L-3/T-2/CE **Date : 09/06/2014**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2011-2012

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

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**.

1. (a) List the goals of environmental engineering profession. Differentiate between "natural needs" and "acquired needs" of humans. **(10)**

   (b) List the objectives of the water supply system and the drainage system of a building. What are the drawbacks of high water pressures in the water supply system of a building? **(9)**

   (c) How will you ensure the non-contamination of supplied water in buildings? What are the considerations of water supply in a tall building? **(9⅓)**

   (d) Write down the two special considerations in designing riser pipe for downfeed zones. How will you evaluate the fitting friction of a water supply pipe line? **(8)**

   (e) Calculate the permissible pressure loss per 100 ft of the riser pipe to supply water in the top-most floor of a building from the following data: **(10)**

   The water supply is intermittent.

   The minimum fixture pressure = 5 psi

   The maximum fixture pressure = 10 psi

   Assume reasonable values for the missing data.

2. (a) What is a fixture trap? What do you understand by strength of a trap and how will you measure it? **(9)**

   (b) Differentiate between "self siphonage" and "induced siphonage" of a building drainage system. How will you avoid these? **(6)**

   (c) What is sustainability of water supply and sanitation systems? List the indicators to measure it. **(11)**

   (d) What is an appropriate technology? List the basic features of it. Why is the conventional water borne sewerage system not suitable for Bangladesh? **(14)**

   (e) Define EIA. Provide a typical outline of the preliminary assessment of the EIA process. **(6⅔)**

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3. (a) State the objectives of preparatory, primary, secondary and advanced treatment methods of wastewater. **(12)**

(b) Discus the principle of wastewater treatment in "Activated sludge Process" and "Trickling Filter Process". What are the advantages of Activated Sludge Process over traditional Waste Stabilization Ponds system? **(19⅔)**

(c) The BOD_5 of a wastewater is determined to be 250 mg/L at 20°C. The reaction rate constant is known to be 0.26/d (base e). What would be the BOD_{20} if the test were run at 30°C? Assume reasonable value of any missing data, if required. **(15)**

4. (a) Explain the symbiosis between bacteria and algae in a facultative pond. **(10⅔)**

(b) State and derive "Marai's Theorem" in relation to Waste Stabilization Ponds system. **(10)**

(c) A trickling filter has a depth of 10 ft, surface area of 18000 ft^2, inflow rate of 4 mgd and a recirculation rate of 200% of the inflow. The influent wastewater BOD_5 is 250 mg/L following primary treatment. Determine the effluent BOD_5. Use the following expressions: **(14)**

$$L_e / L_f = 1/\left(1 + 2.5\, D^{0.67}/Q^{0.5}\right)$$
$$L_f = \left(L_i + RL_e\right)/\left(1 + R\right)$$

where the symbols have their usual meanings.

(d) In a series of three ponds, the hydraulic retention time of wastewater in the first, second, and third ponds are 5 days, 6 days, and 5 days, respectively. Influent FC count is 5×10^6/100 mL. Calculate the FC count in the effluent from the series of ponds. Given, $k_b = 2.3$/d. **(12)**

SECTION – B

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

5. (a) A WWTP employing biological treatment has been designed for long-term average inflow of 55 g/m^3 NH_3-N and 20 g/m^3 P. Given the average flow rate of 2 m^3/s, draw the sustained low-flow loading curves for NH_3-N and P using the typical curves provided in Figure 5(a). **(26⅔)**

(b) Differentiate between "100% sanitation" and "total sanitation". With an appropriate figures, show how disease is transmitted from excreta via different routes along with sanitation barriers for prevention of disease transmission. **(10)**

(c) How does a "pour-flux latrine" differ from a "pit latrine"? What are the main advantages of an "offset twin-pin pour-flush latrine" over an "offset single-pit pour flush latrine"? Explain. **(10)**

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6. (a) A trunk sewer is to be sized for a 25 km^2 (2,500 ha) city which is naturally sloped towards the major river with a gradient of 1 in 1000. It will be 60% residential, 30% commercial, and 10% industrial. The residential area will have 40% large lots, 55% small single family lots, and 5% multi-story apartments. The average domestic wastewater flow rate is 800 L/d/capita ($9.26 \times 10^{-6} m^3$/sec/person), the average commercial flow rate is 25,000 L/d/ha ($2.89 \times 10^{-4} m^3$/sec/ha), and the average industrial flow rate is 40,000 L/d/ha ($4.63 \times 10^{-4}/m^3$/sec/ha). I&I is 1,000 L/d/ha for the entire area. Estimate the peak and minimum flows to be handled by the trunk sewer. Given: $\mathbf{Q_{peak}/Q_{avg} = 5.5/ (p^{0.18})}$ **and** $\mathbf{Q_{min}/Q_{avg} = 0.2/ (p^{0.16})}$, where ***'p'*** is the total city population in thousands. Also design the sewer based on the estimated flow and the saturation densities for the residential areas given in the table below: **(26⅔)**

Type of area	**Density (persons/ha)**
Large lots	5–7
Small lots, single-family	75
Small lots, two-family	125
Multistory apartments	2,500

[Hydraulic element diagram is provided in Figure 6(a)]

(b) A "Sand Envelope" is often provided around latrine pits in: (i) high water table areas, and (ii) areas having compacted clayey soil. Explain the purpose of "Sand Envelope" for each. **(10)**

(c) How does the design of sewer network in SBS system differ from that in a conventional system? How does an SBS system influence treatment processes in a sewage treatment plant? Explain. **(10)**

7. (a) You need to design a septic tank for a family of 11 members. The estimated wastewater flow rate is 100 lcpd, and the tank is to be desludged every two years. The hydraulic retention time of the tank should be at least 1 day in order to maintain acceptable effluent quality. **(26⅔)**

Draw:

(i) A plan of the designed septic tank showing the dimensions of the chambers (considering two chambers),

(ii) A section showing the depths of different zones of the septic tank, and

(iii) A section showing the positions and dimensions of inlet and outlet devices.

[Assume a design temperature of 22°C; Assume reasonable values for parameters not given]

What options are commonly available for disposal of septic tank effluent? What option is commonly used in Bangladesh?

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(b) The conventional method of ranking a set of values for plotting Cumulative Density Function uses the expression **m/(n + 1)**. However, the Blom's Transformation suggests the use of the expression **(m – 3/8)/(n + $^1/_4$)**. What is the justification of using Blom's Transformation compared to the conventional method? **(10)**

(c) You have been given the responsibility to plan crossing of a sewer line across the Airport road near Kuril Interchange. Which agencies do you need to contact during planning and construction stages. Provide brief reasons for contacting each of these agencies. **(10)**

8. (a) Design a suitable latrine for a family of 6 members living in a village where tubewell-based water supply system is available. Estimated water use for the larine is 12 lpcd, and estimated long-term infiltration capacity of the soil in the area is 26 L/m^2.day. The groundwater table is 3.6 m below the ground surface. The pit is to be constructed with concrete rings 1.0 m in diameter and 0.30 m in depth. Mechanical desludging facilities are not available in the village. What type of latrine would you suggest for these users? Explain. **(26⅔)**

Design the latrine (including venting system), and estimate its design life. Draw a neat sketch (both plan and section) showing all elements of the designed latrine. Also, write the most important operation and maintenance issue for the designed latrine.

[Assume reasonable values for the parameters not given]

(b) What are the advantages of using Glassfiber Reinforced Pipes (GRP) over Concrete pipes in sewer system? **(10)**

(c) The schematic diagram shown in Figure 8(c) represents the treatment processes adopted at an ETP in a Textile Industry. **(10)**

(i) On a certain working day, it was observed that the flocs are breaking up at the flocculation chamber.

(ii) On another day, the BOD_5 of the effluent exceeded the discharge standard set by the DoE.

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

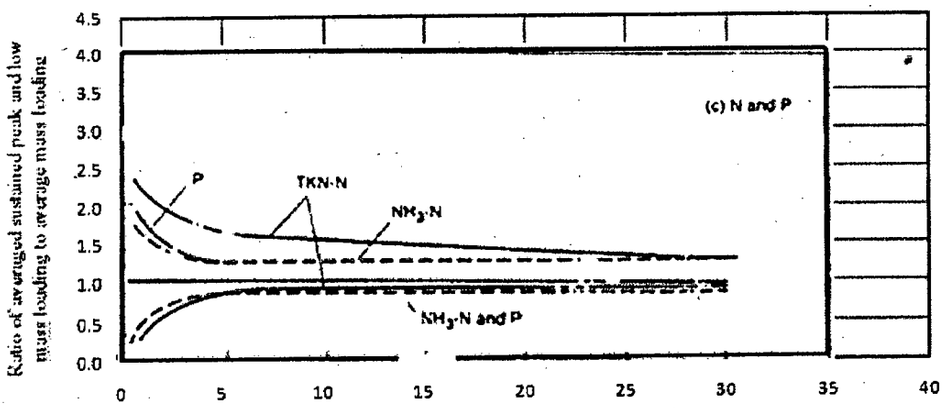

Figure for Question # 5 (a)

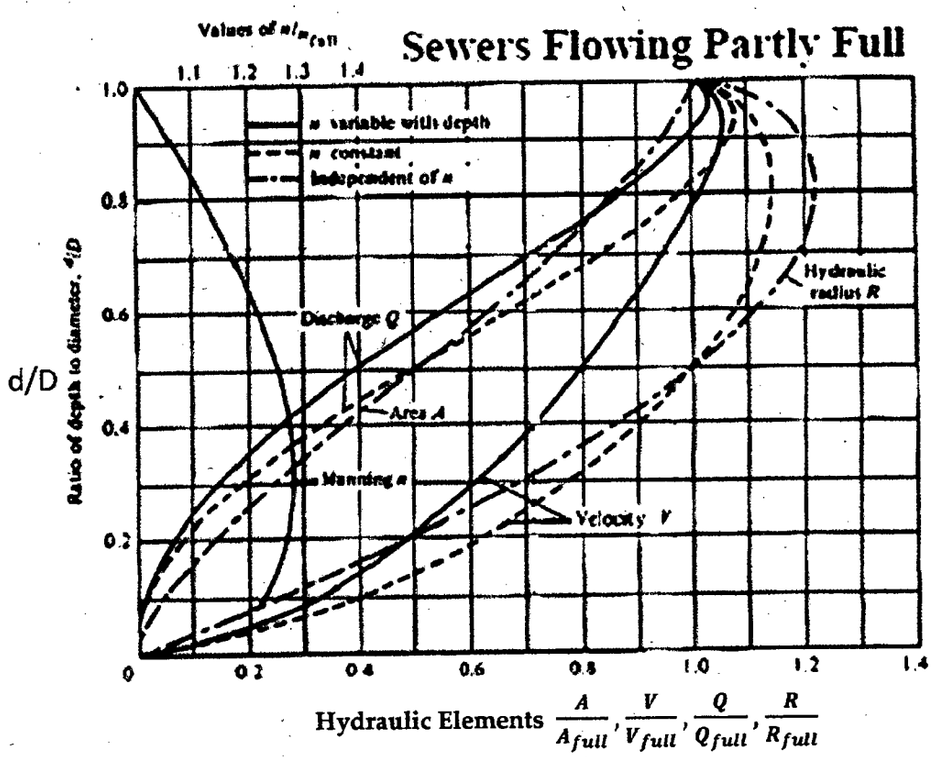

Figure for Question # 6 (a)

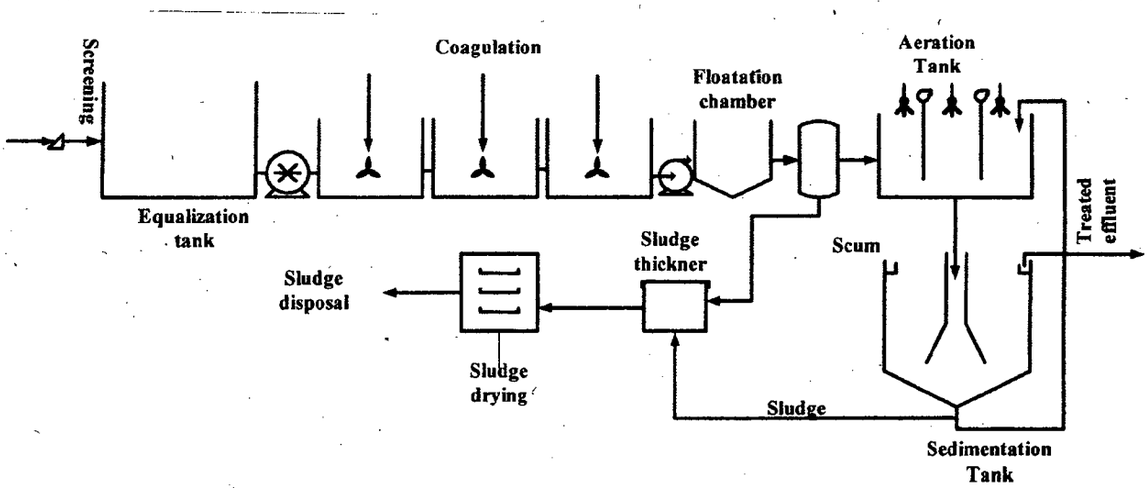

Figure for Question # 8 (c)

L-3/T-2/CE **Date : 12/05/2014**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2011-2012

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**.

1. (a) For column supported slab, 100 percent of the applied load must be carried in each direction - Explain. **(4)**

   (b) State the restrictions of Direct Design Method for analysis of two way slab. **(4)**

   (c) A two-way reinforced concrete building floor system is composed of slab panels measuring 20 ft × 20 ft in plan, supported by shallow column line beams cast monolithically with the slab as shown in Fig. 1. Using concrete strength of f'_c = 4000 psi and steel with f_y = 60,000 psi, design a typical interior panel to carry a service live load of 144 psf in addition to the self-weight of the floor. Show reinforcement in neat sketches. **(27)**

2. (a) What are the common types of shear reinforcement used for flat plates? Show with neat sketches. **(4)**

   (b) A flat plate floor has thickness h = 7½" and is supported by 18 in square columns spaced 20 ft on centers each way. The floor will carry a DL = 160 psf including its self weight and a live load of 90 psf. Check the adequacy of the slab in resisting punching shear and provide shear reinforcement, if needed, using 'bent bars'. Consider d = 6", f'_c = 4000 psi and f_y = 60,000 psi. **(16)**

   (c) A 15-inch concrete wall supports a dead load of 15 kip/ft and a live load of 12 kip/ft. The allowable bearing capacity of soil q_a = 0.12 ksf at the bottom level of footing which is 4 ft below grade. Design the footing with f'_c = 3 ksi and f_y = 40 ksi. Check development length. **(15)**

3. (a) An exterior and interior columns are to be supported by a combined rectangular footing whose outer end cannot protrude beyond the outer face of the exterior column. Column sizes and their respective loads are shown in Fig. 2. The bottom of the footing is 6 ft below grade where the net allowable bearing pressure deducting soil load, self weight of footing and others surcharges is 4000 psf. Determine size of the footing. If d = 18 inch, check adequacy against punching. Also design the transverse beam. **(18)**

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(b) 18" dia cast-in-situ piles shall be provided for a RC column 24" × 24" in section carrying DL = 500^k and LL = 400^k. The allowable load carrying capacity of each pile is 100^k. Pile spacing shall be 3 times the pile diameter. Design the pile cap showing all the reinforcements with necessary details. Given, $f'_c = 4$ ksi and $f_y = 60$ ksi. **(17)**

4. (a) What is ACI spiral? Explain the failure behavior of ACI spirally reinforcement column. **(8)**

(b) Why is seismic detailing essential for earthquake resistant design of structures? Draw and explain seismic detailing provisions for beam of an intermediate moment resisting frame as per ACI/BNBC code. **(10)**

(c) A shear wall of a 16-storey building is subjected to following factored loads:

$P_u = 700^k$

$V_u = 500^k$

$M_u = 7000$ kip-ft.

The wall is 20 ft long, 160 ft high and 12 inch thick. Design the shear wall with $f'_c = 4$ ksi and $f_y = 60$ ksi. Ignore axial force as it is less than balanced load of the section. **(17)**

SECTION – B

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

Assume appropriate value for any missing data.

5. (a) Why are ϕ values lower for compression than those of flexure or shear? What is the significance of using α in column design? **(7)**

(b) Design a square tied column with about 2.5% reinforcement to support unfactored loads: $P_{DL} = 500^k$ and $P_{LL} = 400^k$. Use $f'_c = 4$ ksi and $f_y = 60$ ksi. Also, design the ties required. **(8)**

(c) A 18 × 25 inch column is reinforced with ten No. 9 bars as shown in Fig. 3. Construct the nominal strength interaction diagram for the column with five points corresponding to pure axial load, pure bending, balanced condition, $\varepsilon_s = 0.001$ (tensile), and $\varepsilon_s = 0.003$ (tensile). Also, find corresponding ϕ values for the above points. Assume bending about Y -Y axis. Given: $f'_c = 5$ ksi and $f_y = 72.5$ ksi. **(20)**

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6. (a) The 25 × 25 inch column shown in Fig. 4 is reinforced with twelve No. 9 bars arranged around the column perimeter. Material strengths are f'_c = 4 ksi and f_y = 60 ksi. Using the Load Contour Method, check the adequacy of the column for $P_u = 500^k$, M_{ux} = 325 kip-ft, M_{uy} = 300 kip-ft. Use attached chart. **(17)**

   (b) For the above column, using chart, find the column strength (ϕP_n, ϕM_n) for e = 5" (one directional eccentricity only) **(10)**

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

7. (a) Compare in brief, presstressed concrete with reinforced concrete with respect to serviceability, safety and economy. **(15)**

   (b) Compute the stresses in concrete at section 1-1 of the beam (4'-0" from the left support) shown in Fig. 5. The beam carries a live load of 2.0^k/ft. Use any concept for analyzing the beam. Effective prestress is 200 kips and n = 6. **(20)**

8. (a) Which of the beam, a posttensioned or pretensioned, will undergo a gleater loss? Explain. **(6)**

   (b) Describe briefly the loss of prestress in pretensioned member from each individual source. **(12)**

   (c) A posttensioned concrete member as shown in Fig. 6 is eccentrically prestressed with 1.20 in^2 of steel wires which are anchored at the member ends with a stress of 150 ksi. Assume that the 1.20 in^2 of steel is made up of 4 tendons with 0.3 in^2 per tendon. The tendons are tensioned one after another to the stress of 150 ksi. Compute the loss of prestress at sec. 1-1 due to elastic shortening of concrete. Use n = 6. **(17)**

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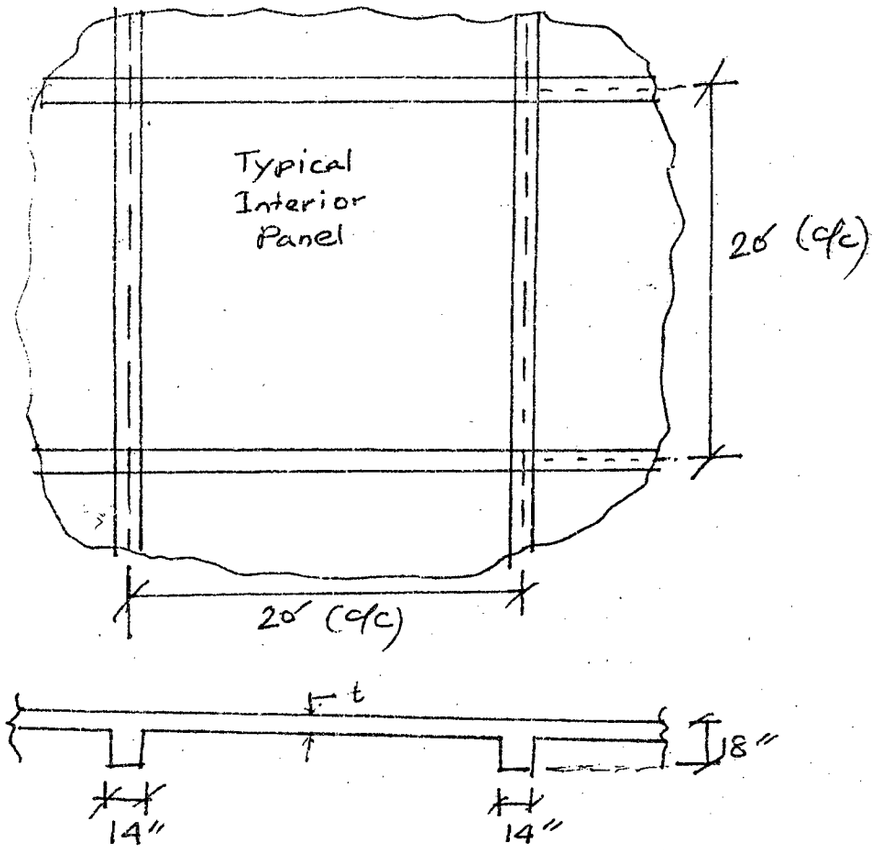

Fig 1.

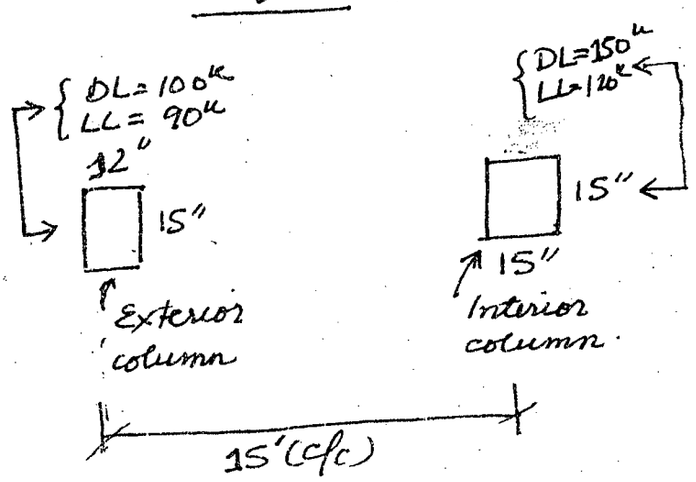

Fig. 2.

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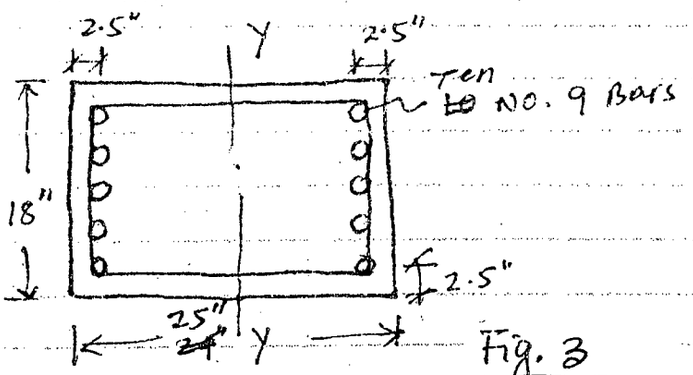
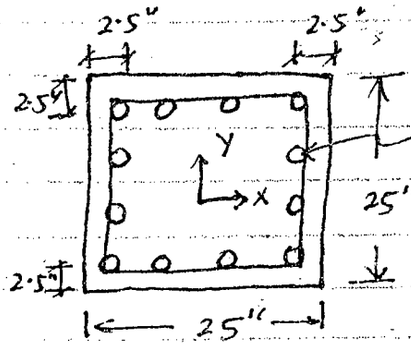


Fig. 3



⇒ Graph A.7

Fig. 4

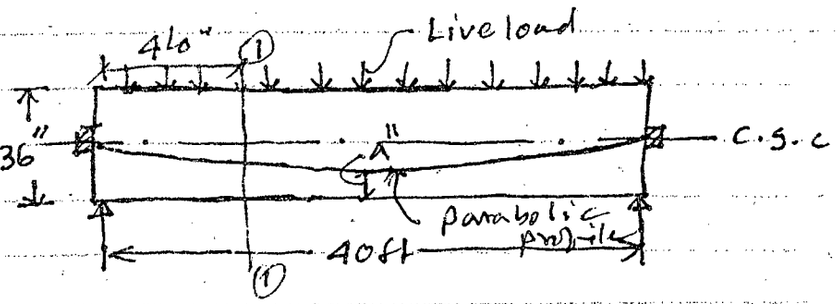
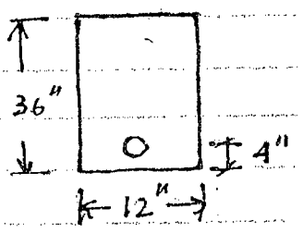
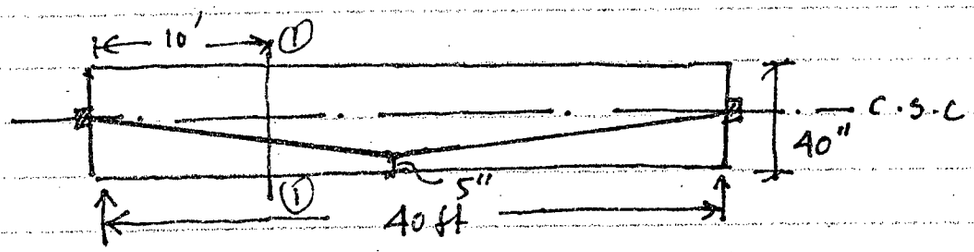
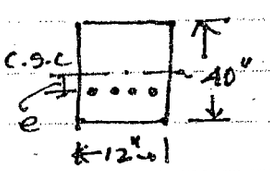


Fig. 5



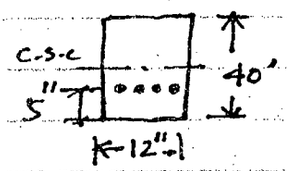
Midspan section





Sec. 1-1

Fig. 6



Midspan section

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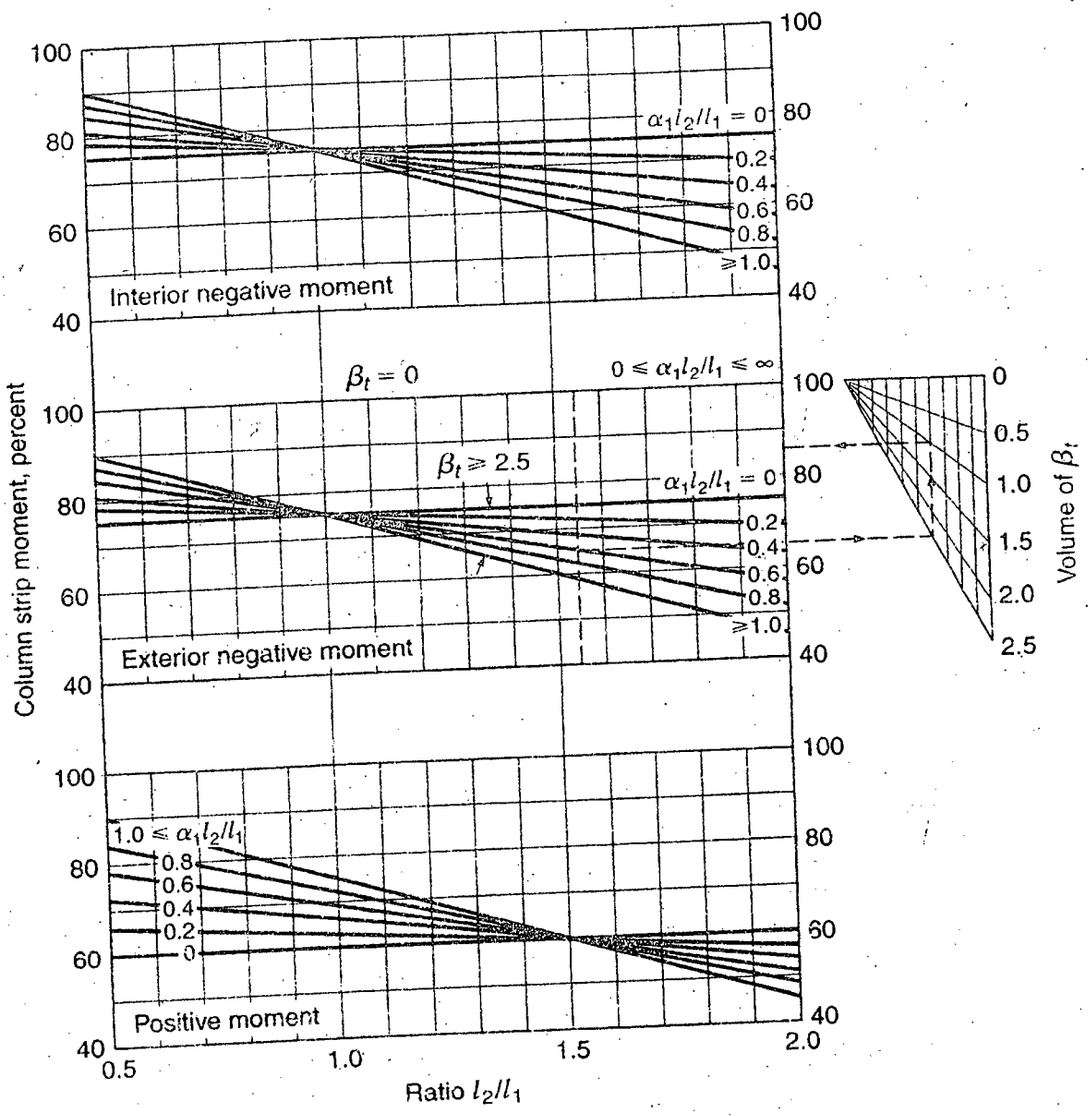
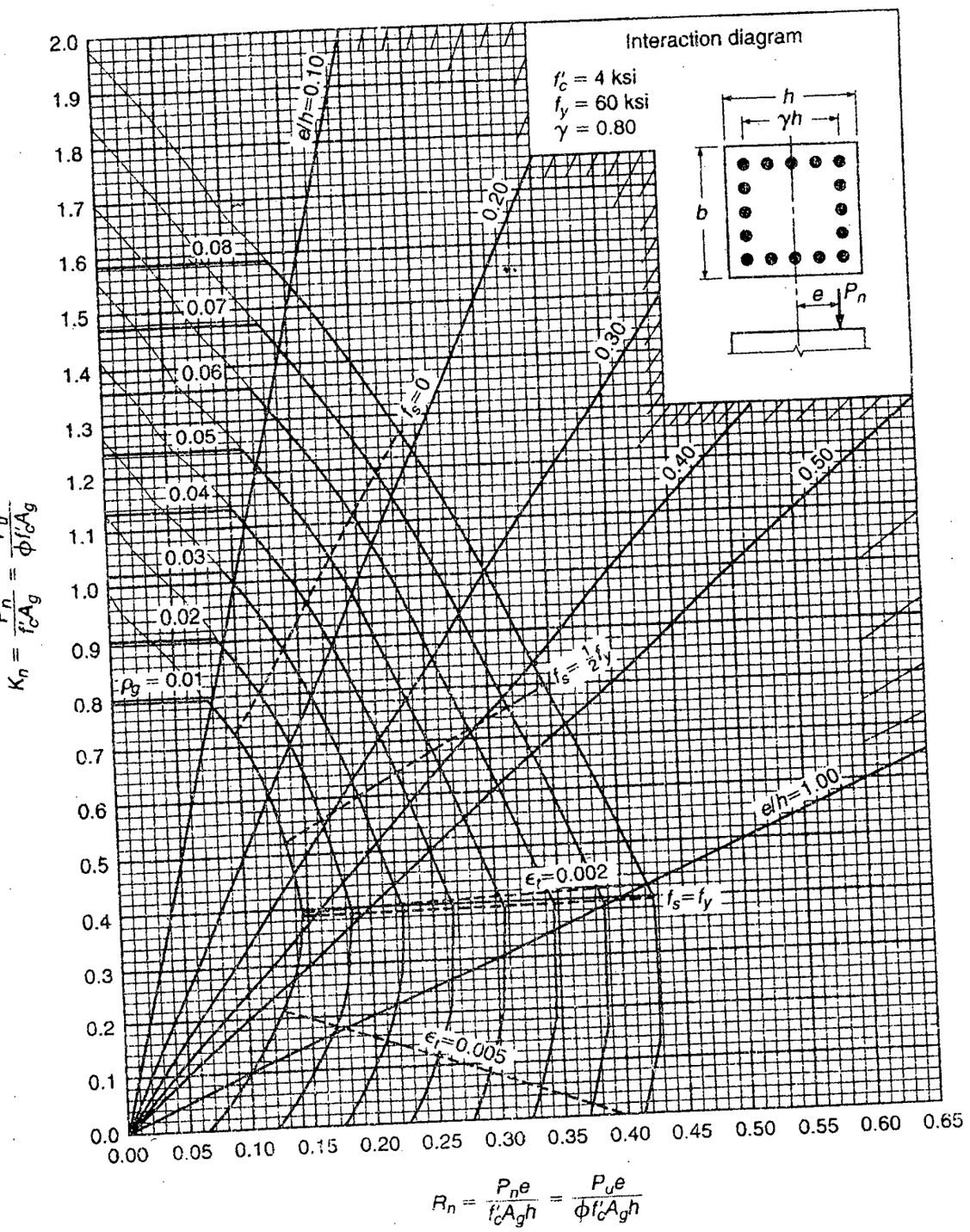

Column strip moment, percent
Interior negative moment
$\alpha_1 l_2/l_1 = 0$
0.2
0.4
0.6
0.8
≥1.0
$\beta_t = 0$
$0 \leq \alpha_1 l_2/l_1 \leq \infty$
$\beta_t \geq 2.5$
Exterior negative moment
$1.0 \leq \alpha_1 l_2/l_1$
Positive moment
Ratio l_2/l_1
Volume of β_t

CE 317



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

L-3/T-2/CE **Date : 26/05/2014**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2011-2012

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

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) Explain different types of traffic that are generally considered in transportation planning process in relation to land use and transport development. **(12)**

   (b) Explain the followings: **(12)**

   (i) Design Speed (ii) Design Designation (iii) Design Vehicle (iv) Level of Service for highway.

   (c) A new office building is expected to add 1000 pedestrians to a 20 ft. sidewalk during the peak 10 min. Period. The sidewalk already has a flow of 1200 pedestrians during the peak period. Around 3 ft. of the width of the sidewalk is used for light posts and other obstructions. Make your comment on the level of service for the sidewalk. **(11)**

2. (a) Explain diagrammatically the traffic movement for a grade separated T-intersection. **(11)**

   (b) Explain recognized bicycle facilities in a roadway for safe bicycle movement. **(12)**

   (c) Determine the minimum passing sight distance for a two-lane, two-way highway for the following conditions: **(12)**

Average speed of the passing vehicle	51 mph
Average speed of the passed vehicle	41 mph
Time of preliminary delay for passing vehicle	4 sec
Average acceleration rate for passing vehicle	1.43 mph ps
Time passing vehicle occupies the opposite lane	10 sec
Safe clearance distance	180 ft.

3. (a) What are the function of shoulder and median in a highway? Why roads are widened at highway curves? **(12)**

   (b) Explain with diagram the general classification of road traffic islands. **(12)**

   (c) A plus 3.0 percent grade intersects a plus 0.9 percent grade at station 50 + 00 and at an elevation of 630.00 ft. Calculate the vertical curve elevations at station 49 + 00 and 51 + 50 for a 500 ft. vertical curve. **(11)**

4. (a) Draw transport demand versus trip characteristic (Trip length, Travel time at speed) graph showing optimum utilization line of walk, bicycle, bus, car and train modes. Considering car ownership level and trip pattern of Dhaka city develop an investment priority option for Dhaka considering above modes. **(15)**

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(b) What are the factors influencing urban transport system? Explain how Dhaka city as a whole and parts of it stand in comparison to ideal "Walking city", "Transit city" and "Automobile city". **(10)**

(c) Explain the geometric and operational feature of six different highway type as suggested by Roads and Highways Department (RHD) of Bangladesh with respective schematic drawings. **(10)**

SECTION – B

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

5. (a) Considering 'Transportation as a system' introduce different forms and tasks of Transportation. **(10)**

(b) What are nine categories of human behavior that are affected by transportation? Explain such behavior of Dhaka city residents under present dilapidated transport condition of Dhaka city. **(15)**

(c) Compare ubiquity, mobility and efficiency characteristics of water, rail and road mode for passenger and freight transportation. Draw reference to Bangladesh conditions for each situation. **(10)**

6. (a) Briefly describe the importance of Traffic Engineering? List the common tools available to the traffic engineer for tackling roadway congestion and safety problems. What are the ways of classifying roadway system? **(6+6+6)**

(b) Briefly characterize pedestrian crossing behavior. Mention the factors which affect drivers' characteristics. Define PIEV and PCU. **(6+6+5)**

7. (a) Write down the objectives and methods of carrying out speed studies and the ways of presenting traffic volume and O-D data? **(6+4)**

(b) Define design parking vehicle and list the steps that are needed in systematic way of developing parking scheme? Explain the importance of street lighting. Enumerate the general requirements of a terminal. **(4+4+4+4)**

(c) An urban secondary road, with 65 ft pavement width having a reflectance of 20%, carries a maximum of 1700 vph at night time in both directions. Design lighting system of the road considering sodium light source (100 wattage bulb of 100 lumen/watt efficiency), with mounting height of 35 ft and a maintenance factor of 0.75. Draw the lighting layout. Necessary information are given in Tables 1-4 and in Figure1. Assume any missing data. **(9)**

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8. (a) Differentiate between : **(4×3=12)**

(i) Recurrent congestion and Non-recurrent congestion

(ii) Conventional sign and variable message sign (VMS)

(iii) Pre-timed signal and vehicle-actuated signal

(b) State the general requirements of traffic control devices. Write down the importance of retro-reflective marking. At what circumstances all-red period is considered in signal design? **(4+4+3)**

(c) Calculate weighted average speed, pace, modal speed, upper and lower speed limits, design speed for the following data: **(12)**

Speed Range (kmph)	No. of vehicle observed (f)
0-5	0
5-10	7
10-15	18
15-20	45
20-25	120
25-30	210
30-35	260
35-40	130
40-45	45
45-50	25
50-55	13
55-60	5
60-65	1
65-70	0

FOR Q. 7(C)

TABLE 1 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 2 ADJUSTMENT FACTORS FOR RECOMMENDED AVERAGE ILLUMINATION VALUES

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

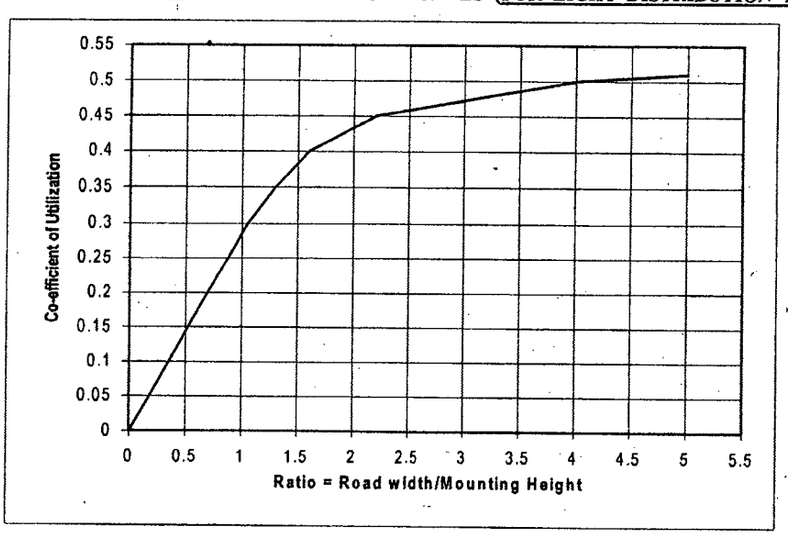
TABLE 3 LIGHTING SOURCE CHARACTERISTICS

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 4 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

02.06.14

L-3/T-2/CE **Date : 02/06/2014**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2011-2012

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

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** questions.

1. (a) Derive an expression for total pressure head in case of curvilinear flow. **(10)**

(b) Calculate the velocity distribution coefficient for the following velocity distribution profile. **(12)**

$$u = u_0 \sin\left(\frac{\pi z}{2h}\right)$$

Where symbols have their usual meaning

(c) What will be the percentage error if you calculate pressure at point A (figure 1) without considering the effect of slope? **(8)**

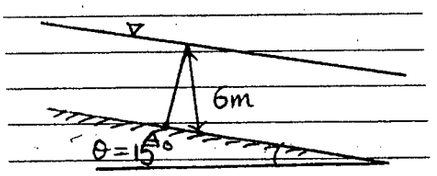


figure 1. for question 1(c)

(d) Calculate the pressure intensities at point 1, 2, 3, 4 for the overflow spillway (figure 2) given that the discharge over the spillway is 6.5 m^3/s and $r_1 = r_2 = 20$ m and depth of flow although the spillway is 1 m. **(16⅔)**

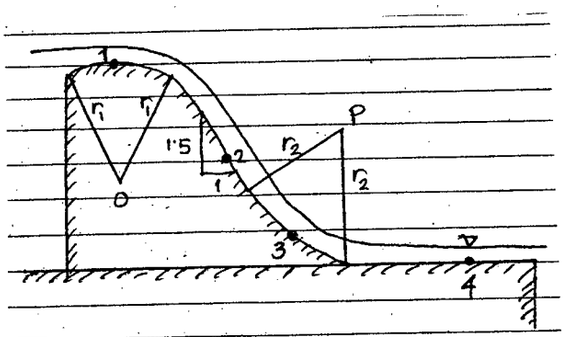


figure 2 for question 1(d)

2. (a) Show that for subcritical flow that depth of flow increases with increase in channel width for a horizontal rectangular channel both mathematically and graphically. **(10)**

(b) Show that for a triangular channel the Froude number corresponding to alternate depths are given by $\frac{F_1}{F_2} = \left(\frac{4+F_1^2}{4+F_2^2}\right)^{5/2}$ **(15)**

Contd P/2

WRE 311

Contd ... Q. No. 2

(c) A rectangular channel 3.0 m wide carries a flow at 1.25 m depth. At a certain section the width is reduced to 2.5 m and the channel bed is raised by 0.20 m through a hump. Estimate the discharge in the channel when the water surface drops by 0.15 m over the hump. Also calculate the change in bed elevation at the contracted section that would make the water surface have same elevation at the upstream and downstream of the contraction. Neglect all types of losses and take $\alpha = 1.03$. **(16⅔)**

(d) Draw the qualitative specific energy curve and corresponding change in water level for the following conditions **(5)**

(i) $b_2 > b_1$
(ii) $b_2 > b_c$
(iii) $b_2 = b_c$
(iv) $b_2 < b_c$

Where b_1, b_2, b_c are the u/s, d/s and critical widths of a long rectangular channel respectively.

3. (a) Show that for a hydraulic jump in a horizontal frictionless rectangular channel the energy loss (E_L) relative to critical depth (y_c) can be expressed as **(10)**

$$\left(\frac{E_L}{y_c}\right)^3 = \left(\frac{(a-1)^9}{32(a+1)a^4}\right)$$

Where a = sequent depth ratio.

(b) An overflow spillway has its crest at an elevation 125.40 m and a horizontal apron at an elevation of 95.00 m on the d/s side. Find the tailwater elevation required to from a hydraulic jump when the elevation of the energy line is 127.90 m. Neglect the energy loss for flow over the spillway. Also assume the value of C_d to be 0.735. **(20)**

(c) Derive the Belanger momentum equation for a hydraulic jump in a horizontal rectangular channel. **(10⅔)**

(d) A spillway discharges a flood flow at a rate of 7.75 m^3/s per meter width. At the downstream horizontal apron the depth of flow was found to be 0.50 m. Find the length and type of the hydraulic jump if a jump is formed in this condition. **(6)**

4. (a) What is tractive force? Prove that the shear stress ratio is $K = \sqrt{1 - \frac{\sin^2\varphi}{\sin^2\psi}}$

Symbols have their usual meaning. **(10)**

(b) Design a lined channel to carry a discharge of 110 m^3/s on a slope of 1 in 3500. The side slope of the channel is to be maintained at 1.5 H: 1V and the lining material is concrete with a value of n = 0.014. The maximum permissible velocity is 2.25 m/s. **(10)**

(c) Show that the best hydraulic trapezoidal section is one half of regular hexagon. **(10)**

(d) Design a stable canal to carry a discharge of 25 m^3/s through 1.5 mm sand using Lacey Method. **(16⅔)**

Contd P/3

WRE 311

SECTION – B

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

5. (a) Name the types of open channel flow for:
(i) Dry season flow in a river (ii) Tidal flow in an estuary (iii) Surge moving up a canal due to sudden drop of sluice gate and (iv) Hydraulic drop due to sudden dip in channel bed. **(4×1.5=6)**

(b) Derive Chezy formula stating necessary assumptions. **(8⅔)**

(c) Water flows at a depth of 1.5 m and a velocity of 2.8 m/s in a circular channel whose diameter is 2.0 m. Compute discharge and determine the state of flow in the channel. **(8)**

(d) For a trapezoidal channel with b = 6 m, z = 2.5, Chezy's C = 47 $m^{1/2}/s$ and $S_0 = 0.002$, compute normal depth and velocity if Q = 35 m^3/s. **(12)**

(e) Define boundary layer thickness. 'Boundary layers quite often grow inside other boundary layers' - explain with sketches. **(3+9=12)**

6. (a) Deduce the expression for normal depth in a triangular channel using Chezy formula. **(7)**

(b) Prove that the hydraulic exponent for uniform flow computation for a circular channel is given by the following equation where conveyance is computed by Chezy formula. **(13)**

$$N = \frac{4y}{d_0}\left(\frac{6\sin\frac{\omega}{2}}{\omega - \sin\omega} - \frac{1}{\omega\sin\frac{\omega}{2}}\right)$$

(c) With a neat sketch show the variation of boundary shear stress when flow occurs in a trapezoidal channel. **(7)**

(d) An unlined irrigation canal (n = 0.025) is trapezoidal and has a bottom width of 6 m, side slope of 1 : 1 and a depth of flow of 2 m. The longitudinal slope of the canal is 0.0005. Compute discharge carried by the canal under uniform flow condition. With a view to minimize the seepage loss, it is proposed to line the canal with concrete having n = 0.013. Compute discharge that would be carried by the canal when only the sides of the canal are lined. **(19⅔)**

7. (a) Explain why H1 and A1 profiles are physically not possible. **(5)**

(b) Explain the behavior of flow profile when $y \to \infty$. **(4⅔)**

(c) Draw the possible flow profiles in the following serial arrangement of channels: **(4×5=20)**

(i) Mild-Critical-Steep.

(ii) Horizontal-Mild-Critical

(iii) Steep-Critical-Mild

(iv) Critical-Horizontal-Steep-Free Overfall.

Contd P/4

WRE 311

Contd ... Q. No. 7

(d) A rectangular channel 8 m wide and having $\alpha = 1.12$ and $n = 0.03$ has three reaches arranged serially. They bottom slopes of these reaches are 0.0035, 0.025 and 0.019, respectively. For a discharge of 40 m^3/s in the channel, sketch the resulting flow profiles. **(9)**

(e) Draw the possible flow profiles produced on the upstream and downstream of a sluice gate in (i) mild slope channel and (ii) steep slope channel. **(8)**

8. (a) Differentiate between Direct Step Method and Standard Step Method. **(6)**

(b) A trapezoidal channel with $b = 5$ m, $S_0 = 0.0004$ and $n = 0.02$ has a side slope of 2 H : 1V. The normal depth of flow is 3.0 m. The channel empties into a pool at the downstream end and the pool elevation is 6.25 m with respect to an arbitrary datum. The elevation of channel bed at the downstream end is 5.0 m with respect to the same datum. Compute the resulting flow profile by using Direct Step Method. Assume $\alpha = 1.10$. **(22)**

(c) A vertical sluice gate having a coefficient of contraction, $C_C = 0.61$ and a gate opening, $y_g = 1.0$ m, discharges 25 m^3/s into a horizontal rectangular channel 5 m wide. Compute the length of the flow profile between the vena contracta and the location where the depth is 0.75 m. Take $n = 0.015$, $\alpha = 1.12$. **(18⅔)**

L-3/T-2/CE **Date : 19/05/2014**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2011-2012

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

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.**

1. (a) Briefly discuss on possible modes on failure in a tension member. **(9)**

   (b) Determine allowable strength "T" for the angle L5 × 4 × ¼ with three ⅞ inch dia bolts in standard holes. Use A36 steel. The member is shown in Fig. 1. **(26)**

2. (a) Write short notes on short column, intermediate column and long column and show their region in a column strength curve. **(9)**

   (b) Using ASD method, calculate the strength of the column having cross section and support condition shown in Fig. 2. Use A992 steel. **(26)**

3. (a) How is residual stress introduced in steel members. Write down its effect. **(9)**

   (b) Select lightest W12 section (From Annexure I) of A992 steel for a column to carry dead load 250^k and live load 150^k. The unbraced lengths are L_x = 20 ft and L_y = 10 ft. The column is pinned at both ends. **(26)**

4. (a) Define effective length factor. Determine effective length factors for column AD, DG and EH (Fig. 3) **(15)**

   (b) An angle L6 × 4 × ⅜ of A992 steel is to be connected to a gusset plate with fillet welds to carry service load of 100^k. Design the weld connection (transverse and longitudinal weld). Use E70XX electrode (Fig. 4) and 3/16 inch weld leg size. **(20)**

SECTION – B

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

Symbols and notation bear their usual meanings.

5. (a) What are the advantages and disadvantages of steel as a structural building material? **(8)**

Contd P/2

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(b) The tension member shown in Fig. 5 is PL $\frac{5}{8}$ × 10, and the steel is A36 ($F_y = 36\ ksi,\ F_u = 50\ ksi$). The bolts are $\frac{7}{8}$-inch in diameter. Following ASD principle, determine the allowable tension capacity considering limit states of plate only. Also, neglect the block shear failure mode. **(12)**

(c) Determine the parameter C_b for the beam shown in Fig. 6. Consider that the beam is laterally un-supported along its whole length except at ends. **(15)**

6. (a) Differentiate between steel and concrete structures from engineering point of view. **(8)**

(b) A $\frac{1}{2}$-inch-thick tension member is spliced with two $\frac{1}{4}$-inch-thick splice plates as shown in Fig. 7. The bolts are $\frac{7}{8}$-inch-diameter, A325 (F_y = 90 ksi, F_u = 120 ksi) and all plates are A36 steel (F_y = 36 ksi, F_u = 50 ksi). Compute the allowable strength of the splice based on bolt limit states. Follow ASD principle. **(12)**

(c) The tension member shown in Fig. 8 is a channel section C12 × 20.7 of A572 steel (F_y = 50 ksi, F_u = 65 ksi). Determine the maximum allowable tensile load capacity based on limits states of the channel section. Follow ASD principle. **(15)**

7. (a) What do you understand by residual stresses in rolled shapes? Briefly discuss with neat sketches. **(8)**

(b) Determine the shape factor for the T section shown in Fig. 9. **(12)**

(c) Determine the maximum allowable moment of a beam having W14×68 section of A242 steel (F_y = 50 ksi, F_u = 70 ksi) subject to (i) continuous lateral support, (ii) an un-braced length of 20 ft with C_b = 1.0 and (iii) an un-braced length of 30 ft with C_b = 1.0. Follow ASD method. **(15)**

8. (a) What do you understand by weldability of steel? Mention the preferred alloy composition of good weldable structural steel. **(8)**

(b) Determine the elastic shear stress distribution on a W14×120 beam subjected to a service load shear force of 65 kips acting for major axis bending. Also compute the portion of the shear carried by the flange and that carried by the web. **(12)**

(c) Tension member shown in Fig. 10 is an L6 × $3^1/_2$ × $^5/_{16}$. It is connected to a $^5/_{16}$-inch-thick gusset plate with $^3/_4$-inch-diameter A325 bearing type bolts (F_y = 90 ksi, F_u = 120 ksi). Both the tension member and the gusset plate are of A36 steel (F_y = 36 ksi, F_u = 50 ksi). What is the total service load that can be supported, based on bolt limit states? The bolt threads are in the plane of shear. Follow ASD method. **(15)**

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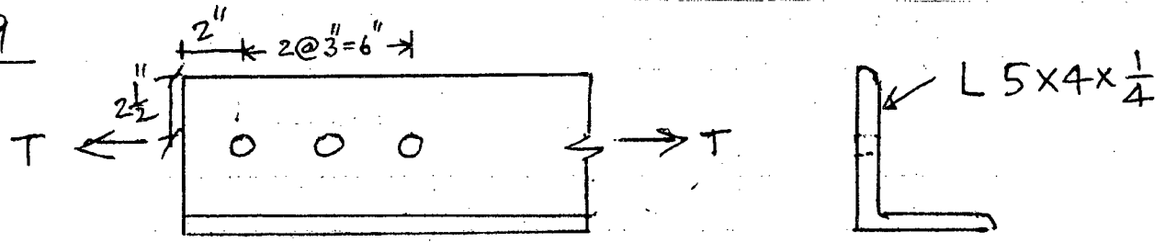


Fig-1

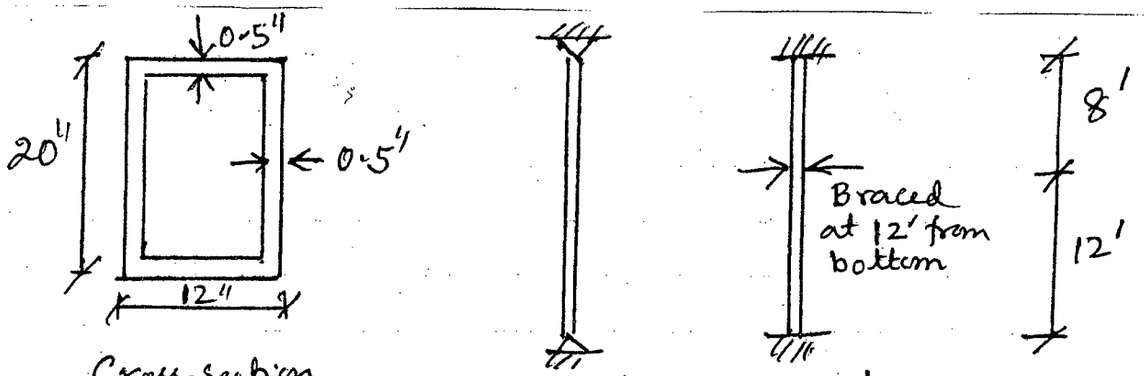
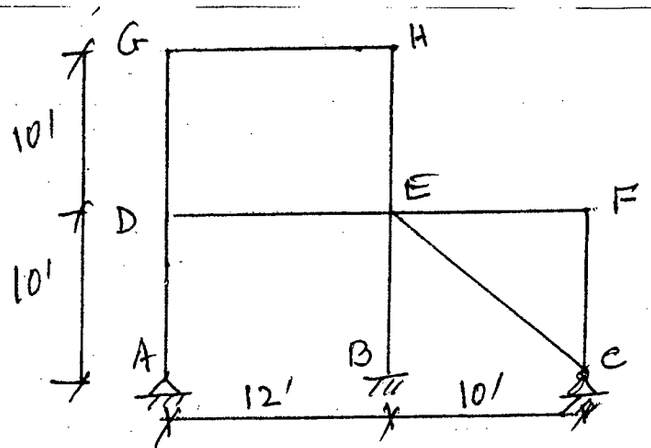


Fig. 2



Column : W12 × 58
Beam : W12×65
Sectional properties included in Annexure - I and K-factor in Annexure - II

Fig. 3

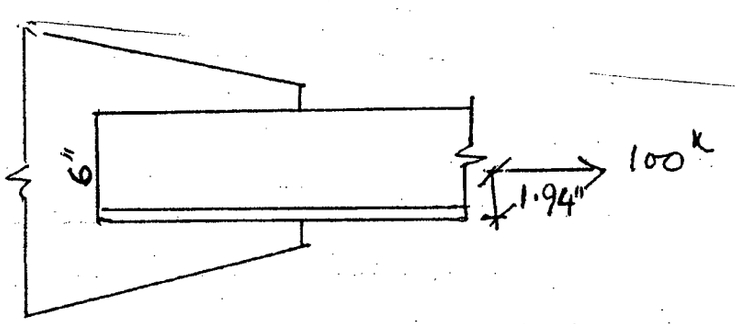


Fig. 4

CE 319

Fig. 5

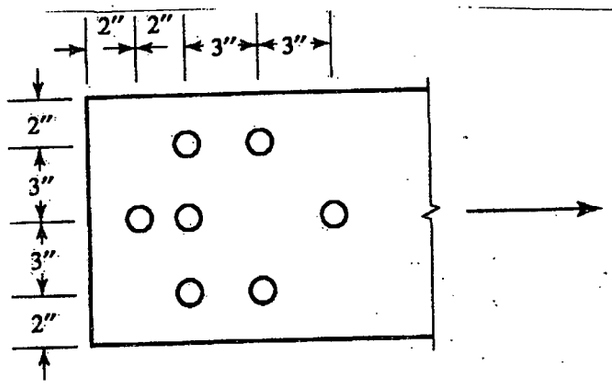


Fig. 6

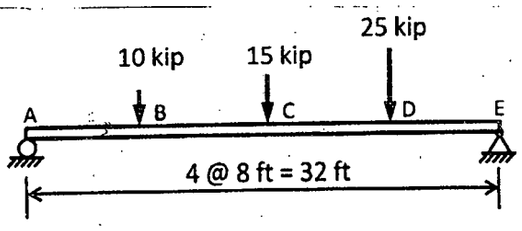
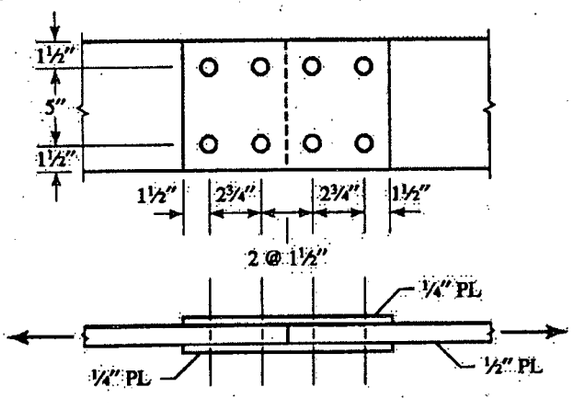


Fig. 7



Plan

Section

Fig. 8

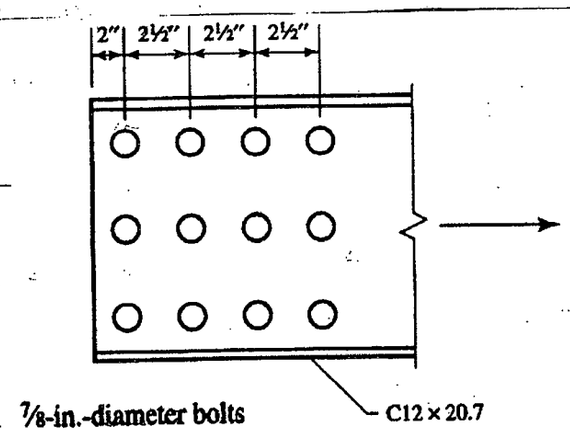


Fig. 9

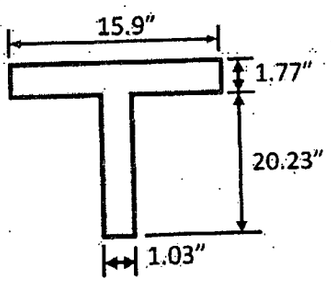
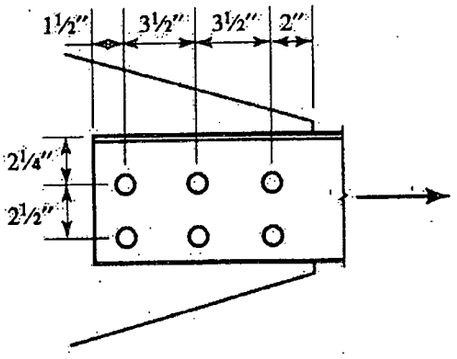
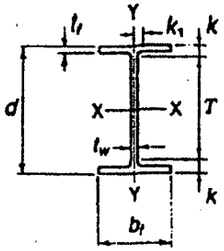


Fig. 10

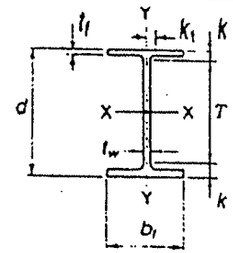




W SHAPES
Dimensions

Design-nation	Area A	Depth d		Web Thickness t_w	$\frac{t_w}{2}$	Flange Width b_f		Flange Thickness t_f		Distance T	Distance k	Distance k_1
	In.^{2}	In.		In.	In.	In.		In.		In.	In.	In.
W 12×336[a]	98.8	16.82	16¾	1.775	1¾	⅞	13.385	13⅜	2.955	2¹⁵⁄₁₆	9½	3¹¹⁄₁₆	1½
×305[a]	89.6	16.32	16⅜	1.625	1⅝	¹³⁄₁₆	13.235	13¼	2.705	2¾	9½	3⅜	1⁷⁄₁₆
×279[a]	81.9	15.86	15⅞	1.530	1½	¾	13.140	13⅛	2.470	2½	9½	3⅛	1⅜
×252[a]	74.1	15.41	15⅜	1.395	1⅜	¹³⁄₁₆	13.005	13	2.260	2⅜	9½	2¹⁵⁄₁₆	1⁵⁄₁₆
×230[a]	67.7	15.05	15	1.285	1¼	¹³⁄₁₆	12.895	12⅞	2.070	2⅛	9½	2¾	1¼
×210[a]	61.8	14.75	14¾	1.180	1³⁄₁₆	¾	12.790	12¾	1.900	1⅞	9½	2⅝	1³⁄₁₆
×190	55.8	14.38	14⅜	1.060	1¹⁄₁₆	⅝	12.670	12⅝	1.735	1¾	9½	2⁷⁄₁₆	1⁹⁄₁₆
×170	50.0	14.03	14	0.960	¹⁵⁄₁₆	½	12.570	12⅝	1.560	1⁹⁄₁₆	9½	2¼	1⅛
×152	44.7	13.71	13¾	0.870	⅞	⁷⁄₁₆	12.480	12½	1.400	1⅜	9½	2⅛	1¹⁄₁₆
×136	39.9	13.41	13⅜	0.790	¹³⁄₁₆	⁷⁄₁₆	12.400	12⅜	1.250	1¼	9½	1¹⁵⁄₁₆	1
×120	35.3	13.12	13⅛	0.710	¹¹⁄₁₆	⅜	12.320	12⅜	1.105	1⅛	9½	1¹³⁄₁₆	1
×106	31.2	12.89	12⅞	0.610	⅝	⁵⁄₁₆	12.220	12¼	0.990	1	9½	1¹¹⁄₁₆	¹⁵⁄₁₆
× 96	28.2	12.71	12¾	0.550	⁹⁄₁₆	⁵⁄₁₆	12.160	12⅛	0.900	⅞	9½	1⅝	⅞
× 87	25.6	12.53	12½	0.515	½	¼	12.125	12⅛	0.810	¹³⁄₁₆	9½	1½	⅞
× 79	23.2	12.38	12⅜	0.470	½	¼	12.080	12⅛	0.735	¾	9½	1⁷⁄₁₆	⅞
× 72	21.1	12.25	12¼	0.430	⁷⁄₁₆	¼	12.040	12	0.670	¹¹⁄₁₆	9½	1⅜	⅞
× 65	19.1	12.12	12⅛	0.390	⅜	³⁄₁₆	12.000	12	0.605	⅝	9½	1⁵⁄₁₆	1³⁄₁₆
W 12× 58	17.0	12.19	12¼	0.360	⅜	³⁄₁₆	10.010	10	0.640	⅝	9½	1⅜	1³⁄₁₆
× 53	15.6	12.06	12	0.345	⅜	³⁄₁₆	9.995	10	0.575	⁹⁄₁₆	9½	1¼	1³⁄₁₆
W 12× 50	14.7	12.19	12¼	0.370	⅜	³⁄₁₆	8.080	8⅛	0.640	⅝	9½	1⅜	1³⁄₁₆
× 45	13.2	12.06	12	0.335	⅜	³⁄₁₆	8.045	8	0.575	⁹⁄₁₆	9½	1¼	1³⁄₁₆
× 40	11.8	11.94	12	0.295	⁵⁄₁₆	³⁄₁₆	8.005	8	0.515	½	9½	1¼	¾
W 12× 35	10.3	12.50	12½	0.300	⁵⁄₁₆	³⁄₁₆	6.560	6½	0.520	½	10½	1	⁹⁄₁₆
× 30	8.79	12.34	12⅜	0.260	¼	⅛	6.520	6½	0.440	⁷⁄₁₆	10½	¹⁵⁄₁₆	½
× 26	7.65	12.22	12¼	0.230	¼	⅛	6.490	6½	0.380	⅜	10½	⅞	½
W 12× 22	6.48	12.31	12¼	0.260	¼	⅛	4.030	4	0.425	⁷⁄₁₆	10½	⅞	½
× 19	5.57	12.16	12⅛	0.235	¼	⅛	4.005	4	0.350	⅜	10½	¹³⁄₁₆	½
× 16	4.71	11.99	12	0.220	¼	⅛	3.990	4	0.265	¼	10½	¾	½
× 14	4.16	11.91	11⅞	0.200	³⁄₁₆	⅛	3.970	4	0.225	¼	10½	¹¹⁄₁₆	½

[a]For application refer to Notes in Table 2.
Shapes in shaded rows are not available from domestic producers.



W SHAPES
Properties

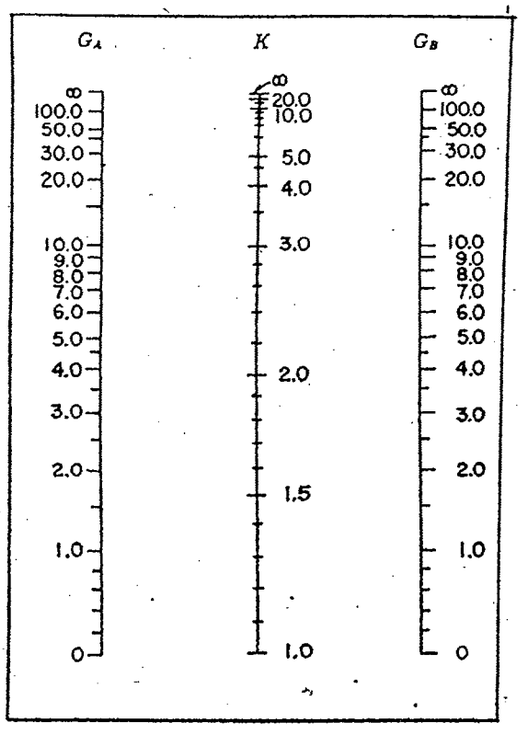
Nominal Wt. per Ft	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria F_y'	Compact Section Criteria $\frac{d}{t_w}$	Compact Section Criteria F_y''	r_T	$\frac{d}{A_f}$	Elastic Properties Axis X-X I	Axis X-X S	Axis X-X r	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Plastic Modulus Z_x	Plastic Modulus Z_y
Lb.		Ksi		Ksi	In.		In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.	In.^{3}	In.^{3}
336	2.3	—	9.5	—	3.71	0.43	4060	483	6.41	1190	177	3.47	603	274
305	2.4	—	10.0	—	3.67	0.46	3550	435	6.29	1050	159	3.42	537	244
279	2.7	—	10.4	—	3.64	0.49	3110	393	6.16	937	143	3.38	481	220
252	2.9	—	11.0	—	3.59	0.53	2720	353	6.06	828	127	3.34	428	196
230	3.1	—	11.7	—	3.56	0.56	2420	321	5.97	742	115	3.31	386	177
210	3.4	—	12.5	—	3.53	0.61	2140	292	5.89	664	104	3.28	348	159
190	3.7	—	13.6	—	3.50	0.65	1890	263	5.82	589	93.0	3.25	311	143
170	4.0	—	14.6	—	3.47	0.72	1650	235	5.74	517	82.3	3.22	275	126
152	4.5	—	15.8	—	3.44	0.79	1430	209	5.66	454	72.8	3.19	243	111
136	5.0	—	17.0	—	3.41	0.87	1240	186	5.58	398	64.2	3.16	214	98.0
120	5.6	—	18.5	—	3.38	0.96	1070	163	5.51	345	56.0	3.13	186	85.4
106	6.2	—	21.1	—	3.36	1.07	933	145	5.47	301	49.3	3.11	164	75.1
96	6.8	—	23.1	—	3.34	1.16	833	131	5.44	270	44.4	3.09	147	67.5
87	7.5	—	24.3	—	3.32	1.28	740	118	5.38	241	39.7	3.07	132	60.4
79	8.2	62.6	26.3	—	3.31	1.39	662	107	5.34	216	35.8	3.05	119	54.3
72	9.0	52.3	28.5	—	3.29	1.52	597	97.4	5.31	195	32.4	3.04	108	49.2
65	9.9	43.0	31.1	—	3.28	1.67	533	87.9	5.28	174	29.1	3.02	96.8	44.1
58	7.8	—	33.9	57.6	2.72	1.90	475	78.0	5.28	107	21.4	2.51	86.4	32.5
53	8.7	55.9	35.0	54.1	2.71	2.10	425	70.6	5.23	95.8	19.2	2.48	77.9	29.1
50	6.3	—	32.9	60.9	2.17	2.36	394	64.7	5.18	56.3	13.9	1.96	72.4	21.4
45	7.0	—	36.0	51.0	2.15	2.61	350	58.1	5.15	50.0	12.4	1.94	64.7	19.0
40	7.8	—	40.5	40.3	2.14	2.90	310	51.9	5.13	44.1	11.0	1.93	57.5	16.8
35	6.3	—	41.7	38.0	1.74	3.66	285	45.6	5.25	24.5	7.47	1.54	51.2	11.5
30	7.4	—	47.5	29.3	1.73	4.30	238	38.6	5.21	20.3	6.24	1.52	43.1	9.56
26	8.5	57.9	53.1	23.4	1.72	4.95	204	33.4	5.17	17.3	5.34	1.51	37.2	8.17
22	4.7	—	47.3	29.5	1.02	7.19	156	25.4	4.91	4.66	2.31	0.847	29.3	3.66
19	5.7	—	51.7	24.7	1.00	8.67	130	21.3	4.82	3.76	1.88	0.822	24.7	2.98
16	7.5	—	54.5	22.2	0.96	11.3	103	17.1	4.67	2.82	1.41	0.773	20.1	2.26
14	8.8	54.3	59.6	18.6	0.95	13.3	88.6	14.9	4.62	2.36	1.19	0.753	17.4	1.90

CE 319

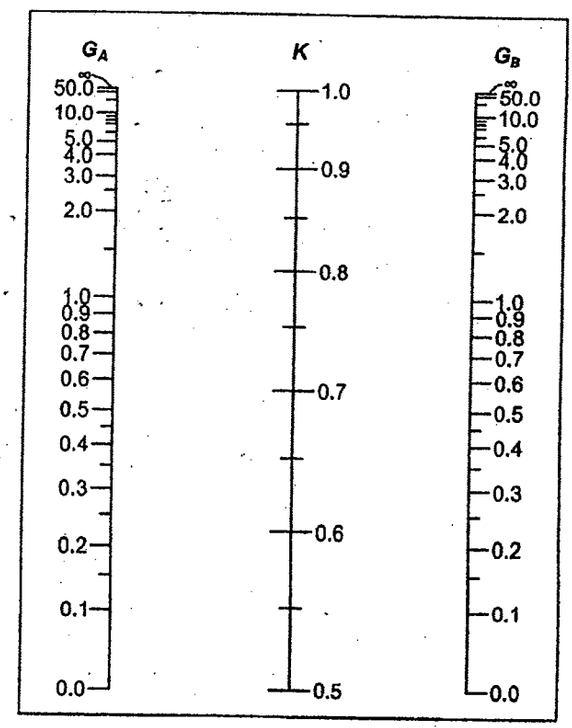
Annexure-1

CE 319

Annexure-2



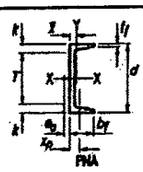
Unbraced Frame



Braced Frame

CE 319

Annex Ref c - 3

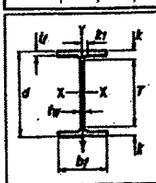


C Shapes
Dimensions

C Shapes
Properties

C SHAPES

Shape	Area, A	Depth, d	Web: Thickness, t_w	Web: $\frac{t_w}{2}$	Flange: Width, b_f	Flange: Thickness, t_f	Distance: k	Distance: T	Distance: Workable Gage	r_{ts}	h_o	Shear Ctr, e_o	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: $\bar{x}$	Axis Y-Y: Z	Axis Y-Y: x_p	Torsional Properties: J	Torsional Properties: C_w	Torsional Properties: $\bar{r}_o$	Torsional Properties: H
	in.²	in.	in.	in.	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.	
C15×50	14.7	15.0	15	0.716	11/16	3/8	3.72	3 3/4	0.650	5/8	1 7/16	12 1/8	2 1/4	1.17	14.4	0.583	404	53.8	5.24	68.5	11.0	3.77	0.865	0.799	8.14	0.490	2.65	492	5.49	0.937
×40	11.8	15.0	15	0.520	1/2	1/4	3.52	3 1/2	0.650	5/8	1 7/16	12 1/8	2	1.15	14.4	0.787	348	46.5	5.45	57.5	9.17	3.34	0.883	0.778	6.84	0.392	1.45	410	5.73	0.927
×33.9	10.0	15.0	15	0.400	3/8	3/16	3.40	3 3/8	0.650	5/8	1 7/16	12 1/8	2	1.13	14.4	0.896	315	42.0	5.62	50.8	8.07	3.09	0.901	0.788	6.19	0.332	1.01	358	5.84	0.920
C12×30	8.81	12.0	12	0.510	1/2	1/4	3.17	3 1/8	0.501	1/2	1 1/8	9 3/4	1 3/4 [a]	1.01	11.5	0.618	162	27.0	4.29	33.8	5.12	2.05	0.762	0.674	4.32	0.367	0.861	151	4.54	0.919
×25	7.34	12.0	12	0.387	3/8	3/16	3.05	3	0.501	1/2	1 1/8	9 3/4	1 3/4 [a]	1.00	11.5	0.746	144	24.0	4.43	29.4	4.45	1.87	0.779	0.674	3.82	0.306	0.538	130	4.72	0.909
×20.7	6.08	12.0	12	0.282	5/16	5/16	2.94	3	0.501	1/2	1 1/8	9 3/4	1 3/4 [a]	0.983	11.5	0.870	129	21.5	4.61	25.8	3.86	1.72	0.787	0.686	3.47	0.253	0.369	112	4.93	0.899



W Shapes
Dimensions

W Shapes
Properties

W14 – W12

Shape	Area, A	Depth, d	Web: Thickness, t_w	Web: $\frac{t_w}{2}$	Flange: Width, b_f	Flange: Thickness, t_f	Distance: k	Distance: k_{det}	Distance: k_1	Distance: T	Distance: Workable Gage	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
	in.²	in.	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
W14×132	38.8	14.7	14 3/8	0.645	5/8	5/16	14.7	14 3/4	1.03	1	1.63	2 9/16	1 9/16	10	5 1/2	7.15	17.7	1530	209	6.28	234	548	74.5	3.76	113	4.23	13.6	12.3	25500
×120	35.3	14.5	14 1/2	0.590	9/16	9/16	14.7	14 5/8	0.940	15/16	1.54	2 1/4	1 1/2			7.80	19.3	1380	190	6.24	212	496	67.5	3.74	102	4.20	13.5	9.37	22700
×109	32.0	14.3	14 3/8	0.525	1/2	1/4	14.8	14 5/8	0.860	7/8	1.46	2 5/16	1 1/2			8.49	21.7	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	14 1/8	0.485	1/2	1/4	14.6	14 5/8	0.780	3/4	1.38	2 1/16	1 7/16			9.34	23.5	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	14	0.440	7/16	1/4	14.5	14 1/2	0.710	11/16	1.31	2	1 7/16			10.2	25.9	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	14 1/4	0.510	1/2	1/4	10.1	10 1/8	0.855	7/8	1.45	1 11/16	1 9/16	10 7/8	5 1/2	5.92	22.4	881	123	6.05	139	148	29.3	2.48	44.8	2.85	13.5	5.07	6710
×74	21.8	14.2	14 1/8	0.450	7/16	1/4	10.1	10 1/8	0.785	13/16	1.38	1 5/8	1 1/16			6.41	25.4	795	112	6.04	126	134	26.6	2.48	40.5	2.82	13.4	3.87	5980
×68	20.0	14.0	14	0.415	7/16	1/4	10.0	10	0.720	3/4	1.31	1 9/16	1 1/16			6.97	27.5	722	103	6.01	115	121	24.2	2.48	36.9	2.80	13.3	3.01	5380
×61	17.9	13.9	13 7/8	0.375	3/8	5/16	10.0	10	0.645	5/8	1.24	1 1/2	1			7.75	30.4	640	92.1	5.98	102	107	21.5	2.45	32.8	2.78	13.2	2.19	4710

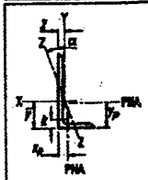


Table 1–7 (continued)
Angles
Properties

Table 1–7 (continued)
Angles
Properties

L6-L4

Shape	k	Wt.	Area, A	Axis X-X: I	Axis X-X: S	Axis X-X: r	Axis X-X: $\bar{y}$	Axis X-X: Z	Axis X-X: y_p	Flexural-Torsional Properties: J	Flexural-Torsional Properties: C_w	Flexural-Torsional Properties: $\bar{r}_o$	Axis Y-Y: I	Axis Y-Y: S	Axis Y-Y: r	Axis Y-Y: $\bar{x}$	Axis Y-Y: Z	Axis Y-Y: x_p	Axis Z-Z: I	Axis Z-Z: S	Axis Z-Z: r	$\tan\alpha$	Q_s: F_y=36 ksi
	in.	lb/ft	in.²	in.⁴	in.³	in.	in.	in.³	in.	in.⁴	in.⁶	in.	in.⁴	in.³	in.	in.	in.³	in.	in.⁴	in.³	in.		
L6×6×7/8	1 3/8	27.2	7.98	27.7	7.13	1.86	2.12	12.7	1.44	2.03	4.04	2.82	9.70	3.37	1.10	1.12	6.28	0.665	5.82	1.90	0.854	0.421	1.00
×3/4	1 1/4	23.6	6.94	24.5	6.23	1.88	2.07	11.1	1.36	1.31	2.64	2.85	8.63	2.95	1.12	1.07	5.42	0.578	5.08	1.66	0.856	0.428	1.00
×5/8	1 1/8	20.0	5.86	21.0	5.29	1.89	2.03	9.44	1.31	0.775	1.59	2.88	7.48	2.52	1.13	1.03	4.56	0.488	4.32	1.42	0.859	0.435	1.00
×9/16	1 1/16	18.1	5.31	19.2	4.81	1.90	2.00	8.59	1.28	0.572	1.18	2.90	6.88	2.29	1.14	1.00	4.13	0.442	3.94	1.30	0.861	0.438	1.00
×1/2	1	16.2	4.75	17.3	4.31	1.91	1.96	7.71	1.25	0.407	0.843	2.91	6.22	2.06	1.14	0.981	3.69	0.396	3.55	1.17	0.864	0.440	1.00
×7/16	15/16	14.3	4.18	15.4	3.81	1.92	1.95	6.81	1.22	0.276	0.575	2.93	5.56	1.83	1.15	0.957	3.24	0.348	3.14	1.04	0.867	0.443	0.973
×3/8	7/8	12.3	3.61	13.4	3.30	1.93	1.93	5.89	1.19	0.177	0.389	2.94	4.86	1.58	1.16	0.933	2.79	0.301	2.73	0.908	0.870	0.446	0.912
×5/16	13/16	10.3	3.03	11.4	2.77	1.94	1.90	4.96	1.16	0.104	0.217	2.96	4.13	1.34	1.17	0.908	2.33	0.252	2.31	0.769	0.874	0.449	0.826
L6×3 1/2×1/2	1	15.3	4.50	18.6	4.23	1.92	2.07	7.49	1.48	0.386	0.779	2.88	4.24	1.59	0.968	0.829	2.88	0.376	2.58	0.914	0.756	0.343	1.00
×3/8	7/8	11.7	3.42	12.9	3.23	1.93	2.02	5.74	1.41	0.168	0.341	2.90	3.33	1.22	0.984	0.781	2.18	0.287	2.00	0.714	0.763	0.349	0.912
×5/16	13/16	9.80	2.87	10.9	2.72	1.94	2.00	4.84	1.38	0.0990	0.201	2.92	2.84	1.03	0.991	0.756	1.82	0.241	1.70	0.609	0.767	0.352	0.826

Beam formulas:

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

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