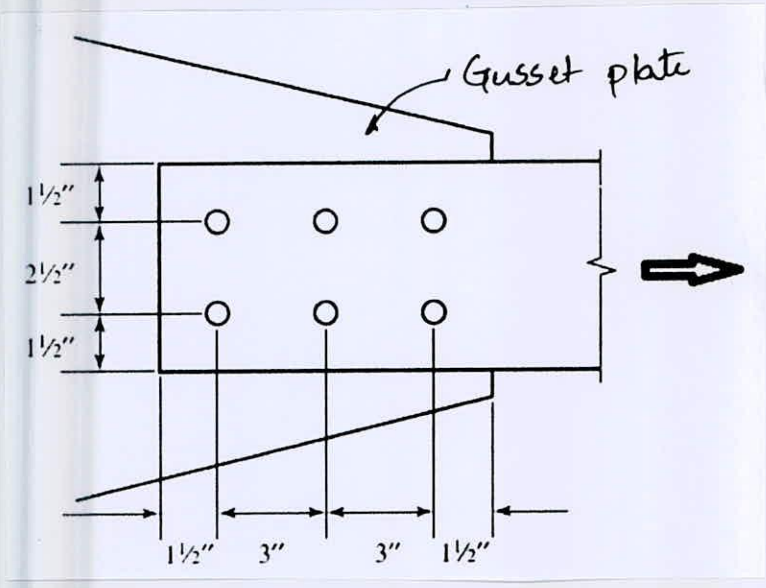

Fig. 6 for Question No. 5(b)

6. (a) Discuss briefly the various possible defects in welds. **(12)**

(b) Use an elastic analysis and determine the maximum load per inch of the weld as shown in Figure 7. **(23)**

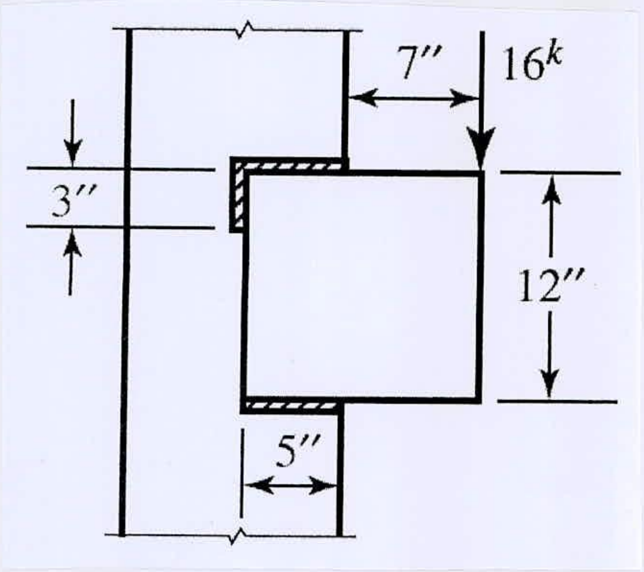

Fig. 7 for Question No. 6(b)

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7. Check the adequacy in flexure of a simply supported beam having a cross-section of W 18×119 and loaded as shown in Figure 8. The beam is laterally braced at A, B, C, and D and loaded in addition to self-weight. Use F_y = 50 ksi and AISC LRFD method. **(35)**

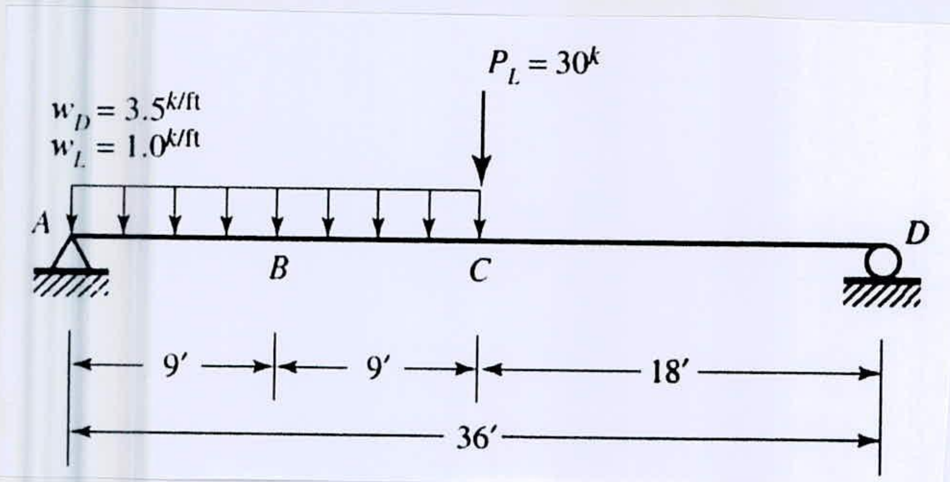

Fig. 8 for Question No. 7

8. (a) Write down the advantages and disadvantages of steel as a structural material. **(10)**

(b) Define alloy steel, stainless steel, and weathering steel. **(9)**

(c) A W16 × 57 steel column transmits an axial compressive live load of 700 kip and dead load of 250 kips on to a concrete base having a top surface of 30 in by 40 in. Determine the size and thickness of the base plate using A36 material. The concrete base has f'_c = 4 ksi. Follow the ASD method. **(16)**

Annex

Beam LTB Formulae

$$\frac{L_p}{r_y} = 1.76\sqrt{\frac{E}{F_y}} = \frac{300}{\sqrt{F_y,\ \text{ksi}}}, \quad L_r = 1.95 r_{ts}\frac{E}{0.7F_y}\sqrt{\frac{Jc}{S_x h_o}}\sqrt{1+\sqrt{1+6.76\left(\frac{0.7F_y}{E}\frac{S_x h_o}{Jc}\right)^2}}$$

$$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_{ts}}\right)^2}\sqrt{1 + 0.078\frac{Jc}{S_x h_o}\left(\frac{L_b}{r_{ts}}\right)^2}$$

End Plate Connection Formulae

$$d_b = \sqrt{\frac{2M_u}{\pi \phi F_t \sum d_n}}; \quad t_p = \sqrt{\frac{1.11\gamma_r \phi M_{np}}{\phi_b F_{py} Y}}$$

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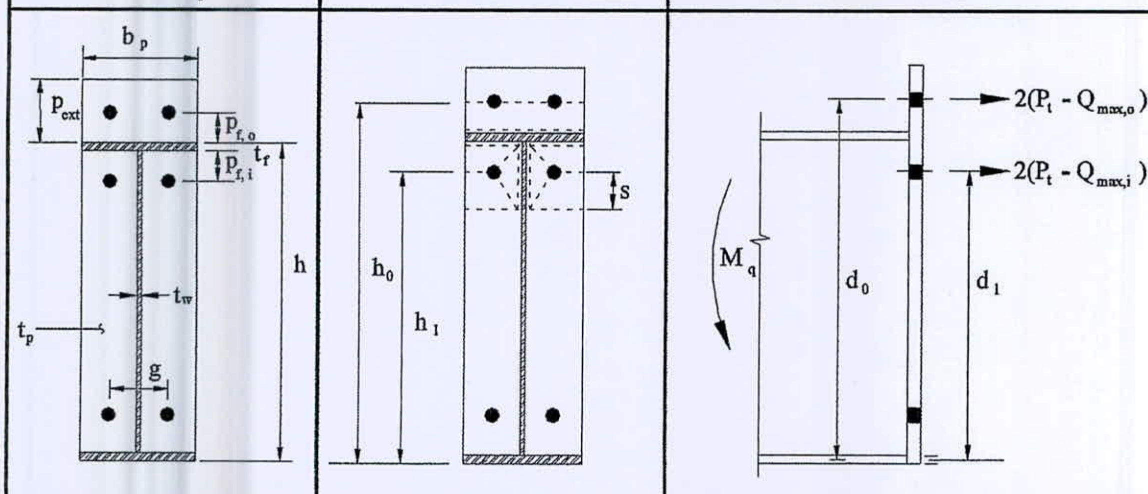
Annex

End-plate connection yield line mechanism charts

Geometry	Yield-Line Mechanism	Bolt Force Model



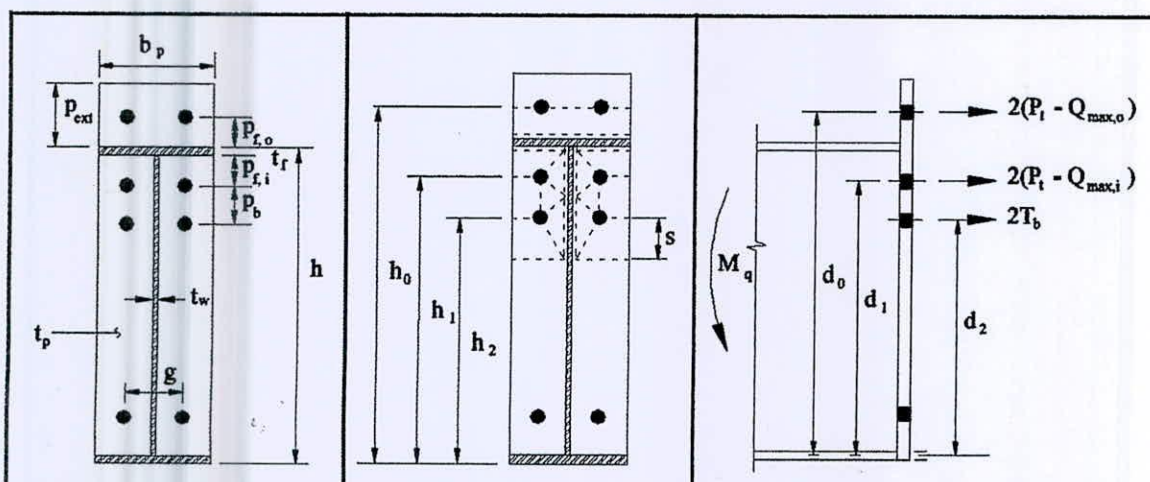
End-Plate Yield

$$\phi M_n = \phi_b M_{pl} = \phi_b F_{py} t_p^2 Y$$

$$Y = \frac{b_p}{2}\left[h_1\left(\frac{1}{p_{f,i}}+\frac{1}{s}\right)+h_0\left(\frac{1}{p_{f,o}}\right)-\frac{1}{2}\right]+\frac{2}{g}\left[h_1\left(p_{f,i}+s\right)\right]$$

Note: Use $p_{f,i} = s$, if $p_{f,i} > s$

$s = \frac{1}{2}\sqrt{b_p g}$ $\qquad \phi_b = 0.90$



End-Plate Yield

$$\phi M_n = \phi_b M_{pl} = \phi_b F_{py} t_p^2 Y$$

$$Y = \frac{b_p}{2}\left[h_1\left(\frac{1}{p_{f,i}}\right)+h_2\left(\frac{1}{s}\right)+h_0\left(\frac{1}{p_{f,o}}\right)-\frac{1}{2}\right]+\frac{2}{g}\left[h_1\left(p_{f,i}+0.75p_b\right)+h_2\left(s+0.25p_b\right)\right]+\frac{g}{2}$$

$s = \frac{1}{2}\sqrt{b_p g}$ $\qquad \phi_b = 0.90$ $\qquad$ Note: Use $p_{f,i} = s$, if $p_{f,i} > s$

= 7 =

Annex

Properties of W sections

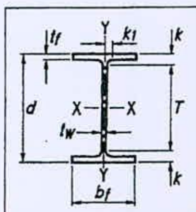


Table 1–1 (continued) W Shapes Dimensions / Table 1–1 (continued) W Shapes Properties

Shape	Area, A	Depth, d	Web Thickness, t_w	Flange Width, b_f	Flange Thickness, t_f	Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Workable Gage	Axis X-X I	Axis X-X S	Axis X-X r	Axis X-X Z	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Axis Y-Y Z	r_{ts}	h_o	Torsional Properties J	Torsional Properties C_w
	in.²	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.⁴	in.³	in.	in.³	in.⁴	in.³	in.	in.³	in.	in.	in.⁴	in.⁶
W21×201	59.2	23.0	0.910	12.6	1.63	2.13	2 1/2	1 5/16	18	5 1/2	5310	461	9.47	530	542	86.1	3.02	133	3.55	21.4	40.9	62000
×182	53.6	22.7	0.830	12.5	1.48	1.98	2 3/8	1 1/4			4730	417	9.40	476	483	77.2	3.00	119	3.51	21.2	30.7	54400
×166	48.8	22.5	0.750	12.4	1.36	1.86	2 1/4	1 3/16			4280	380	9.36	432	435	70.0	2.99	108	3.48	21.1	23.6	48500
×147	43.2	22.1	0.720	12.5	1.15	1.65	2	1 3/16			3630	329	9.17	373	376	60.1	2.95	92.6	3.45	20.9	15.4	41100
×132	38.8	21.8	0.650	12.4	1.04	1.54	1 15/16	1 1/8			3220	295	9.12	333	333	53.5	2.93	82.3	3.42	20.8	11.3	36000
×122	35.9	21.7	0.600	12.4	0.960	1.46	1 13/16	1 1/8			2960	273	9.09	307	305	49.2	2.92	75.6	3.40	20.7	8.98	32700
×111	32.7	21.5	0.550	12.3	0.875	1.38	1 3/4	1 1/8			2670	249	9.05	279	274	44.5	2.90	68.2	3.37	20.6	6.83	29200
×101[c]	29.8	21.4	0.500	12.3	0.800	1.30	1 11/16	1 1/16			2420	227	9.02	253	248	40.3	2.89	61.7	3.35	20.6	5.21	26200
W21×93	27.3	21.6	0.580	8.42	0.930	1.43	1 5/8	15/16	18 3/8	5 1/2	2070	192	8.70	221	92.9	22.1	1.84	34.7	2.24	20.7	6.03	9940
×83[c]	24.3	21.4	0.515	8.36	0.835	1.34	1 1/2	7/8			1830	171	8.67	196	81.4	19.5	1.83	30.5	2.21	20.6	4.34	8630
×73[c]	21.5	21.2	0.455	8.30	0.740	1.24	1 7/16	7/8			1600	151	8.64	172	70.6	17.0	1.81	26.6	2.19	20.5	3.02	7410
×68[c]	20.0	21.1	0.430	8.27	0.685	1.19	1 3/8	7/8			1480	140	8.60	160	64.7	15.7	1.80	24.4	2.17	20.4	2.45	6760
×62[c]	18.3	21.0	0.400	8.24	0.615	1.12	1 5/16	13/16			1330	127	8.54	144	57.5	14.0	1.77	21.7	2.15	20.4	1.83	5960
×55[c]	16.2	20.8	0.375	8.22	0.522	1.02	1 3/16	13/16			1140	110	8.40	126	48.4	11.8	1.73	18.4	2.11	20.3	1.24	4980
×48[c,f]	14.1	20.6	0.350	8.14	0.430	0.930	1 1/8	13/16			959	93.0	8.24	107	38.7	9.52	1.66	14.9	2.05	20.2	0.803	3950
W18×71	20.8	18.5	0.495	7.64	0.810	1.21	1 1/2	7/8	15 1/2	3 1/2[g]	1170	127	7.50	146	60.3	15.8	1.70	24.7	2.05	17.7	3.49	4700
×65	19.1	18.4	0.450	7.59	0.750	1.15	1 7/16	7/8			1070	117	7.49	133	54.8	14.4	1.69	22.5	2.03	17.6	2.73	4240
×60[c]	17.6	18.2	0.415	7.56	0.695	1.10	1 3/8	13/16			984	108	7.47	123	50.1	13.3	1.68	20.6	2.02	17.5	2.17	3850
×55[c]	16.2	18.1	0.390	7.53	0.630	1.03	1 5/16	13/16			890	98.3	7.41	112	44.9	11.9	1.67	18.5	2.00	17.5	1.66	3430
×50[c]	14.7	18.0	0.355	7.50	0.570	0.972	1 1/4	13/16			800	88.9	7.38	101	40.1	10.7	1.65	16.6	1.98	17.4	1.24	3040
W14×132	38.8	14.7	0.645	14.7	1.03	1.63	2 5/16	1 9/16	10	5 1/2	1530	209	6.28	234	548	74.5	3.76	113	4.23	13.6	12.3	25500
×120	35.3	14.5	0.590	14.7	0.940	1.54	2 1/4	1 1/2			1380	190	6.24	212	495	67.5	3.74	102	4.20	13.5	9.37	22700
×109	32.0	14.3	0.525	14.6	0.860	1.46	2 3/16	1 1/2			1240	173	6.22	192	447	61.2	3.73	92.7	4.17	13.5	7.12	20200
×99[f]	29.1	14.2	0.485	14.6	0.780	1.38	2 1/16	1 7/16			1110	157	6.17	173	402	55.2	3.71	83.6	4.14	13.4	5.37	18000
×90[f]	26.5	14.0	0.440	14.5	0.710	1.31	2	1 7/16			999	143	6.14	157	362	49.9	3.70	75.6	4.11	13.3	4.06	16000
W14×82	24.0	14.3	0.510	10.1	0.855	1.45	1 11/16	1 1/16	10 7/8	5 1/2	881	123	6.05	139	148	29.3	2.48	44.8	2.85	13.5	5.07	6710
×74	21.8	14.2	0.450	10.1	0.785	1.38	1 5/8	1 1/16			795	112	6.04	126	134	26.6	2.48	40.5	2.82	13.4	3.87	5990
×68	20.0	14.0	0.415	10.0	0.720	1.31	1 9/16	1 1/16			722	103	6.01	115	121	24.2	2.46	36.9	2.80	13.3	3.01	5380
×61	17.9	13.9	0.375	10.0	0.645	1.24	1 1/2	1			640	92.1	5.98	102	107	21.5	2.45	32.8	2.78	13.2	2.19	4710
W14×53	15.6	13.9	0.370	8.06	0.660	1.25	1 1/2	1	10 7/8	5 1/2	541	77.8	5.89	87.1	57.7	14.3	1.92	22.0	2.22	13.3	1.94	2540
×48	14.1	13.8	0.340	8.03	0.595	1.19	1 7/16	1			484	70.2	5.85	78.4	51.4	12.8	1.91	19.6	2.20	13.2	1.45	2240
×43[c]	12.6	13.7	0.305	8.00	0.530	1.12	1 3/8	1			428	62.6	5.82	69.6	45.2	11.3	1.89	17.3	2.18	13.1	1.05	1950
W12×58	17.0	12.2	0.360	10.0	0.640	1.24	1 1/2	15/16	9 1/4	5 1/2	475	78.0	5.28	86.4	107	21.4	2.51	32.5	2.82	11.6	2.10	3570
×53	15.6	12.1	0.345	10.0	0.575	1.18	1 3/8	15/16	9 1/4	5 1/2	425	70.6	5.23	77.9	95.8	19.2	2.48	29.1	2.79	11.5	1.58	3160
W12×50	14.6	12.2	0.370	8.08	0.640	1.14	1 1/2	15/16	9 1/4	5 1/2	391	64.2	5.18	71.9	56.3	13.9	1.96	21.3	2.25	11.6	1.71	1880
×45	13.1	12.1	0.335	8.05	0.575	1.08	1 3/8	15/16			348	57.7	5.15	64.2	50.0	12.4	1.95	19.0	2.23	11.5	1.26	1650
×40	11.7	11.9	0.295	8.01	0.515	1.02	1 3/8	7/8			307	51.5	5.13	57.0	44.1	11.0	1.94	16.8	2.21	11.4	0.906	1440
W12×35[c]	10.3	12.5	0.300	6.56	0.520	0.820	1 3/16	3/4	10 1/8	3 1/2	285	45.6	5.25	51.2	24.5	7.47	1.54	11.5	1.79	12.0	0.741	879
×30[c]	8.79	12.3	0.260	6.52	0.440	0.740	1 1/8	3/4			238	38.6	5.21	43.1	20.3	6.24	1.52	9.56	1.77	11.9	0.457	720
×26[c]	7.65	12.2	0.230	6.49	0.380	0.680	1 1/16	3/4			204	33.4	5.17	37.2	17.3	5.34	1.51	8.17	1.75	11.8	0.300	607
W12×22[c]	6.48	12.3	0.260	4.03	0.425	0.725	15/16	5/8	10 3/8	2 1/4[g]	156	25.4	4.91	29.3	4.66	2.31	0.848	3.66	1.04	11.9	0.293	164
×19[c]	5.57	12.2	0.235	4.01	0.350	0.650	7/8	9/16			130	21.3	4.82	24.7	3.76	1.88	0.822	2.98	1.02	11.8	0.180	131
×16[c]	4.71	12.0	0.220	3.99	0.265	0.565	13/16	9/16			103	17.1	4.67	20.1	2.82	1.41	0.773	2.26	0.982	11.7	0.103	96.9
×14[c,v]	4.16	11.9	0.200	3.97	0.225	0.525	3/4	9/16			88.6	14.9	4.62	17.4	2.36	1.19	0.753	1.90	0.962	11.7	0.0704	80.4
W10×112	32.9	11.4	0.755	10.4	1.25	1.75	1 15/16	1	7 1/2	5 1/2	716	126	4.66	147	236	45.3	2.68	69.2	3.07	10.1	15.1	6020
×100	29.4	11.1	0.680	10.3	1.12	1.62	1 13/16	1			623	112	4.60	130	207	40.0	2.65	61.0	3.03	10.0	10.9	5150
×88	25.9	10.8	0.605	10.3	0.990	1.49	1 11/16	15/16			534	98.5	4.54	113	179	34.8	2.63	53.1	2.99	9.85	7.53	4330
×77	22.6	10.6	0.530	10.2	0.870	1.37	1 9/16	7/8			455	85.9	4.49	97.6	154	30.1	2.60	45.9	2.95	9.73	5.11	3630
×68	20.0	10.4	0.470	10.1	0.770	1.27	1 7/16	7/8			394	75.7	4.44	85.3	134	26.4	2.59	40.1	2.91	9.63	3.56	3100
×60	17.6	10.2	0.420	10.1	0.680	1.18	1 3/8	13/16			341	66.7	4.39	74.6	116	23.0	2.57	35.0	2.88	9.54	2.48	2640
×54	15.8	10.1	0.370	10.0	0.615	1.12	1 5/16	13/16			303	60.0	4.37	66.6	103	20.6	2.56	31.3	2.86	9.48	1.82	2320
×49	14.4	10.0	0.340	10.0	0.560	1.06	1 1/4	13/16			272	54.6	4.35	60.4	93.4	18.7	2.54	28.3	2.84	9.42	1.39	2070

= 8 =

Annex

Properties of Channel Sections

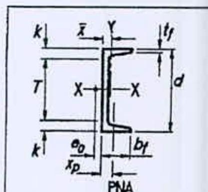


Table 1–5
C Shapes
Dimensions

Table 1–5 (continued)
C Shapes
Properties

C SHAPES

Shape	Area, A	Depth, d	Web	Flange		Distance			Shear Ctr, e_o	Axis X-X				Axis Y-Y						Torsional Properties			
			Thickness, t_w	Width, b_f	Thickness, t_f	k	T	Workable Gage		I	S	r	Z	I	S	r	$\bar{x}$	Z	x_p	J	C_w	$\bar{r}_o$	H
	in.²	in.	in.	in.	in.	in.	in.	in.	in.	in.⁴	in.³	in.	in.³	in.⁴	in.³	in.	in.	in.³	in.	in.⁴	in.⁶	in.	
C9×20	5.87	9.00	0.448	2.65	0.413	1	7	1 1/2[9]	0.515	60.9	13.5	3.22	16.9	2.41	1.17	0.640	0.583	2.46	0.326	0.427	39.4	3.46	0.899
×15	4.41	9.00	0.285	2.49	0.413	1	7	1 3/8[9]	0.681	51.0	11.3	3.40	13.6	1.91	1.01	0.659	0.586	2.04	0.245	0.208	31.0	3.69	0.882
×13.4	3.94	9.00	0.233	2.43	0.413	1	7	1 3/8[9]	0.742	47.8	10.6	3.49	12.6	1.75	0.954	0.666	0.601	1.94	0.219	0.168	28.2	3.79	0.875
C8×18.7	5.51	8.00	0.487	2.53	0.390	15/16	6 1/8	1 1/2[9]	0.431	43.9	11.0	2.82	13.9	1.97	1.01	0.598	0.565	2.17	0.344	0.434	25.1	3.05	0.894
×13.7	4.04	8.00	0.303	2.34	0.390	15/16	6 1/8	1 3/8[9]	0.604	36.1	9.02	2.99	11.0	1.52	0.848	0.613	0.554	1.73	0.252	0.186	19.2	3.26	0.874
×11.5	3.37	8.00	0.220	2.26	0.390	15/16	6 1/8	1 3/8[9]	0.697	32.5	8.14	3.11	9.63	1.31	0.775	0.623	0.572	1.57	0.211	0.130	16.5	3.41	0.862
C7×14.7	4.33	7.00	0.419	2.30	0.366	7/8	5 1/4	1 1/4[9]	0.441	27.2	7.78	2.51	9.75	1.37	0.772	0.561	0.532	1.63	0.309	0.267	13.1	2.75	0.875
×12.2	3.60	7.00	0.314	2.19	0.366	7/8	5 1/4	1 1/4[9]	0.538	24.2	6.92	2.60	8.46	1.16	0.696	0.568	0.525	1.42	0.257	0.161	11.2	2.86	0.862
×9.8	2.87	7.00	0.210	2.09	0.366	7/8	5 1/4	1 1/4[9]	0.647	21.2	6.07	2.72	7.19	0.957	0.617	0.578	0.541	1.26	0.205	0.0996	9.15	3.03	0.846

Properties of Rectangular HSS Sections

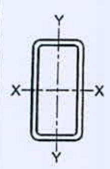


Table 1-11 (continued)
Rectangular HSS
Dimensions and Properties

Table 1-11 (continued)
Rectangular HSS
Dimensions and Properties

HSS9–HSS8

Shape	Design Wall Thickness, t	Nominal Wt.	Area, A	b/t	h/t	Axis X-X				Axis Y-Y				Workable Flat		Torsion		Surface Area
						I	S	r	Z	I	S	r	Z	Depth	Width	J	C	
	in.	lb/ft	in.²			in.⁴	in.³	in.	in.³	in.⁴	in.³	in.	in.³	in.	in.	in.⁴	in.³	ft²/ft
HSS9×5×5/8	0.581	50.81	14.0	5.61	12.5	133	29.6	3.08	38.5	52.0	20.8	1.92	25.3	6 3/16	2 3/16	128	42.5	2.17
×1/2	0.465	42.05	11.6	7.75	16.4	115	25.5	3.14	32.5	45.2	18.1	1.97	21.5	6 3/4	2 3/4	109	35.6	2.20
×3/8	0.349	32.58	8.97	11.3	22.8	92.5	20.5	3.21	25.7	36.8	14.7	2.03	17.1	7 5/16	3 5/16	86.9	27.9	2.23
×5/16	0.291	27.59	7.59	14.2	27.9	79.8	17.7	3.24	22.0	32.0	12.8	2.05	14.6	7 5/8	3 5/8	74.4	23.8	2.25
×1/4	0.233	22.42	6.17	18.5	35.6	66.1	14.7	3.27	18.1	26.6	10.6	2.08	12.0	7 7/8	3 7/8	61.2	19.4	2.27
×3/16	0.174	17.08	4.67	25.7	48.7	51.1	11.4	3.31	13.8	20.7	8.28	2.10	9.25	8 3/16	4 3/16	46.9	14.8	2.28
HSS9×3×1/2	0.465	35.24	9.74	3.45	16.4	80.8	18.0	2.88	24.6	13.2	8.81	1.17	10.8	6 3/4	–	40.0	19.7	1.87
×3/8	0.349	27.48	7.58	5.60	22.8	66.3	14.7	2.96	19.7	11.2	7.45	1.21	8.80	7 5/16	–	33.1	15.8	1.90
×5/16	0.291	23.34	6.43	7.31	27.9	57.7	12.8	3.00	16.9	9.88	6.59	1.24	7.63	7 5/8	–	28.9	13.6	1.92
×1/4	0.233	19.02	5.24	9.88	35.6	48.2	10.7	3.04	14.0	8.38	5.59	1.27	6.35	7 7/8	–	24.2	11.3	1.93
×3/16	0.174	14.53	3.98	14.2	48.7	37.6	8.35	3.07	10.8	6.64	4.42	1.29	4.92	8 3/16	2 3/16	18.9	8.66	1.95
HSS8×6×5/8	0.581	50.81	14.0	7.33	10.8	114	28.5	2.85	36.1	72.3	24.1	2.27	29.5	5 3/16	3 3/16	150	46.0	2.17
×1/2	0.465	42.05	11.6	9.90	14.2	98.2	24.6	2.91	30.5	62.5	20.8	2.32	24.9	5 3/4	3 3/4	127	38.4	2.20
×3/8	0.349	32.58	8.97	14.2	19.9	79.1	19.8	2.97	24.1	50.6	16.9	2.38	19.8	6 5/16	4 5/16	100	30.0	2.23
×5/16	0.291	27.59	7.59	17.6	24.5	68.3	17.1	3.00	20.6	43.8	14.6	2.40	16.9	6 5/8	4 5/8	85.8	25.5	2.25
×1/4	0.233	22.42	6.17	22.8	31.3	56.6	14.2	3.03	16.9	36.4	12.1	2.43	13.9	6 7/8	4 7/8	70.3	20.8	2.27
×3/16	0.174	17.08	4.67	31.5	43.0	43.7	10.9	3.06	13.0	28.2	9.39	2.46	10.7	7 3/16	5 3/16	53.7	15.8	2.28
HSS8×4×5/8	0.581	42.30	11.7	3.88	10.8	82.0	20.5	2.64	27.4	26.6	13.3	1.51	16.6	5 3/16	–	70.3	28.7	1.83
×1/2	0.465	35.24	9.74	5.60	14.2	71.8	17.9	2.71	23.5	23.6	11.8	1.56	14.3	5 3/4	–	61.1	24.4	1.87
×3/8	0.349	27.48	7.58	8.46	19.9	58.7	14.7	2.78	18.8	19.6	9.80	1.61	11.5	6 5/16	2 5/16	49.3	19.3	1.90
×5/16	0.291	23.34	6.43	10.7	24.5	51.0	12.8	2.82	16.1	17.2	8.58	1.63	9.91	6 5/8	2 5/8	42.6	16.5	1.92
×1/4	0.233	19.02	5.24	14.2	31.3	42.5	10.6	2.85	13.3	14.4	7.21	1.66	8.20	6 7/8	2 7/8	35.3	13.6	1.93
×3/16	0.174	14.53	3.98	20.0	43.0	33.1	8.27	2.88	10.2	11.3	5.65	1.69	6.33	7 3/16	3 3/16	27.2	10.4	1.95
×1/8	0.116	9.86	2.70	31.5	66.0	22.9	5.73	2.92	7.02	7.90	3.95	1.71	4.36	7 7/16	3 7/16	18.7	7.10	1.97
HSS8×3×1/2	0.465	31.84	8.81	3.45	14.2	58.6	14.6	2.58	20.0	11.7	7.81	1.15	9.64	5 3/4	–	34.3	17.4	1.70
×3/8	0.349	24.93	6.88	5.60	19.9	48.5	12.1	2.65	16.1	10.0	6.63	1.20	7.88	6 5/16	–	28.5	14.0	1.73
×5/16	0.291	21.21	5.85	7.31	24.5	42.4	10.6	2.69	13.9	8.81	5.87	1.23	6.84	6 5/8	–	24.9	12.1	1.75
×1/4	0.233	17.32	4.77	9.88	31.3	35.5	8.88	2.73	11.5	7.49	4.99	1.25	5.70	6 7/8	–	20.8	10.0	1.77
×3/16	0.174	13.25	3.63	14.2	43.0	27.8	6.94	2.77	8.87	5.94	3.96	1.28	4.43	7 3/16	2 3/16	16.2	7.68	1.78
×1/8	0.116	9.01	2.46	22.9	66.0	19.3	4.83	2.80	6.11	4.20	2.80	1.31	3.07	7 7/16	2 7/16	11.3	5.27	1.80

Note: For width-to-thickness criteria, refer to Table 1-12A.

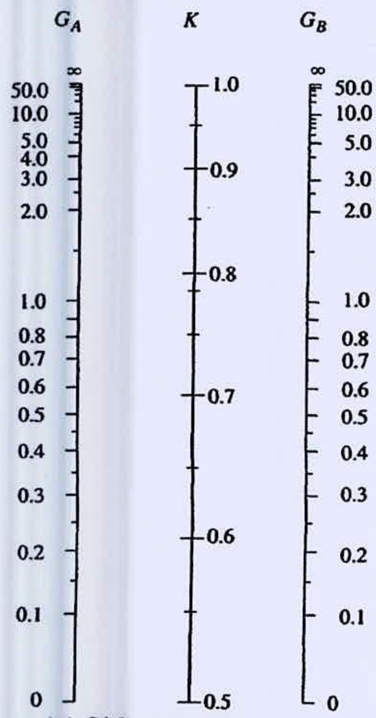
– Indicates flat depth or width is too small to establish a workable flat.

Annex

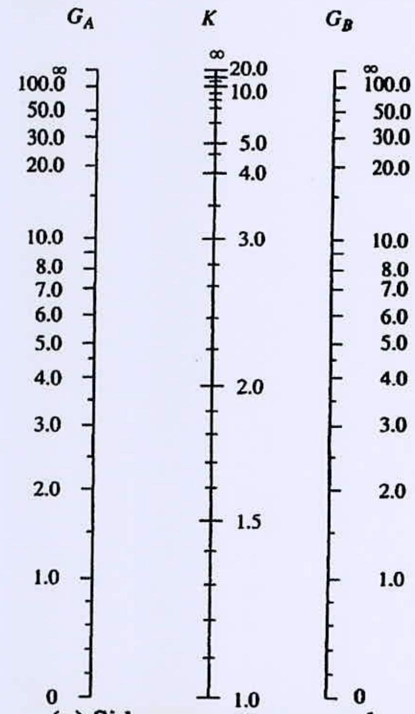
= 9 =

Alignment Charts for Column

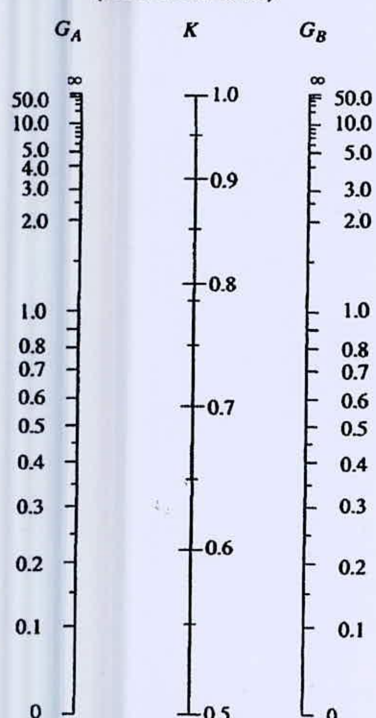
Note: If Q.2(a) is answered, attach this chart with the answer script.



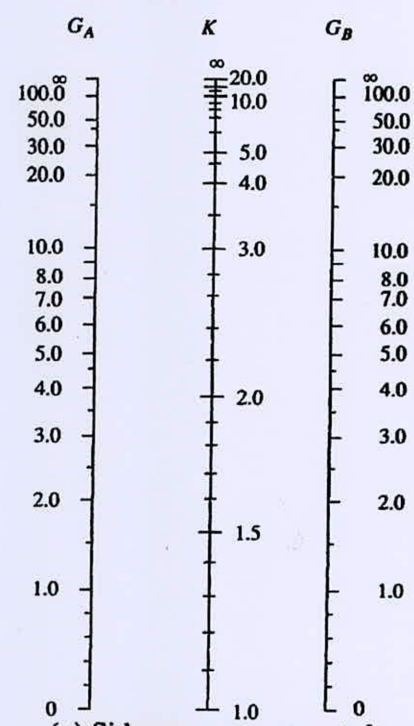
(a) Sidesway prevented
(Braced frame)



(a) Sidesway not prevented
(Unbraced frame)



(a) Sidesway prevented
(Braced frame)



(a) Sidesway not prevented
(Unbraced frame)

CE 319

$$L_p = 1.76 r_y \sqrt{\frac{E}{F_y}}.$$

$$L_r = 1.95 r_{ts}\frac{E}{0.7F_y}\sqrt{\frac{Jc}{S_x h_o}}\sqrt{1+\sqrt{1+6.76\left(\frac{0.7F_y}{E}\frac{S_x h_o}{Jc}\right)^2}}$$

$$r_{ts} = \left(\frac{\sqrt{I_y C_w}}{S_x}\right)^{1/2}$$

$$M_n = C_b\left[M_p - \left(M_p - 0.7F_y S_x\right)\left(\frac{L_b-L_p}{L_r-L_p}\right)\right] \le M_p.$$

$$F_{cr} = \frac{C_b\pi^2 E}{\left(\frac{L_b}{r_{ts}}\right)^2}\sqrt{1+0.078\frac{Jc}{S_x h_o}\left(\frac{L_b}{r_{ts}}\right)^2}$$

$$C_b = \frac{12.5M_{\max}}{2.5M_{\max}+3M_A+4M_B+3M_C}R_m \le 3.0$$

$$P_p = 0.85 f'_c A_1\sqrt{\frac{A_2}{A_1}}$$

$$f_{p(max)} = \phi\left(0.85 f'_c\right)\sqrt{\frac{A_2}{A_1}}$$

$$\sqrt{\frac{A_2}{A_1}} \le 2$$

CE 319

Dimensions and Properties of Structural Steel Shapes

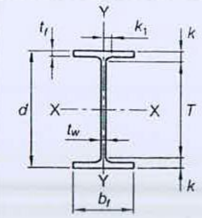


Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W18×311[h]	91.6	22.3	22 3/8	1.52	1 1/2	3/4	12.0	12	2.74	2 3/4	3.24	3 9/16	1 9/16	15 1/8	5 1/2
×283[h]	83.3	21.9	21 7/8	1.40	1 3/8	11/16	11.9	11 7/8	2.50	2 1/2	3.00	3 3/8	1 1/2		
×258[h]	76.0	21.5	21 1/2	1.28	1 1/4	5/8	11.8	11 3/4	2.30	2 5/16	2.70	3 3/16	1 7/16		
×234[h]	68.6	21.1	21	1.16	1 3/16	5/8	11.7	11 5/8	2.11	2 1/8	2.51	3	1 3/8		
×211	62.3	20.7	20 5/8	1.06	1 1/16	9/16	11.6	11 1/2	1.91	1 15/16	2.31	2 13/16	1 3/8		
×192	56.2	20.4	20 3/8	0.960	15/16	1/2	11.5	11 1/2	1.75	1 3/4	2.15	2 5/8	1 5/16		
×175	51.4	20.0	20	0.890	7/8	7/16	11.4	11 3/8	1.59	1 9/16	1.99	2 7/16	1 1/4		
×158	46.3	19.7	19 3/4	0.810	13/16	7/16	11.3	11 1/4	1.44	1 7/16	1.84	2 3/8	1 1/4		
×143	42.0	19.5	19 1/2	0.730	3/4	3/8	11.2	11 1/4	1.32	1 5/16	1.72	2 3/16	1 3/16		
×130	38.3	19.3	19 1/4	0.670	11/16	3/8	11.2	11 1/8	1.20	1 3/16	1.60	2 1/16	1 3/16		
×119	35.1	19.0	19	0.655	5/8	5/16	11.3	11 1/4	1.06	1 1/16	1.46	1 15/16	1 3/16		
×106	31.1	18.7	18 3/4	0.590	9/16	5/16	11.2	11 1/4	0.940	15/16	1.34	1 13/16	1 1/8		
×97	28.5	18.6	18 5/8	0.535	9/16	5/16	11.1	11 1/8	0.870	7/8	1.27	1 3/4	1 1/8		
×86	25.3	18.4	18 3/8	0.480	1/2	1/4	11.1	11 1/8	0.770	3/4	1.17	1 5/8	1 1/16		
×76[c]	22.3	18.2	18 1/4	0.425	7/16	1/4	11.0	11	0.680	11/16	1.08	1 9/16	1 1/16		
W18×71	20.9	18.5	18 1/2	0.495	1/2	1/4	7.64	7 5/8	0.810	13/16	1.21	1 1/2	7/8	15 1/2	3 1/2[g]
×65	19.1	18.4	18 3/8	0.450	7/16	1/4	7.59	7 5/8	0.750	3/4	1.15	1 7/16	7/8		
×60[c]	17.6	18.2	18 1/4	0.415	7/16	1/4	7.56	7 1/2	0.695	11/16	1.10	1 3/8	13/16		
×55[c]	16.2	18.1	18 1/8	0.390	3/8	3/16	7.53	7 1/2	0.630	5/8	1.03	1 5/16	13/16		
×50[c]	14.7	18.0	18	0.355	3/8	3/16	7.50	7 1/2	0.570	9/16	0.972	1 1/4	13/16		
W18×46[c]	13.5	18.1	18	0.360	3/8	3/16	6.06	6	0.605	5/8	1.01	1 1/4	13/16	15 1/2	3 1/2[g]
×40[c]	11.8	17.9	17 7/8	0.315	5/16	3/16	6.02	6	0.525	1/2	0.927	1 3/16	13/16		
×35[c]	10.3	17.7	17 3/4	0.300	5/16	3/16	6.00	6	0.425	7/16	0.827	1 1/8	3/4		
W16×100	29.4	17.0	17	0.585	9/16	5/16	10.4	10 3/8	0.985	1	1.39	1 7/8	1 1/8	13 1/4	5 1/2
×89	26.2	16.8	16 3/4	0.525	1/2	1/4	10.4	10 3/8	0.875	7/8	1.28	1 3/4	1 1/16		
×77	22.6	16.5	16 1/2	0.455	7/16	1/4	10.3	10 1/4	0.760	3/4	1.16	1 5/8	1 1/16		
×67[c]	19.6	16.3	16 3/8	0.395	3/8	3/16	10.2	10 1/4	0.665	11/16	1.07	1 9/16	1		
W16×57	16.8	16.4	16 3/8	0.430	7/16	1/4	7.12	7 1/8	0.715	11/16	1.12	1 3/8	7/8	13 5/8	3 1/2[g]
×50[c]	14.7	16.3	16 1/4	0.380	3/8	3/16	7.07	7 1/8	0.630	5/8	1.03	1 5/16	13/16		
×45[c]	13.3	16.1	16 1/8	0.345	3/8	3/16	7.04	7	0.565	9/16	0.967	1 1/4	13/16		
×40[c]	11.8	16.0	16	0.305	5/16	3/16	7.00	7	0.505	1/2	0.907	1 3/16	13/16		
×36[c]	10.6	15.9	15 7/8	0.295	5/16	3/16	6.99	7	0.430	7/16	0.832	1 1/8	3/4		
W16×31[c]	9.13	15.9	15 7/8	0.275	1/4	1/8	5.53	5 1/2	0.440	7/16	0.842	1 1/8	3/4	13 5/8	3 1/2
×26[c,v]	7.68	15.7	15 3/4	0.250	1/4	1/8	5.50	5 1/2	0.345	3/8	0.747	1 1/16	3/4	13 5/8	3 1/2

[c] Shape is slender for compression with $F_y = 50$ ksi.
[g] The actual size, combination and orientation of fastener components should be compared with the geometry of the cross section to ensure compatibility.
[h] Flange thickness greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1c.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

Table 1-1 (continued)
W-Shapes
Properties

W18–W16

Nominal Wt.	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria $\frac{h}{t_w}$	Axis X-X I	Axis X-X S	Axis X-X r	Axis X-X Z	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Axis Y-Y Z	r_{ts}	h_o	Torsional Properties J	Torsional Properties C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
311	2.19	10.4	6970	624	8.72	754	795	132	2.95	207	3.53	19.6	176	76200
283	2.38	11.3	6170	565	8.61	676	704	118	2.91	185	3.47	19.4	134	65900
258	2.56	12.5	5510	514	8.53	611	628	107	2.88	166	3.42	19.2	103	57600
234	2.76	13.8	4900	466	8.44	549	558	95.8	2.85	149	3.37	19.0	78.7	50100
211	3.02	15.1	4330	419	8.35	490	493	85.3	2.82	132	3.32	18.8	58.6	43400
192	3.27	16.7	3870	380	8.28	442	440	76.8	2.79	119	3.28	18.7	44.7	38000
175	3.58	18.0	3450	344	8.20	398	391	68.8	2.76	106	3.24	18.4	33.8	33300
158	3.92	19.8	3060	310	8.12	356	347	61.4	2.74	94.8	3.20	18.3	25.2	29000
143	4.25	22.0	2750	282	8.09	322	311	55.5	2.72	85.4	3.17	18.2	19.2	25700
130	4.65	23.9	2460	256	8.03	290	278	49.9	2.70	76.7	3.13	18.1	14.5	22700
119	5.31	24.5	2190	231	7.90	262	253	44.9	2.69	69.1	3.13	17.9	10.6	20300
106	5.96	27.2	1910	204	7.84	230	220	39.4	2.66	60.5	3.10	17.8	7.48	17400
97	6.41	30.0	1750	188	7.82	211	201	36.1	2.65	55.3	3.08	17.7	5.86	15800
86	7.20	33.4	1530	166	7.77	186	175	31.6	2.63	48.4	3.05	17.6	4.10	13600
76	8.11	37.8	1330	146	7.73	163	152	27.6	2.61	42.2	3.02	17.5	2.83	11700
71	4.71	32.4	1170	127	7.50	146	60.3	15.8	1.70	24.7	2.05	17.7	3.49	4700
65	5.06	35.7	1070	117	7.49	133	54.8	14.4	1.69	22.5	2.03	17.7	2.73	4240
60	5.44	38.7	984	108	7.47	123	50.1	13.3	1.68	20.6	2.02	17.5	2.17	3850
55	5.98	41.1	890	98.3	7.41	112	44.9	11.9	1.67	18.5	2.00	17.5	1.66	3430
50	6.57	45.2	800	88.9	7.38	101	40.1	10.7	1.65	16.6	1.98	17.4	1.24	3040
46	5.01	44.6	712	78.8	7.25	90.7	22.5	7.43	1.29	11.7	1.58	17.5	1.22	1720
40	5.73	50.9	612	68.4	7.21	78.4	19.1	6.35	1.27	10.0	1.56	17.4	0.810	1440
35	7.06	53.5	510	57.6	7.04	66.5	15.3	5.12	1.22	8.06	1.51	17.3	0.506	1140
100	5.29	24.3	1490	175	7.10	198	186	35.7	2.51	54.9	2.92	16.0	7.73	11900
89	5.92	27.0	1300	155	7.05	175	163	31.4	2.49	48.1	2.88	15.9	5.45	10200
77	6.77	31.2	1110	134	7.00	150	138	26.9	2.47	41.1	2.85	15.7	3.57	8590
67	7.70	35.9	954	117	6.96	130	119	23.2	2.46	35.5	2.82	15.6	2.39	7300
57	4.98	33.0	758	92.2	6.72	105	43.1	12.1	1.60	18.9	1.92	15.7	2.22	2660
50	5.61	37.4	659	81.0	6.68	92.0	37.2	10.5	1.59	16.3	1.89	15.7	1.52	2270
45	6.23	41.1	586	72.7	6.65	82.3	32.8	9.34	1.57	14.5	1.87	15.5	1.11	1990
40	6.93	46.5	518	64.7	6.63	73.0	28.9	8.25	1.57	12.7	1.86	15.5	0.794	1730
36	8.12	48.1	448	56.5	6.51	64.0	24.5	7.00	1.52	10.8	1.83	15.5	0.545	1460
31	6.28	51.6	375	47.2	6.41	54.0	12.4	4.49	1.17	7.03	1.42	15.5	0.461	739
26	7.97	56.8	301	38.4	6.26	44.2	9.59	3.49	1.12	5.48	1.38	15.4	0.262	565

=11=

TABLE 5.2 Limiting Width–Thickness Ratios for Compression Elements

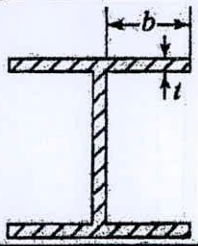
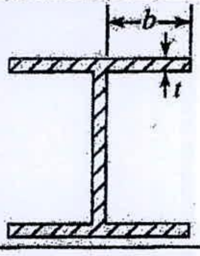
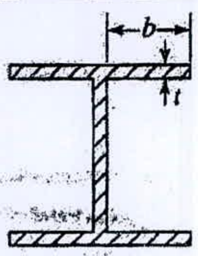
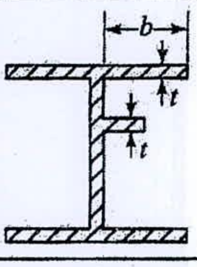
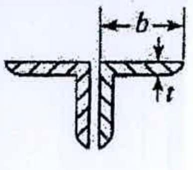
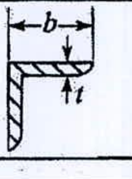
	Case	Description of Element	Width–Thickness Ratio	Limiting Width–Thickness Ratios: λ_p (compact)	Limiting Width–Thickness Ratios: λ_r (noncompact)	Example
Unstiffened Elements	1	Flexure in flanges of rolled I-shaped sections and channels	b/t	$0.38\sqrt{E/F_y}$	$1.0\sqrt{E/F_y}$	
	2	Flexure in flanges of doubly and singly symmetric I-shaped built-up sections	b/t	$0.38\sqrt{E/F_y}$	$0.95\sqrt{k_cE/F_L}$ [a],[b]	
	3	Uniform compression in flanges of rolled I-shaped sections, plates projecting from rolled I-shaped sections; outstanding legs of pairs of angles in continuous contact and flanges of channels	b/t	NA	$0.56\sqrt{E/F_y}$	
	4	Uniform compression in flanges of built-up I-shaped sections and plates or angle legs projecting from built-up I-shaped sections	b/t	NA	$0.64\sqrt{k_cE/F_y}$ [a]	
	5	Uniform compression in legs of single angles, legs of double angles with separators, and all other unstiffened elements	b/t	NA	$0.45\sqrt{E/F_y}$	
	6	Flexure in legs of single angles	b/t	$0.54\sqrt{E/F_y}$	$0.91\sqrt{E/F_y}$	

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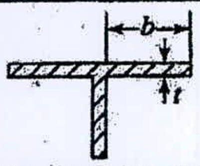
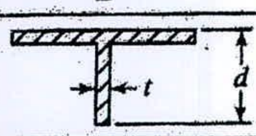
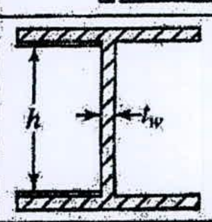
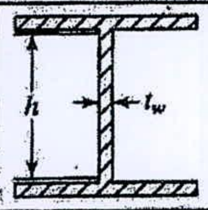
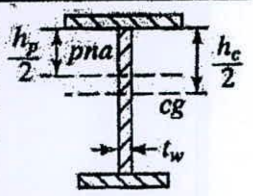
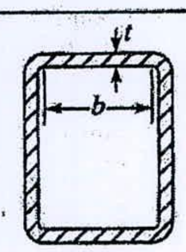
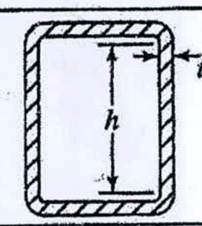
TABLE 5.2 (cont.)		Limiting Width–Thickness Ratios for Compression Elements				
	Case	Description of Element	Width–Thickness Ratio	Limiting Width–Thickness Ratios λ_p (compact)	λ_r (noncompact)	Example
Stiffened Elements	7	Flexure in flanges of tees	b/t	$0.38\sqrt{E/F_y}$	$1.0\sqrt{E/F_y}$	
	8	Uniform compression in stems of tees	d/t	NA	$0.75\sqrt{E/F_y}$	
	9	Flexure in webs of doubly symmetric I-shaped sections and channels	h/t_w	$3.76\sqrt{E/F_y}$	$5.70\sqrt{E/F_y}$	
	10	Uniform compression in webs of doubly symmetric I-shaped sections	h/t_w	NA	$1.49\sqrt{E/F_y}$	
	11	Flexure in webs of single-symmetric I-shaped sections	h_c/t_w	$\dfrac{\dfrac{h_c}{h_p}\sqrt{\dfrac{E}{F_y}}}{\left(0.54\dfrac{M_p}{M_y}-0.09\right)^2} \leq \lambda_r$	$5.70\sqrt{E/F_y}$	
	12	Uniform compression in flanges of rectangular box and hollow structural sections of uniform thickness subject to bending or compression; flange cover plates and diaphragm plates between lines of fasteners or welds	b/t	$1.12\sqrt{E/F_y}$	$1.40\sqrt{E/F_y}$	
	13	Flexure in webs of rectangular HSS	h/t	$2.42\sqrt{E/F_y}$	$5.70\sqrt{E/F_y}$	

L-3/T-2/CE **Date: 30/04/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2020-2021

Sub: **CE 333** (Environmental Engineering II)

Full Marks: 280 Time: 3 Hours

The figures in the margin indicate full marks

Assume reasonable value of any missing data, if needed.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) List the abilities of humans that have made human population to thrive and flourish beyond natural constraints. **(8)**

   (b) Differentiate between natural needs and acquired needs of humans. **(15)**

   (c) Discuss briefly the impact of environmental pollutants upon human health. **(15)**

   (d) How will you plan the plumbing system of a building? **($8\frac{2}{3}$)**

2. (a) Explain how the rural sanitation can be made sustainable. **($10\frac{2}{3}$)**

   (b) What are the basic considerations of water supply for tall buildings? **(8)**

   (c) How will you select the most suitable plumbing-drainage system of a building? **(8)**

   (d) Design suitable zoning of a 30 storied building for water supply using the following data: **(20)**

   Floor to floor height = 10 ft
   Service main pressure = 65 psi
   Distance between the service main and foot of the riser = 60 ft
   Pressure loss in the water meter = 3.5 psi
   Pressure loss in the service pipe per 100 ft = 4 psi
   Fixture pressure in the top most 2 floors varies from 5 psi to 10 psi
   Fixture pressure in any other floor varies from a 5 psi to 18 psi
   Maximum allowable pressure in the water supply system of the building is 70 psi.

3. (a) To design a completely mixed activated sludge process, the following information are obtained: **(18)**

   Raw wastewater flow rate = 20,000 m^3/day
   Soluble biodegradable substrate concentration in raw wastewater (S_0) = 235 mg/L
   Sludge density index, SDI = 0.943
   Aeration tank F:M ratio = 1:3.5
   Aeration tank hydraulic retention time, θ = 5.76 hr = 0.24 day
   Maximum yield coefficient, Y = 0.62 mg/mg
   Net microbial growth rate (r_g') = 305 mg/L-d
   Microbial decay rate (r_d) = 138 mg/L-d
   ASP system efficiency = 93.5%

CE 333

Contd.... for Q. No. 3(a)

Calculate:

(i) MLVSS concentration in the aeration tank (X)

(ii) Mean cell residence time, MCRT (Θ_C)

(iii) Aeration tank volume (V)

(iv) Return sludge biomass concentration (X_r)

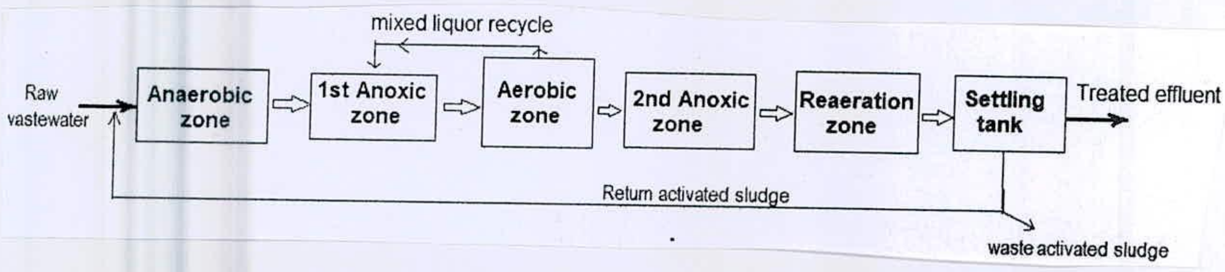
(b) Differentiate between high rate and low rate trickling filter system. Describe in short the contact stabilization activated sludge process. **(8+5)**

(c) Write short note on: **(10)**

(i) sludge stabilization using lime and

(ii) sludge dewatering by filter presses

(d) The figure shown below is the flow diagram of a modified activated sludge process used to remove nitrogen and phosphorus from wastewater. Explain briefly the function of each zone. **($5\frac{2}{3}$)**



4. (a) State the role of the following factors in secondary wastewater treatment using microorganism– (i) endogenous respiration phase of bacterial growth and (ii) food to microorganism ratio. Diagrammatically show the thioglycolate tubes test for determination of oxygen requirements by different types of microorganism. **(8+5=13)**

(b) Write down some advantages and disadvantages of COD and TOC measurement in wastewater analysis. Discuss importance of algae in wastewater treatment. **($8+5\frac{2}{3}=13\frac{2}{3}$)**

(c) Design a primary facultative-maturation pond system to treat 30,000 m^3/day of domestic septic tank sewage with BOD_5 of 255 mg/L and fecal coliform (FC) of 4×10^7 cfu/100 mL. According to ECR'97, the required STP effluent standards are: **(20)**

$BOD_5 < 30$ mg/L, FC < 1000 cfu/100 mL. Assume design temperature = 24°C.

Given, the value of k and k_b at temperature of 20°C are 0.27/day and 2.5/day, respectively and Arrhenius constant (θ) for k and k_b are 1.01 and 1.19, respectively. Consider, facultative and maturation pond depth to be = 1.8 m and 1.2 m respectively. Assume any other reasonable values, if needed.

Contd P/3

SECTION – B

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

5. (a) An STP reported the following weekly BOD_5 data of treated effluent for 13 weeks. **($26\frac{2}{3}$)**

(i) Plot these values on a Log-Probability paper following the conventional method and the Blom's Transformation [Log-Probability paper provided].

(ii) Graphically, determine the Mean and Standard Deviations for both plots.

(iii) Determine how many weeks in a year the STP will discharge effluent exceeding the ECR '97 regulations for BOD_5 discharge level.

(iv) Compare and comment on the results for both methods.

Week	1	2	3	4	5	6	7	8	9	10	11	12	13
BOD_5	72	65	50	45	51	48	52	38	52	47	45	55	35

(b) Why is a "sanitary Tee" (instead of a straight pipe) used as an inlet device and an outlet device in a septic tank? Explain. **(10)**

Briefly discuss the working principle of an anaerobic baffled reactor (ABR) (with an appropriate sketch). Compare the typical performance of an ABR with that of a conventional septic tank.

(c) Draw the process flow diagram of an ETP employing physiochemical and activated sludge processes to treat effluent from a Textile dyeing industry. Unfortunately, the following problems occurred on different occasions in the treatment processes at the ETP. **(10)**

(i) On a particular workday, it was observed that there were floating flocs in the sample collected from the outlet.

(ii) On another day, some Styrofoam pieces and plastic bottles were in the Equalization tank.

(iii) During a routine inspection, it was observed that the froth on the surface of flotation chamber broke up immediately after formation.

(iv) On a particular workday, it was observed that in the Aeration Chamber, the Fine Bubble Blower was blowing coarse bubbles. What may be the reason for this? What would be its effect on the operation of the ETP? How would you fix it?

(v) Sludge samples collected from the final disposal had a significant amount of water. What may be the cause for such an occurrence? How would you fix it?

Being the Environmental Engineer in charge of ETP operations, it is your responsibility to identify the reasons for each of the above scenarios. What are the locations in the ETP you need to sample to identify the problem in case of (i), (ii), and (iii)?

Contd P/4

6. (a) Draw a flow diagram showing all elements of the complete sanitation system based on an alternating twin off-set pit pour-flush latrine. **($26\frac{2}{3}$)**

Design a suitable latrine for a family of 8 members living in a high water table area, with a tubewell-based water supply. The depth to groundwater level is 3.0 m below the existing ground surface. The estimated water use for the latrine is 15 lpcd, and the long-term infiltration capacity of soil in the area is 28 L/m^2.day. The latrine pit is to be constructed with concrete rings 1.2 m in diameter and 0.15 m in depth.

(i) What type of latrine would you suggest for the family? Justify your answer.

(ii) Design the latrine (keeping adequate vertical clearance between the pit-bottom and groundwater level) and estimate its design life.

(iii) Draw a neat sketch (both plan and section) showing all elements of the designed latrine.

[Assume reasonable values for parameters not given]

(b) You have been given the responsibility to design a wastewater collection network for a jail. The STP is located about one km away from the last node of the collection network. Identify the major impediment to the conveyance of sewage to the STP and suggest and innovative way to overcome the problem. Provide a neat sketch of your conceptual design. **(10)**

(c) What do you understand by a small bore sewerage (SBS) system? Discuss the changes in the design of a sewer network and a treatment plant in an SBS system compared to a conventional sewerage system. **(10)**

7. (a) (i) A 610 mm (24 in) clay sewer (thickness of 64 mm and 51 mm for extra strength and standard strength, respectively) is to be placed in an ordinary trench 3.66 m (12 ft) deep and 1.22 m (4 ft) wide which will be filled with wet clay weighing 1920 kg/m^3 (120 lb/ft^3). Determine the load on the pipe (for both the Extra Strength and Standard Strength pipes) and the type of bedding required if the installation is to have a factor of safety 1.5. [Use the Tables and figures provided, if needed.] Draw the designed Bedding Section. **($26\frac{2}{3}$)**

(ii) A concrete structure 0.91 m with a weight of 1340 kg/m crosses the above trench (width 1.22 m) in wet clay. Find the superimposed load transmitted to the pipe (in kg/m). Also, determine the total load on the pipe.

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Contd.... for Q. No. 7

(b) "Pit latrines" are not hygienic latrines. For what type of areas/scenarios are these latrines recommended? **(10)**

What are the relative advantages and disadvantages of a ROEC latrine over a VIP latrine?

Why are different values of the parameter "C" (solids accumulation rate) used for "pit" and "pour-flush" latrines?

(c) Define the following: **(10)**

(i) Self-cleansing Velocity
(ii) Combined Sewer System
(iii) Infiltration and Inflow of a Sewer System
(iv) Interceptor Sewers
(v) Sustained Loading

8. (a) List the major processes that occur in a septic tank. **($26\frac{2}{3}$)**

Design a "septic tank system" for a family of 12 members. The estimated wastewater flow rate is 90 lpcd, and the desludging frequency is 2 years. The hydraulic detention time of the tank should be at least 1 day in order to maintain acceptable effluent quality. Also, draw:

(i) A plan view of the designed septic tank (consider two chambers)
(ii) A section showing depths of different zones of the septic tank, and
(iii) A section showing the positions and sizes of inlet and outlet devices, dimensions of the vertical legs of the inlet and outlet devices, partition wall, and the vent pipe.

[Consider a design temperature of 23°C; assume reasonable values for parameters not given]

(b) Draw a flow diagram showing the treatment processes commonly employed for treating fecal sludge. What are the common options for the processing of dried sludge? **(10)**

The estimated population of a town is 45,000, and the average family size is 5. Among the households, 30% use single-pit pour-flush latrines, 20% use alternating twin-pit latrines, and 50% use septic tank systems. The average size of a pit is 1.5 m^3 and that of a septic tank is 3.0 m^3. If 85% of all types of containments are accessible and the average desludging frequency is 2 years, estimate the volume of fecal sludge that needs to be desludged every working day (consider six working days a week).

(c) Draw the schematic diagram for Hydogen Sulfide generation in a sewer carrying wastewater with DO of more than 1 mg/L. Explain the reactions taking place in such wastewater in a sewer. **(10)**

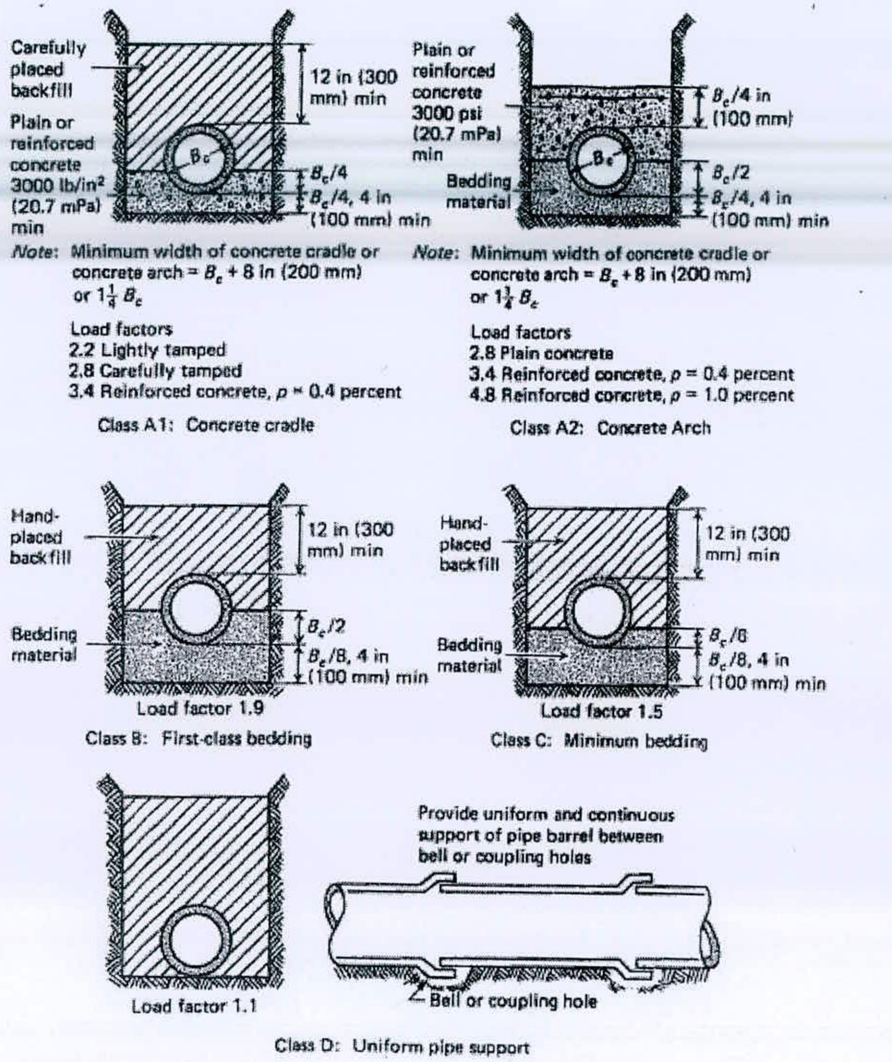


FIGURE 14-4
Methods of bedding clay pipe and load factors applicable to strength. (*Reprinted by permission of the American Society for Testing and Materials, Copyright 1977.*)

Figure for Question 7(a)

TABLE 14-1
Minimum crushing strength of clay pipe (*reprinted by permission of the American Society for Testing and Materials, copyright 1977*)

Nominal size, in (mm)	Extra strength clay pipe		Standard strength clay pipe	
	lb/linear ft	kg/linear m	lb/linear ft	kg/linear m
4 (100)	2,000	2,980	1,200	1,790
6 (150)	2,000	2,980	1,200	1,790
8 (200)	2,200	3,270	1,400	2,080
10 (250)	2,400	3,570	1,600	2,380
12 (305)	2,600	3,870	1,800	2,680
15 (380)	2,900	4,320	2,000	2,980
18 (460)	3,300	4,910	2,200	3,270
21 (530)	3,850	5,730	2,400	3,570
24 (610)	4,400	6,550	2,600	3,870
27 (690)	4,700	6,990	2,800	4,170
30 (760)	5,000	7,440	3,300	4,910
33 (840)	5,500	8,190	3,600	5,360
36 (915)	6,000	8,930	4,000	5,950
39 (990)	6,600	9,820		
42 (1,070)	7,000	10,410		

Table for Question 7(a)

TABLE 14-9
Proportion of "short" superficial loads reaching pipe in trenches

Ratio of depth to width	Sand and damp topsoil		Saturated topsoil		Damp clay		Saturated clay	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	0.77	0.12	0.78	0.13	0.79	0.13	0.81	0.13
1.0	0.59	0.02	0.61	0.02	0.63	0.02	0.66	0.02
1.5	0.46		0.48		0.51		0.54	
2.0	0.35		0.38		0.40		0.44	
2.5	0.27		0.29		0.32		0.35	
3.0	0.21		0.23		0.25		0.29	
4.0	0.12		0.14		0.16		0.19	
5.0	0.07		0.09		0.10		0.13	
6.0	0.04		0.05		0.06		0.08	
8.0	0.02		0.02		0.03		0.04	
10.0	0.01		0.01		0.01		0.02	

Table for Question 7(a)

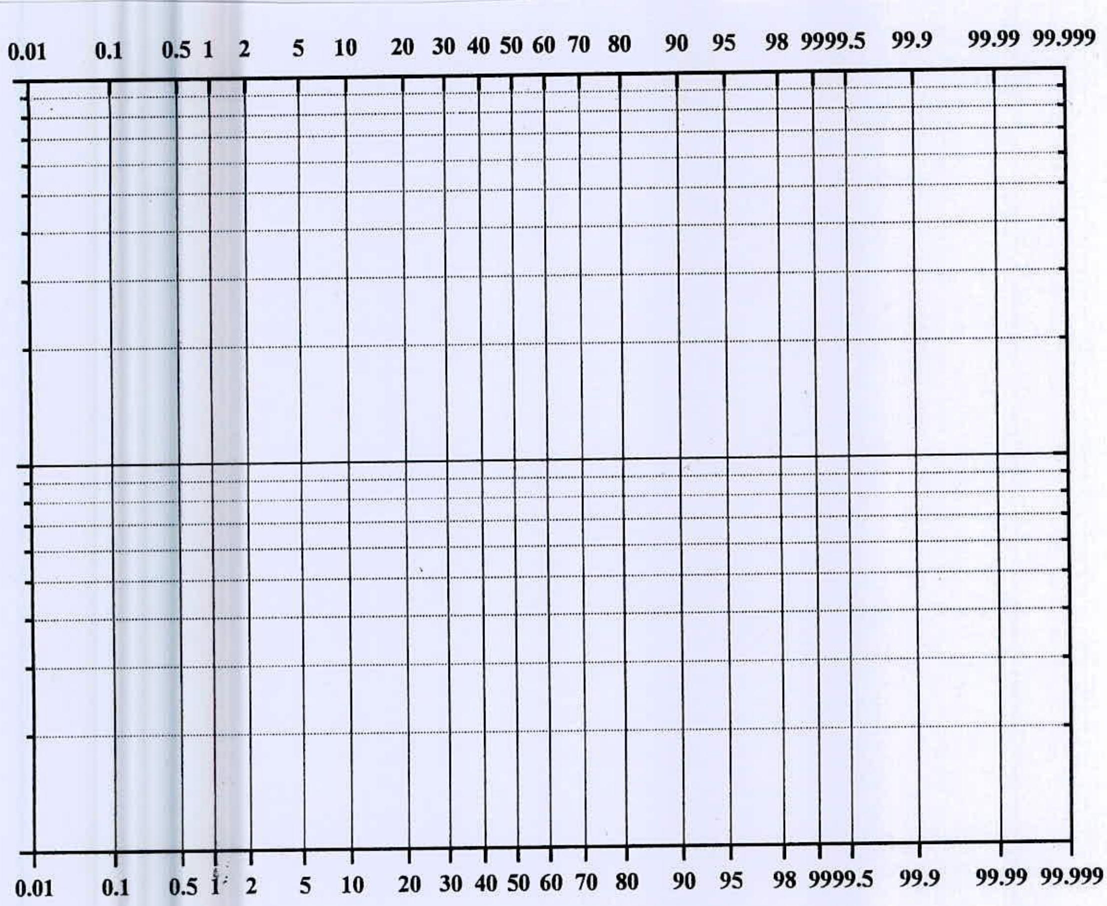


Figure for Q.# 5(a)

L-3/T-2/CE **Date: 05/04/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2020-2021

Sub: **CE 351** (Transportation Engineering I: Transportation Planning & Traffic Engineering)

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) Explain the importance of system approach in transport sector using transport system model diagram with its components. Discuss the system analysis steps with particular reference to Dhaka Urban Transport System. **(10+10=20)**

(b) Discuss four categories of human behavior that are affected by transportation. Also, discuss four properties of the physical environment that have a direct impact on human behavior. **(8+7=15)**

2. (a) Explain the parameters for measuring Transport System performance. Critically compare various transportation modes using the performance parameters for generalized situation. **(10+10=20)**

(b) Discuss various factors influencing urban transport pattern with critical reference to various cities. Also, discuss the emerging transport technologies with their application potentials. **(8+7=15)**

3. (a) Develop a comparative table showing capacity, cost, flexibility, safety and implementation difficulties features of public transport modes: Elevated Metro Rail in City, Bus Rapid Transit (BRT) on arterial, and Commuter Train (CT) in large city surrounding. Explain city public transport issues in general and relevant service design issues in particular. **(11+8=19)**

(b) Write short notes on: i. Investment of transport modes in Bangladesh ii. Road network development in Bangladesh iii. Urban Transport Development in Bangladesh iv. Shortcomings of Bangladesh Railway development. **(4×4=16)**

4. (a) Explain the following: **(3×5=15)**

i) Design Speed

ii) Design Vehicle,

iii) Transition Runoff

iv) Widening of Curves.

v) Stopping sight distance (SSD)

Contd P/2

CE 351

Contd... Q. No. 4

(b) What is meant by "Transportation Planning"? Show with a neat sketch the basic elements of transportation planning. Show with neat sketches the minimum passing sight distance for a two-lane two-way highway for right-hand drive vehicle and keep-to-left convention. **(10+10=20)**

SECTION – B

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

5. (a) In road safety studies, what is the difference between an "accident" and a "crash"? Show the following collisions at a cross-intersection with a collision diagram: (i) rear-end, (ii) right angle, (iii) side swipes and (iv) head-on. **(11)**

(b) State the advantages and disadvantages of a rotary intersection. **(12)**

(c) Show diagrammatically the method of attaining super elevation considering pavement revolved about inside edge. **(12)**

6. (a) Explain why traffic engineering is so important. Write short note on PIEV, PCU and VMS. Exactly how is "before-after" spot speed studies used? **(3+6+2=11)**

(b) State the main objectives of following studies: **(3×4=12)**

(i) Volume (iii) Speed-delay

(ii) Speed (iv) Origin – destination

(c) Briefly differentiate between: **(6)**

(i) Induced Flow and Tidal Flow

(ii) Recurrence delay and Non-Recurrence delay

(iii) Time-mean Speed and Space-mean Speed

(d) A traffic engineer urgently needs to determine AADT on a rural primary road that has the volume distribution characteristics shown in Tables 1, 2 and 3. The engineer collected following data on a Wednesday during the month of June. Determine the AADT of the road. **(6)**

Hour	Volume
6:00-7:00 a.m.	700
8:00-9:00 a.m.	800

7. (a) Name the common bottlenecks of roadway system. Briefly differentiate between 'on-street' parking and 'off-street' parking. In order to develop parking facilities in a systematic manner, what steps should be taken? Is it necessary to have roadway capacity and flow-fluctuation information for proper implementation of on-street parking schemes? If yes, why? **(4+3+2+2=11)**

Contd P/3

CE 351

Contd... Q. No. 7

(b) Name the different types of traffic surveys that are usually undertaken in Transportation Engineering. Draw travel movement patterns (O-D) of a city. Write down the problems associated with the larger sized vehicles and state what sorts of regulations are needed to ensure proper functioning and effective use of a terminal? **(4+4+4=12)**

(c) An urban central business street, with 65 ft pavement width having a reflectance of 20%, carriers a maximum of 1150 vph at night time in both directions. Design the lighting system of the road considering mercury light as a source with mounting height of 30 ft and a maintenance factor of 0.8. Draw the lighting layout. Necessary information are given in Tables 4 to 7 and in Figure 1. **(7)**

(d) Spot speed data were collected at a section of highway during an improvement work. The speed characteristics are given below. Determine whether there was any significant difference between the average speeds at the 95% confidence level. **(5)**

U_1	=	40.0 mph	U_2	=	38.0 mph
S_1	=	8.0 mph	S_2	=	7.0 mph
n_1	=	290 no.	n_2	=	300 no.

8. (a) List different traffic control devices and state the FIVE general requirements of them. Mention the main objectives of traffic control devices. Differentiate between traffic signs and markings. **(4+3+4=11)**

(b) Discuss briefly the new trend in roadway signs and marking. Under what circumstances does the all-red period have to be considered in traffic signal design? List different types of signal controllers and differentiate between pre-timed signal and vehicle-actuated signal controllers. **(4+3+5=12)**

(c) Design a two-phase signal of an isolated cross-junction for the following data. **(12)**

		N-S phase	E-W phase
Inter-green period	=	4 sec	5 sec
Initial and final lost time	=	3 sec	2 sec

		North	South	East	West
Flow (pcu/hr)	=	700	400	800	600
Saturation flow (pcu/hr)	=	2000	1800	2200	2100

Assume reasonable value for any missing data. Draw the phase and cycle time bar diagram.

FOR Q. 6(d)

Table 1 Hourly Expansion Factors for a Rural Primary Road

Hour of Day	Volume	HEF	Hour	Volume	HEF
6:00-7:00 a.m.	294	42.01	6:00-7:00 p.m.	743	16.62
7:00-8:00 a.m.	426	28.99	7:00-8:00 p.m.	706	17.49
8:00-9:00 a.m.	560	22.05	8:00-9:00 p.m.	606	20.38
9:00-10:00 a.m.	657	18.8	9:00-10:00 p.m.	489	25.26
10:00-11:00 a.m.	722	17.11	10:00-11:00 p.m.	396	31.19
11:00-12:00 p.m.	667	18.52	11:00-12:00 a.m.	360	34.31
12:00-1:00 p.m.	660	18.71	12:00-1:00 a.m.	241	51.24
1:00-2:00 p.m.	739	16.71	1:00-2:00 a.m.	150	82.33
2:00-3:00 p.m.	832	14.84	2:00-3:00 a.m.	100	123.5
3:00-4:00 p.m.	836	14.77	3:00-4:00 a.m.	90	137.22
4:00-5:00 p.m.	961	12.85	4:00-5:00 a.m.	86	143.6
5:00-6:00 p.m.	892	13.85	5:00-6:00 a.m.	137	90.15

Table 2 Daily Expansion Factors for a Rural Primary Road

Day of Week	Volume	DEF
Sunday	7895	9.515
Monday	10714	7.012
Tuesday	9722	7.727
Wednesday	11413	6.582
Thusrday	10714	7.012
Friday	13125	5.724
Saturday	11539	6.51

Table 3 Monthly Expansion Factors for a Rural Primary Road

Month of Year	ADT	MEF
January	1350	1.756
February	1200	1.976
March	1450	1.635
April	1600	1.482
May	1700	1.395
June	2500	0.948
July	4100	0.578
August	4550	0.521
September	3750	0.632
October	2500	0.948
November	2000	1.186
December	1750	1.355

FOR Q. 7(C)

TABLE 4 RECOMMENDED AVERAGE ILLUMINATION (LUMENS/FT^2)

Pedestrian traffic(1)	Vehicular traffic(2) (vph)			
	Very light (<150 vph)	Light (150 – 500 vph)	Medium (500 – 1,200 vph)	Heavy (>1,200 vph)
Heavy	-	0.8	1.0	1.2
Medium	-	0.6	0.8	1.0
Light	0.2	0.4	0.6	0.8

Notes:
(1) Heavy: As on main business street
Medium: As on secondary business streets
Light: As on local streets
(2) Night hour flow in both directions

TABLE 5 ADJUSTMENT FACTORS FOR RECOMMENDED AVERAGE ILLUMINATION VALUES

Surface Reflectance	Adjustment Factors
3 % or less	1.5
10%	1.0
20% or more	0.75

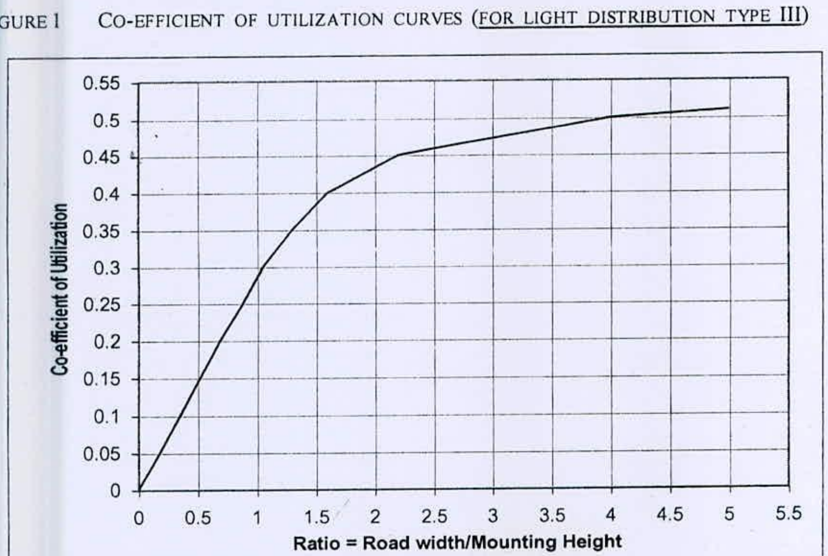
TABLE 6 LIGHTING SOURCE CHARACTERISTICS

Source Types	Expected Life (hrs)	Lighting Efficiency (Lumens/Watt)	Wattage (Watt)
Tungsten	1000	8 – 14	Up to 1000
Fluorescent	6000	50 – 75	Up to 250
Sodium	6000	100 – 120	Up to 160
Mercury	7500	20 – 60	Up to 400

TABLE 7 RECOMMENDED ARRANGEMENT OF STREET LIGHTING

Type of Arrangement	Pavement Width
One side	Width <= 30ft
Both sides – Staggered	30ft > Width <= 60ft
Both sides – Opposite	Width > 60ft

FIGURE 1 CO-EFFICIENT OF UTILIZATION CURVES (FOR LIGHT DISTRIBUTION TYPE III)



Note: Due to poor maintenance, the actual co-efficient of utilization is reduced by a factor usually 0.8 (i.e. taken as 80%).

L-3/T-2/CE **Date: 29/03/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2020-2021

Sub: **WRE 311** (Open Channel Flow)

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.

1. (a) In a rectangular channel the flow has a free overfall. The velocity measurements at the end of the overfall are shown in the figure. Estimate the discharge per unit width of the channel. **(10)**

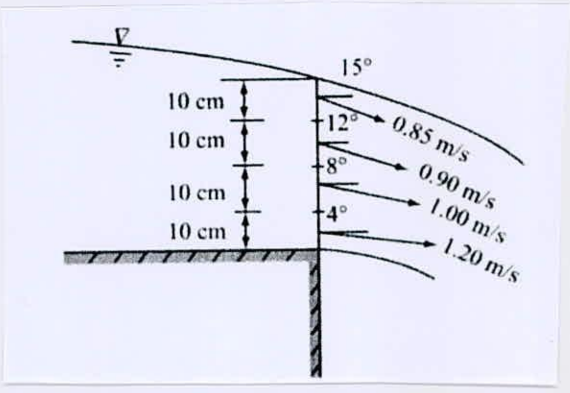


Figure 1 for question 1(a)

(b) At a bridge crossing, the mean flow velocities (in m/s) were measured at the midpoints of various subareas as shown in figure 2. Computer the values of α and β. Also determine the state of flow for the channel. **(20)**

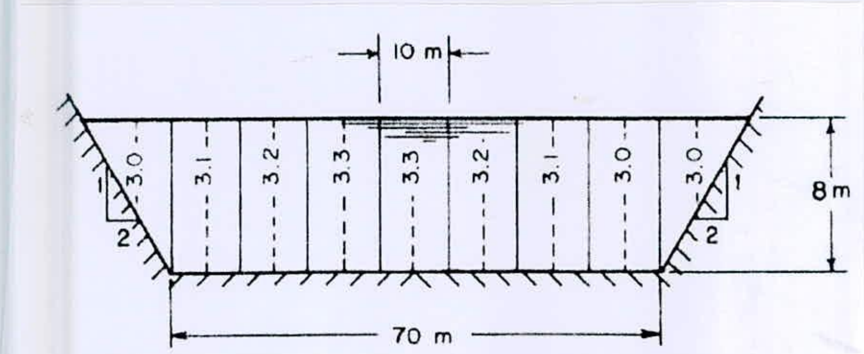


Figure 2 for question 1(b)

(c) While computing the bending moment and shear force acting on the sidewalls of a spillway chute shown in figure 3 a structural engineer assumed hydrostatic pressure distribution at the invert of the chute. What are the computed values of bending moment and shear force at the invert level? Are these computed results, correct? If not compute the percentage error. **(16 $\frac{2}{3}$)**

Contd P/2

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Contd… Q. No. 1(c)

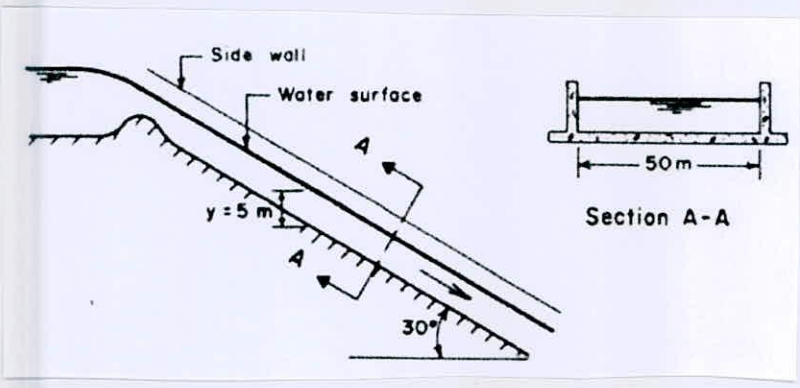

Figure 3 for question 1(c)

2. (a) Show that for a triangular section the relationship between critical depth and alternate depths can be expressed as, **(10)**

$$\frac{4y_1^2y_2^4}{(y_1^2+y_2^2)(y_1+y_2)}=y_c^5$$

(b) What flows in a rectangular channel at a depth of 1.5m. A 30cm high smooth hump produces a drop of 15cm in the water surface elevation. Estimate the discharge per unit width of the channel considering an energy loss of 10% of the approach velocity head. **(16)**

(c) The drainage canal shown in figure has a flow of 96 m^3/s. If the flow depth at section 1 is 4.22m what is the depth at section 2? Assume there is energy loss 10% of the upstream velocity head in the transition. Also determine the flow depth at the downstream end if the canal ends in a free overfall. Assume that critical depth occurs at the overfall. **($20\frac{2}{3}$)**

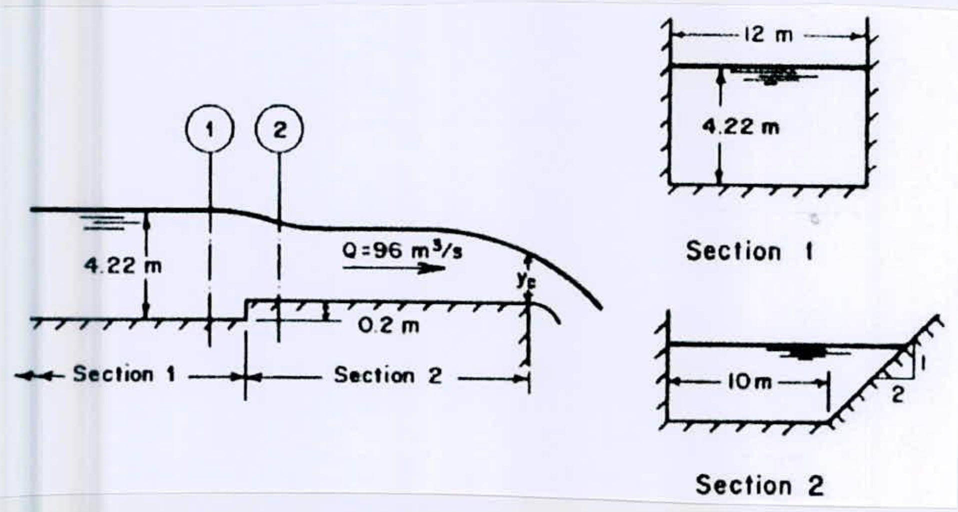

Figure 4 for question 2(c)

3. (a) A sluice gate in a 3 m wide rectangular channel releases a discharge of 18 m^3/s. The gate opening is 0.67m and the coefficient of contraction can be assumed to be 0.6. If a hydraulic jump forms in this channel, determine.

Contd …… P/3

WRE 311

Contd... Q. No. 3(a)

a. the type of jump

b. The downstream depth needed to form the jump

c. The horsepower dissipation in the jump

d. The efficiency of the jump

e. The relative height of the jump

f. the length of the jump using Sliverster formula

g. The force on the gate if the energy loss through the gate is 6% of the velocity head at vena contracta.

h. What would happen to the jump when the tailwater depth is 4.96m?

i. What would be the length of the jump if the channel was laid on a slope of 1 horizontal and 0.15 vertical.

j. Calculate the sequent depth of the jump for this slope. **(30)**

(b) An overflow spillway has its crest at 125.40m elevation and a horizontal apron at an elevation of 95.00 m on the downstream side. Find the tailwater elevation required to form a hydraulic jump when the elevation of energy line is 127.90m. The C_d for flow can be assumed as 0.735. The energy loss for the flow over the spillway can be neglected. **($16\frac{2}{3}$)**

4. (a) Show that for best hydraulic trapezoidal section is half of a regular hexagon. **(10)**

(b) A trapezoidal channel carrying $20 m^3/s$ is built with non-erodible bed having a slope of 1 in 1000 and manning's roughness n = 0 0.025. Design the channel by the concept of best hydraulic section method. **($16\frac{2}{3}$)**

(b) Design a slightly sinuous trapezoidal channel for a design discharge of $10\ m^3/s$. The bottom slope is 0.00025 and the channel is excavated through fine gravel having particle size of 8mm. Assume particles are moderately rounded and the water carries sediments at low concentrations. **(20)**

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Contd... Q. No. 4(c)

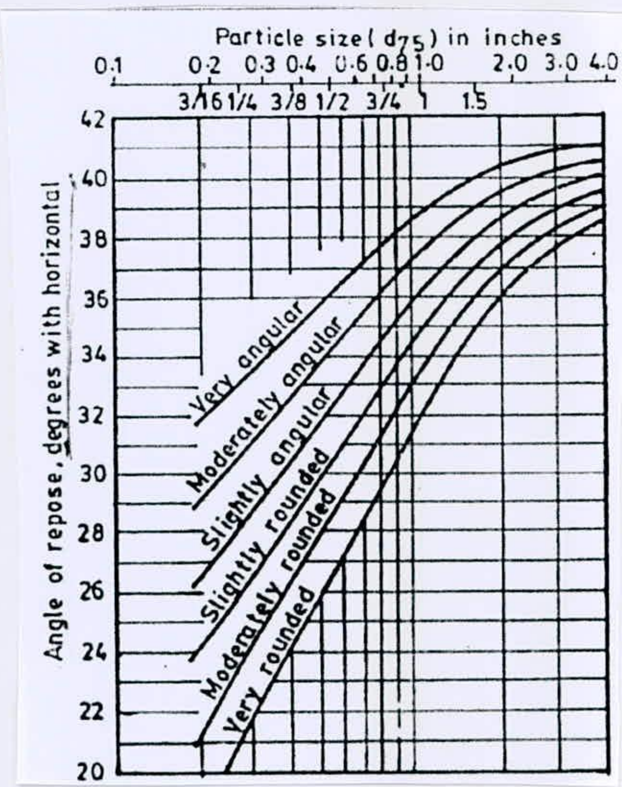

Figure 5 for question 4(c)

SECTION – B

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

5. (a) Classify the following open channel flow situations: **(9)**

   i. River flow around a bridge pier

   ii. Flow in a long prismatic irrigation canal

   iii. Flow due to breaking of a dam

   (b) Sketch the possible gradually varied flow profiles in the following serial arrangement of channels and control. The flow is from left to right. **(12)**

   i. free intake-steep slope-sluice gate-mild slope

   ii. steep slope-sluice gate in mild slope-sudden drop

   iii. overflow weir on mild slope-steep slope-horizontal slope-sudden drop

   (c) A symmetrical channel consists of a main river and two floodplains. The main river is trapezoidal with bottom width of 10.0m and side slope as 2H: 1V. Each floodplain is a 10.0 m wide rectangular section. The maximum water depth in the main channel is 15.0m whereas the water depth in each floodplain is 5.0m. Consider the channel bed slope as 1 in 10000 and Manning's roughness co-efficient, n as 0.015 and 0.030 for main river and floodplains respectively. **($16\frac{2}{3}$)**

   i. Compute the total discharge and mean velocity of flow for the entire section

   ii. Compute the numerical values of roughness co-efficient, energy and momentum correction factors for the entire section.

Contd P/5

WRE 311
Contd... Q. No. 5

(d) What diameter of a semi-circular channel will have the same discharge as a rectangular channel of 2.25m width and depth of flow of 1.25m? Assume the bed slope and Manning's roughness co-efficient, n have the same values in both the channels. **(9)**

6. (a) Using the Manning's formula, determine the hydraulic exponent for uniform flow, N for the following channel sections **(16)**

   i. a very narrow rectangular channel

   ii. an equilateral triangle with a vertex at the bottom

   (b) Compute the normal depth of flow of any natural river. Use simplified trapezoidal section and assume reasonable data for the natural river. Use Newton-Raphson method for your computation. **(15)**

   (c) During a flood flow the depth of water in a 10.0m wide rectangular channel was found to be 3.0m and 2.9m at two sections 200.0m apart. The drop in water surface elevation was found to be 0.12m. Assume Manning's roughness co-efficient, n = 0.025. Estimate the flood discharge through the channel by slope-area method. **($15\frac{2}{3}$)**

7. (a) Is uniform flow possible in an adverse sloped channel? Explain your answer. **($6\frac{2}{3}$)**

   (b) Using the dynamic equation of gradually varied flow, show that dy/dx is positive for Sl and M3 profiles. **(10)**

   (c) Deduce the expression for the length of flow profile between two sections in a wide channel by Bresse method. Consider that the conveyance is expressed in terms of Chezy formula. **(12)**

   (d) A rectangular channel of 6.0m width and a bed slope of 0.006 is carrying a discharge of $5m^2/s$. A barrier of height 4.0m is constructed across the channel to raise the water level. Compute the gradually varied flow profile upstream of the barrier. Consider that the rectangular channel is wide channel and use Bresse method for computation. **(18)**

8. (a) A rectangular channel of width 2.0m is made of glass (manning's roughness co-efficient, n=0.01). The channel allows water to freefall after traversing a length of 50.0m. The channel bed drops by 5.0cm in the entire length. At the entrance of the channel, the water depth is observed to be constant at 0.5m whereas critical flow is occurring at the freefall end of the channel. Compute the length of the gradually varied flow profile from the freefall brink to a section where the depth of flow is 0.45m. Use direct step method for determining the flow profile length. **(20)**

Contd P/6

WRE 311
Contd... Q. No. 8

(b) A 3.0m wide rectangular channel has a longitudinal slope of 150mm/km and Manning's roughness coefficient, n = 0.02. When the discharge is 0.85 cumecs, estimate the slope of water surface in the channel (relative to horizontal) at a point where the depth of flow is 0.75m. **(13)**

(c) A sluice gate in a 2.0m wide rectangular channel is discharging water freely. The depth of water upstream and downstream of the sluice gate is 2.5m and 0.2m respectively. Compute the channel discharge by assuming energy loss at the gate as 10% of the upstream depth. **($13\frac{2}{3}$)**
