**L-3/T-2/CE** **Date : 17/01/2016**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2013-2014

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.

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## SECTION – A

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

1. (a) Discuss briefly why the impact of modern human populations upon the environment is of major concern to environmental engineers? **(7⅔)**

(b) Differentiate between "environmental strategies" and "environmental tactics". **(5)**

(c) State the use of valves in water supply system of a building. Why is high water pressure not desirable in the plumbing system of a building? **(5)**

(d) How will you supply water to a tall building? **(6)**

(e) What are the special considerations for sizing of riser pipes of a downfeed zone? How will you evaluate fitting friction? **(8)**

(f) Given: **(15)**

* 30-story building 12 ft floor to floor.
* 55 psi at public main.
* Flush-valve fixtures except on 29th and 30th floors where flux-tank fixtures are used.
* Maximum pressure at any fixture is not to exceed 55 psi.
* Minimum permissible fixture pressures vary from 5 psi to 8 psi for flush-tank fixtures.
* Minimum permissible fixture pressures vary from 7 psi to 14 psi for flush-valve fixtures.
* Pressure loss in the water meter is 4 psi.
* Public main is 50 ft away from the foot of the riser.
* The pressure loss is 7 psi/100 ft for a 3-inch main and that is 1.6 psi/100 ft for a 4-inch main.

Assume reasonable values for missing data if required.

Determine zoning of the tall building.

2. (a) State the principles of design of plumbing drainage system. **(6)**

(b) Write down five important general requirements about installation of drainage pipes in a building. **(7½)**

Contd .......... P/2

**CE 333**

**Contd... Q. No. 2**

(c) Differentiate between "self-siphonage" and "induced siphonage". How can you avoid these? **(6½)**

(d) What do you mean by sustainability of water and sanitation services? List the indicators for evaluating the performance of a water supply system. **(6⅔)**

(e) State the merits of community participation in a water supply or sanitation program. How will you ensure the sustainability of urban sanitation? **(12)**

(f) Draw a flow diagram for municipal solid waste management system. What are the benefits of recycling of solid waste? **(8)**

3. (a) What is hydraulic shock load and organic shock load with respect to water treatment plants? How are the shock loads accommodated in waste stabilization pond, trickling filter, and activated sludge systems? **(12)**

(b) Which phase of the bacterial growth pattern is desirable for wastewater treatment? Explain. **(7⅔)**

(c) Describe the different components of bacterial metabolism. An activated sludge treatment facility is not operating effectively in removing BOD from an industrial effluent devoid of nitrogen. Adequate provisions have been made for aeration, sludge settling and recycling in the treatment plant. Explain the reasons of the inefficient removal of BOD. **(17)**

(d) What is a comminutor? Explain why and where a comminutor is installed in a wastewater treatment plant. **(10)**

4. (a) Explain the symbiosis between algae and bacteria in a facultative pond. **(6⅔)**

(b) "Although a trickling filter is considered as an aerobic process, it is not a true aerobic system" — explain. How the growth of microbial layer is controlled in a trickling filter? What are the merits of recirculation in a trickling filter? **(15)**

(c) Why is tertiary treatment necessary? Explain the suitability of using membrane processes in tertiary treatment of a wastewater. How will you ensure a zero liquid discharge system in a membrane process? **(15)**

(d) What are membrane bioreactors? State the major advantages of membrane bioreactor systems. **(10)**

Contd .......... P/3

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.
Log probability paper is attached.

5. (a) Draw a typical graph to estimate the Inflow and Infiltration for new construction of RCC sewers and explain the nature of the graph. **(10)**

(b) A 125 mm thick, 1200 mm dia. RCC pipe is laid in a trapezoidal trench with side slope 1:1.5 (V:H). The pipe rests on 150 mm thick hardcore overlain by 150 mm sand bed. The RL of the finished level (Road) is +3.000 m. The trench is backfilled with wet sand and damp clay (density 1920 kg/m$^3$). Determine the load on the sewer pipe. Neatly draw the trench section with every detail along with the RL of each level in the section. Assume reasonable value for missing data. **(18⅓)**

(c) A 2000 mm dia. RCC pipe is laid with a slope of 0.002 for a design flow of 0.5 m$^3$/sec when flowing partially full having a flow width of 1.414 m at the top of flow surface. The sewer pipe provided is designed to carry domestic sewage having $BOD_5$ of 200 mg/L at a maximum temperature of 30°C. Determine the potential for Sulfide Generation (Z) and specify the appropriate measures to be taken to for stability of the sewer. **(18⅓)**

6. (a) List the advantages of Glass Reinforced Plastic (GRP) pipes over Reinforced Concrete pipes (RCC) for use in sewer system. **(10)**

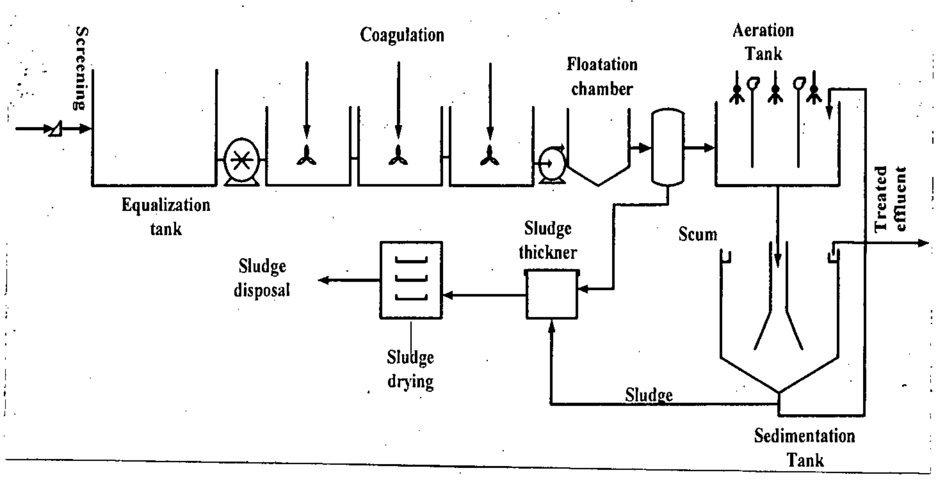
(b) The following schematic diagram represents the treatment processes adopted at an ETP in a Textile Industry. Following are the observations at the ETP- **(10)**

(i) On a certain workday 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 (ECR, 1997).

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 observation (i) and (ii).

| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $BOD_5$ (mg/L) | 35 | 60 | 38 | 57 | 42 | 55 | 50 | 51 | 45 | 47 | 52 |



## CE 333

**Contd... Q. No. 6**

(c) An STP reported following weekly $BOD_5$ data of treated effluent for 13 weeks. **(26⅔)**

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

(ii) Determine the Mean and Standard Deviations from both the plots.

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

(iv) Determine the probable annual maximum weekly $BOD_5$ from both plots.

(v) Compare the comment on the results for both methods.

| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $BOD_5$ (mg/L) | 35 | 60 | 38 | 57 | 42 | 55 | 50 | 51 | 45 | 47 | 52 | 48 | 54 |

7. (a) What are the major problems associated with pour-flush latrines in high water table areas? What design options are available for construction of pour-flush latrines in such areas? Explain with appropriate figures/sketches. **(10)**

(b) What are the elements of a small bore sewerage (SBS) system? Why small diameter sewers could be used in SBS system (compared to conventional sewerage system)? Explain. **(10)**

(c) Design a "septic tank system" for a family of 12 members. Consider a wastewater flow rate of 100 lpcd and desludging frequency of 2.5 years. The hydraulic detention time of the septic tank should be at least 1 day. The long-term infiltration capacity of soil is 45 L/m$^2$.day. **(26⅔)**

Draw:

(i) Plan of the designed septic tank (consider two chambers)

(ii) Section showing depths of different zones of the septic tank

(iii) Section showing positions of inlet and outlet devices, including their dimensions.

[Assume a temperature of 24°C for the design; assume reasonable values for parameters not given]

8. (a) With an appropriate figure, show how disease is transmitted from excreta via different routes, along with sanitation barriers to prevent such disease transmission. What do you understand by: (i) fecal sludge, (ii) municipal sewage, and (iii) sanitary sewage? **(10)**

(b) What do you understand by a "hygienic latrine"? Why "pit latrines" are not hygienic latrines? Explain. For which types of areas would you propose "pit latrines"? Discuss the relative advantages and disadvantages of different forms of pit latrines. **(10)**

Contd .......... P/5

**CE 333**

**Contd... Q. No. 8**

(c) Design a suitable latrine for a family of 10 members living in a town where tubewell based water supply is available; estimated water use for the latrine is 11 lpcd. Long-term infiltration capacity of soil is 25 L/m$^2$.day, and the groundwater table is 3.9 m below the ground surface. The pit(s) for the latrine is to be constructed with concrete rings. Three types of concrete rings are available in the market – 1.0 m diameter; 1.25 m diameter; and 1.50 m diameter; all rings are 0.3 m in depth. Mechanical de-sludging facilities are available in the town. **(26⅔)**

(i) What type of latrine would you suggest for the family? Explain.

(ii) Design the latrine (including venting system) using one of the three types of concrete rings (use minimum size that satisfy your design criteria), and estimate its design life.

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

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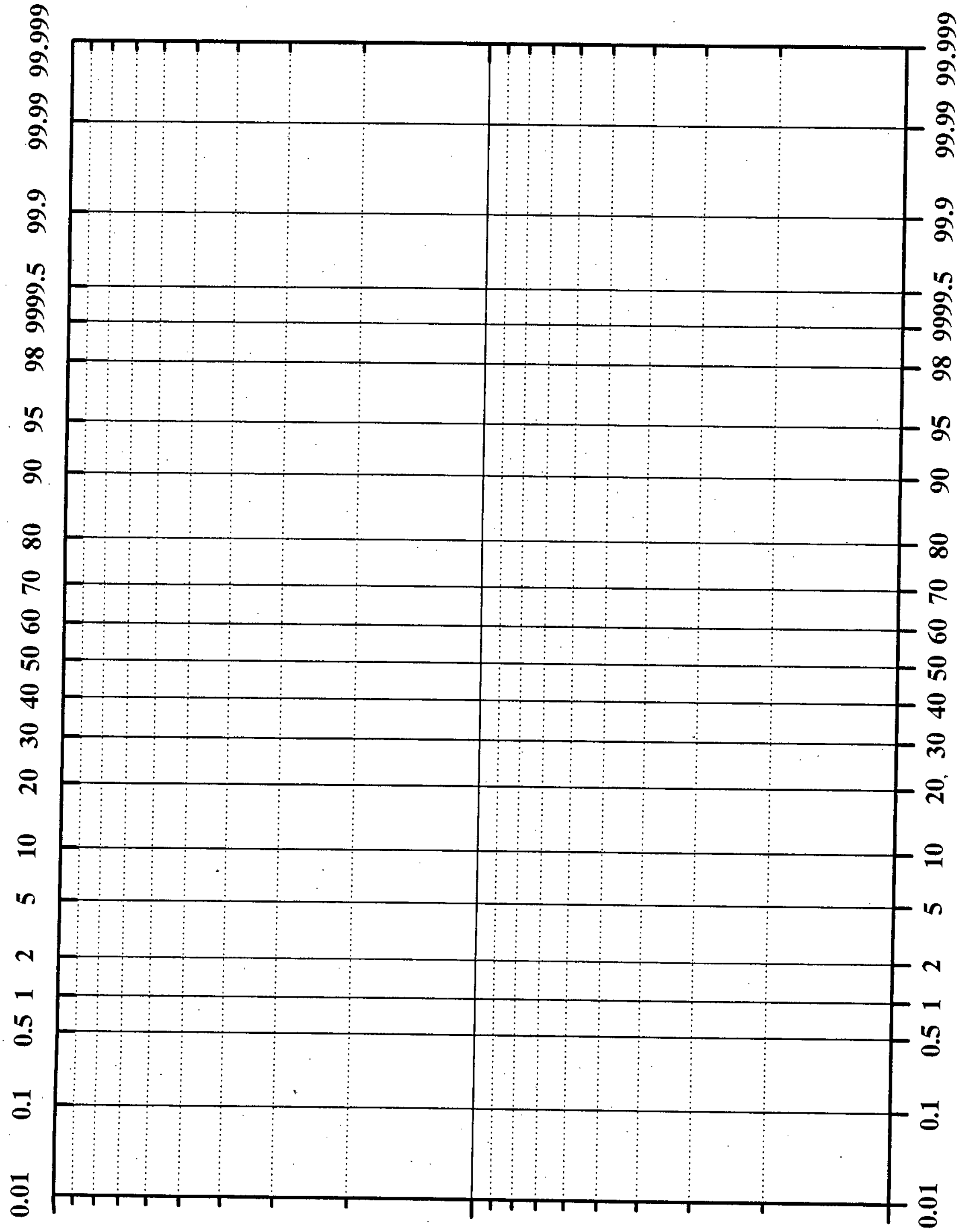

**L-3/T-2/CE** **Date : 23/01/2016**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2013-2014

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

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## SECTION – A

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

Use USD Method of Design. Assume reasonable value for any missing data.

1. (a) Design a square tied column with about 2.5% reinforcement to support working unfactored loads: $P_{DL}$ = 1000 kip and $P_{LL}$ = 600 kip. Given: $f_c'$ = 5.0 ksi, $f_y$ = 72.5 ksi. Also, design the ties required. **(10)**

   (b) A 16 × 30 inch column is reinforced with Ten No. 10 bars as shown in Fig. 1. Construct the nominal strength interaction diagram for the column with five points corresponding to pure axial load, pure bending, balance condition, $\varepsilon_s$ = 0.001 (tensile) and $\varepsilon_s$ = 0.004 (tensile). Also find corresponding $\phi$ for the above points. Assume bending about Y-Y axis. Given: $f_c'$ = 5 ksi, $f_y$ = 60 ksi. **(25)**

2. (a) A ground floor column of a multistoried building is to be designed for the following load combinations (axial force and uniaxial bending)- **(16)**

   Gravity load condition $P_u$ = 700 kip, $M_u$ = 80 kip-ft

   Lateral load combination $P_u$ = 500 kip, $M_u$ = 300 kip-ft

   Architectural considerations require that a rectangular column with b = 12 in. and h = 25 in. is to be used. Material strengths are $f_c'$ = 4 ksi, $f_y$ = 60 ksi. Find the required column reinforcement and show in sketch. Use supplied column strength interaction design chart assuming reinforcement distributed along the parameter.

   (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. **(10)**

   (c) Explain the Seismic Design Philosophy under different levels of earthquakes. **(9)**

3. (a) Discuss different modes of failure of a high-rise shear wall. **(8)**

   (b) A shear wall of a 15-storey building is subjected to following factored loads. **(20)**

   $$P_u = 400 \text{ kip},\ V_u = 700 \text{ kip},\ M_u = 5000 \text{ kip-ft}$$

   The wall is 15 ft long, 150 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.

   (c) What is ACI spiral? Explain the failure behavior of ACI spirally reinforced column. **(7)**

Contd .......... P/2

**CE 317**

4. (a) A 39 inch diameter circular tied column is reinforced with twenty-four No. 9 bars arranged uniformly around the column perimeter. Material strengths are $f'_c$ = 4.0 ksi and $f_y$ = 60 ksi. Check adequacy of the short column using Load Contour Method for: **(17)**

$$P_u = 2000 \text{ kip}, M_{ux} = 800 \text{ kip-ft}, M_{uy} = 600 \text{ kip-ft}$$

Use supplied column strength interaction diagram chart. Assume $\gamma$ = 0.9

(b) The plan of a pile cap with 12 nos. 20 in. diameter cast-in-situ piles with the column (30 in × 30 in) is shown in Fig. 2. The column carries a DL = 1200 kip and a LL = 500 kip (working). The individual pile capacity is adequate. Design the pile cap. Given: $f'_c$ = 3.0 ksi and $f_y$ = 60 ksi. **(18)**

## SECTION – B

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

5. (a) Compare prestressed concrete with reinforced concrete in respect of serviceability, safety and economy. **(7)**

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

(c) A post-tensioned bonded concrete beam has a prestress of 1800 kN in the steel immediately after transfer, which eventually reduces to 1500 kN due to losses. The beam carries two live loads of 50 kN each at the third points in addition to its own weight. Compute the extreme fibre stresses at midspan: **(18)**

(i) Under initial condition of full prestress without live load.

(ii) Under final working condition.

The beam has a rectangular cross-section of 300 mm × 800 mm and total prestressing steel of 1500 $mm^2$ laid parabolically with e = 250 mm at midspan and e = 0 at the ends. Span = 12.0 m (simply supported).

6. (a) What are the different sources of prestress loss in a prestressed concrete member? Explain briefly. **(7)**

(b) Calculate the loss of prestress due to elastic shortening of concrete for the 25.0 m simply supported girder shown in Fig. 3. The girder is prestressed with 4 Nos 10-seven wire strands. Area of each seven wire strand is 98.7 $mm^2$. Given: $E_s = 2 \times 10^5$ MPa, $E_c = 2.7 \times 10^4$ MPa and $F_{pu}$ = 1860 MPa. **(16)**

(i) Neglecting self wt. (ii) Considering self wt.

Consider prestress at transfer = 0.7 $f_{pu}$.

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**Contd ... Q. No. 6**

(c) Calculate the cracking moment for the section shown in Fig. 4. The section is prestressed with 780 $mm^2$ steel area. Given: $f'_c$ = 40 MPa, $f_r$ = 4.0 MPa. Effective prestress $f_{se}$ = 1000 MPa and $f_{pu}$ = 1860 MPa. Assume that the crack will initiate at the bottom fibre. **(12)**

7. (a) A residential building is to be designed using a 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 the reinforcement in long direction only with neat sketch. 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 $f_y$ = 60,000 psi. **(25)**

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

8. (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 $f_y$ = 60,000 psi. **(17)**

   (b) Design a square footing for an interior column that carries total working DL = 600 kips and LL = 400 kips. The column is 25″ × 25″ in cross-section. Allowable bearing capacity of soil is 4200 psf. The bottom of the footing is 6 ft below grade. Show the reinforcement in plan and sections with neat sketches. **(18)**

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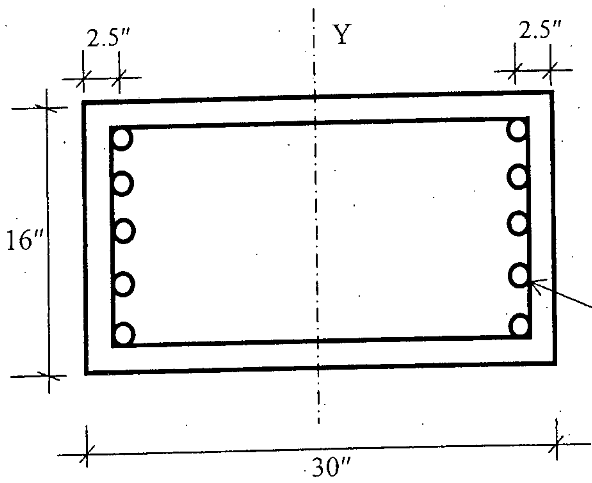



Given:
$f_c' = 5$ ksi
$f_y = 60$ ksi

Fig. 1

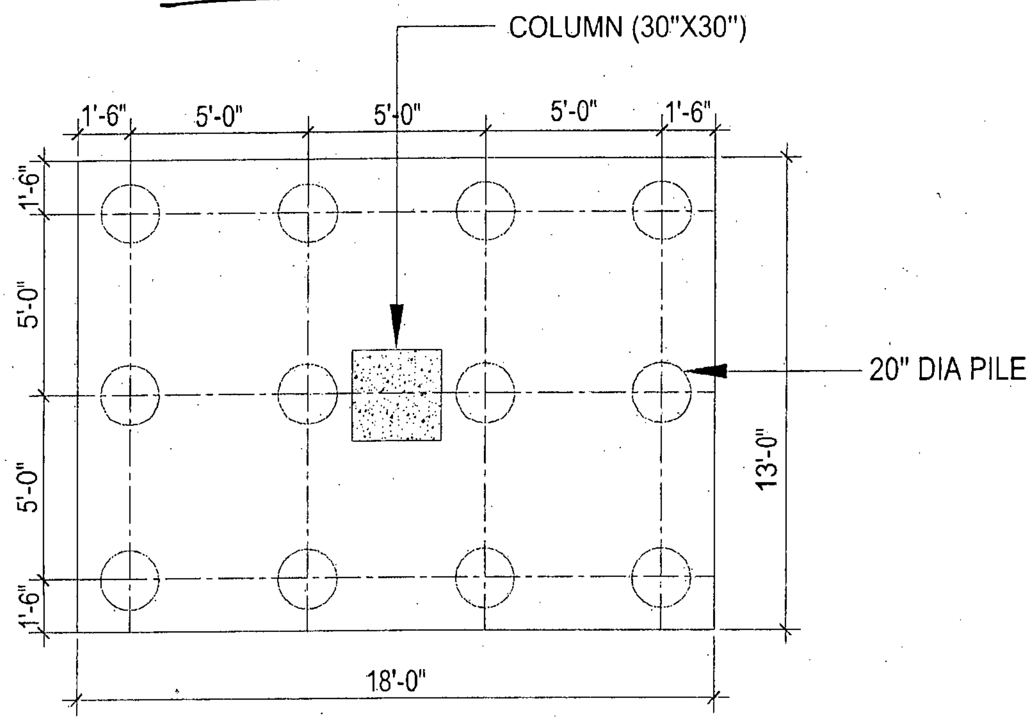
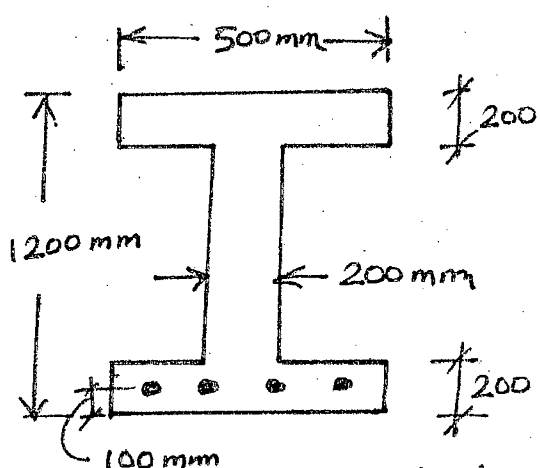


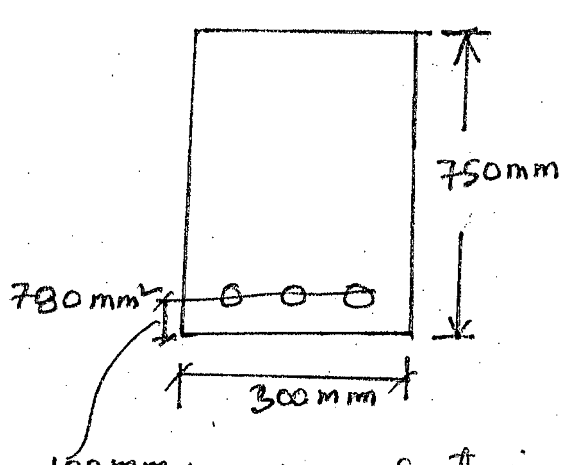

Fig. 2

Fig. 3




midspan Section

Fig. 4




midspan Section

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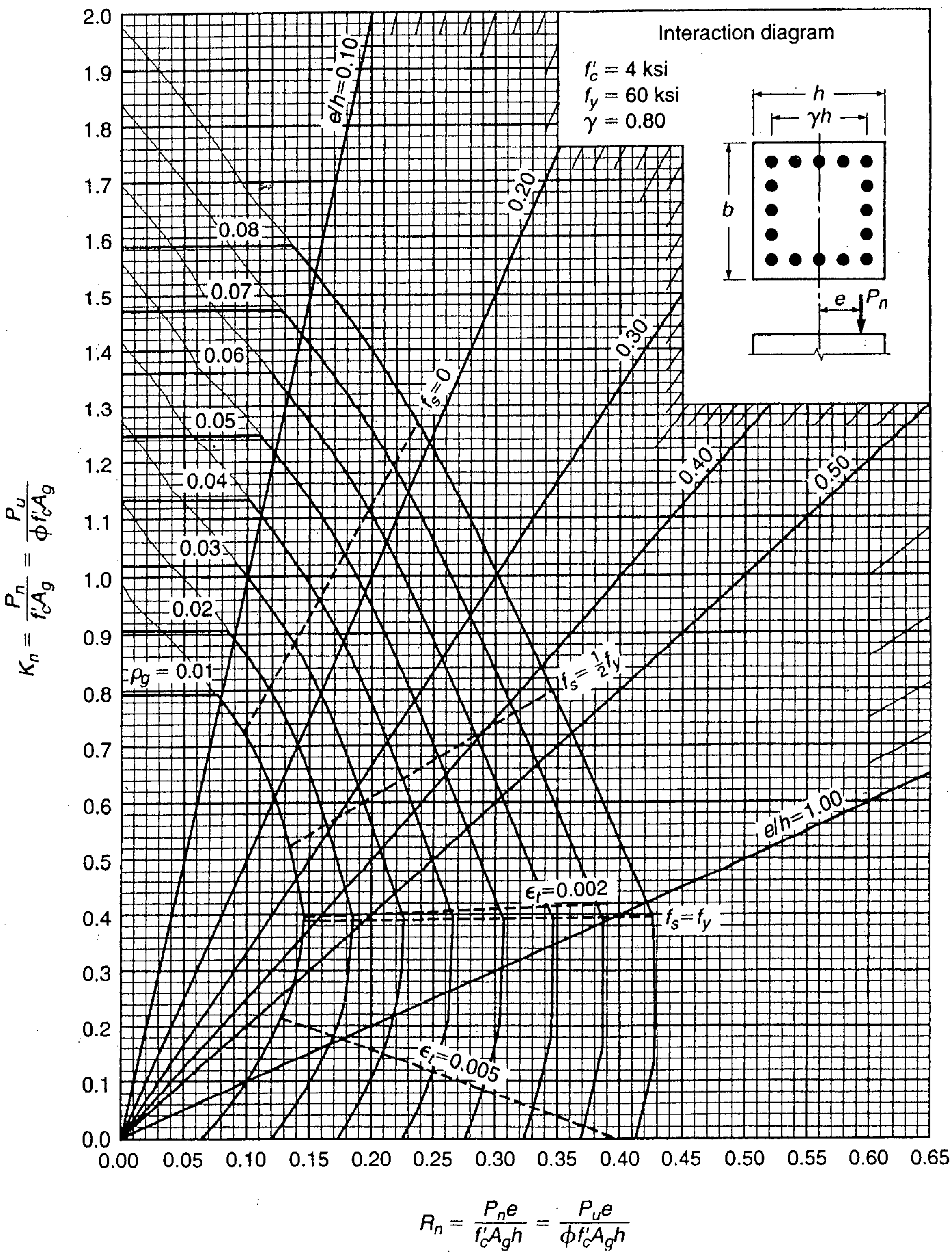


**GRAPH A.7**
Column strength interaction diagram for rectangular section with bars on four faces and $\gamma$ = 0.80.

Design of Concrete Structures – Nilson, Darwin, Dolan

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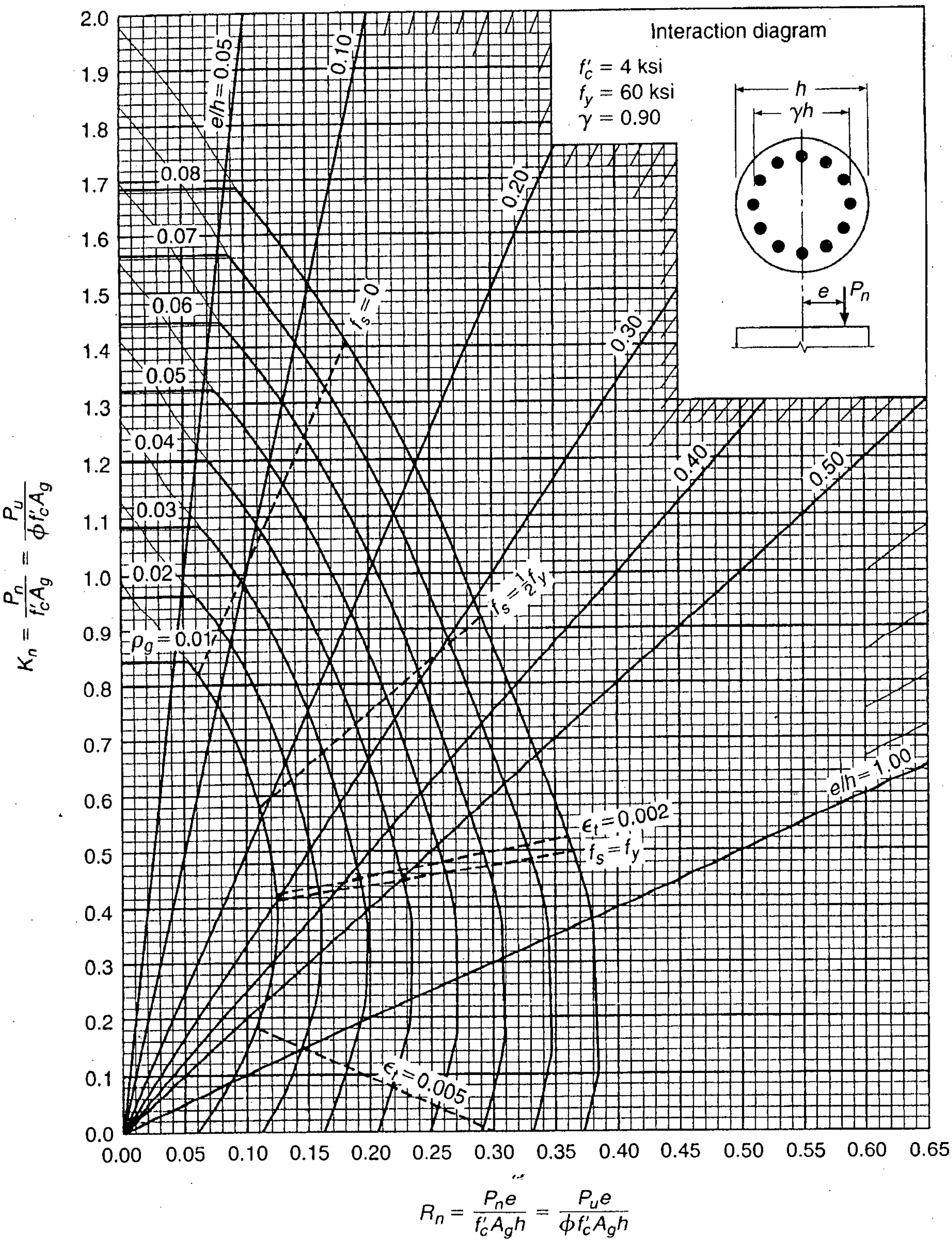
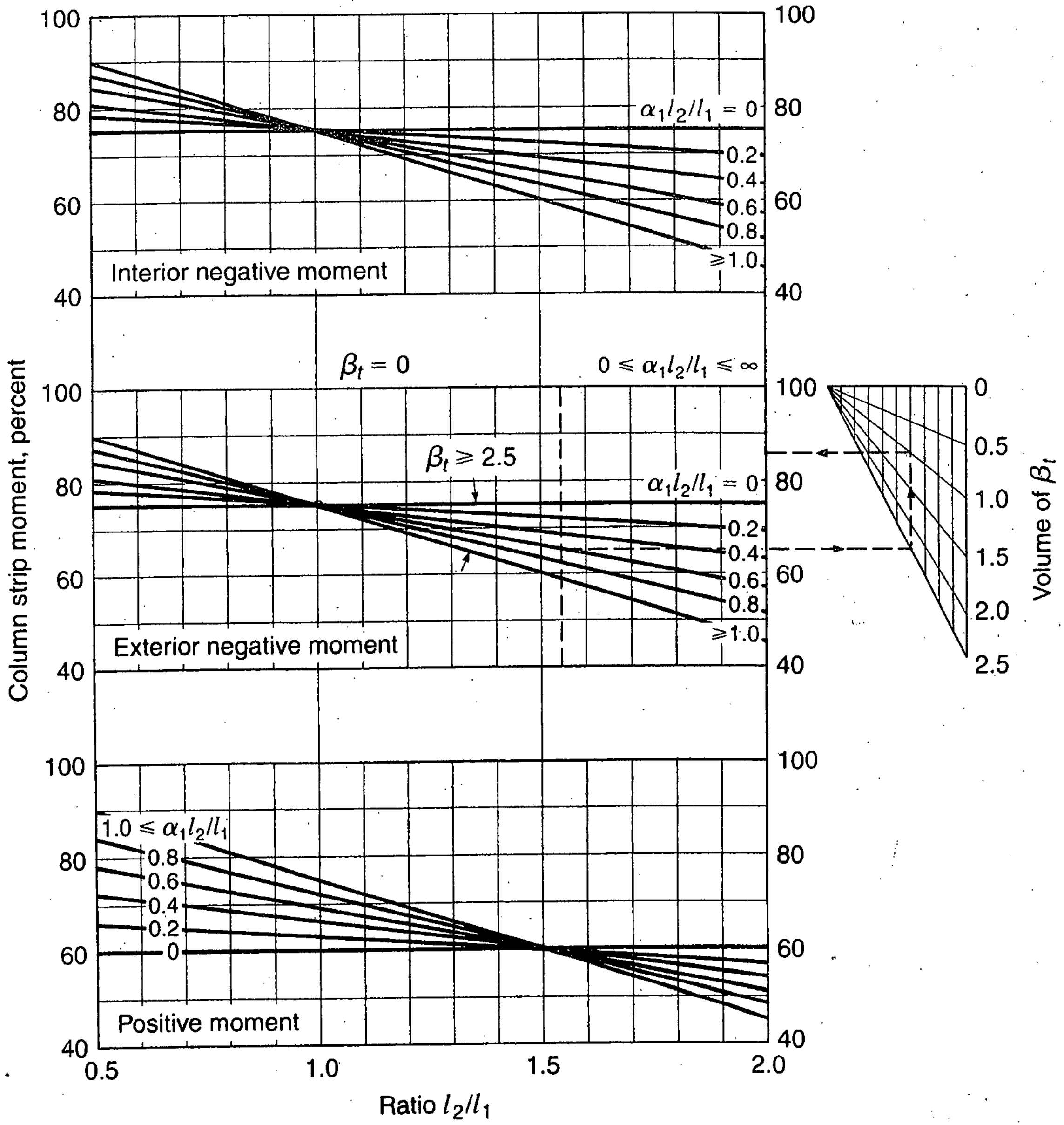



**GRAPH A.16**
Column strength interaction diagram for circular section with $\gamma$ = 0.90.

Design of Concrete Structures – Nilson, Darwin, Dolan

**GRAPH A.4**
Interpolation charts for lateral distribution of slab moments.



L-3/T-2/CE Date : 27/01/2016

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2013-2014

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.

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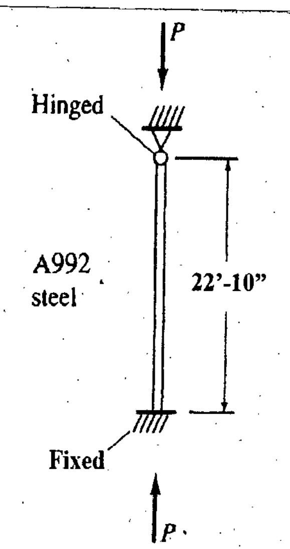
## SECTION – A

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

Symbols and notations have their usual meanings.

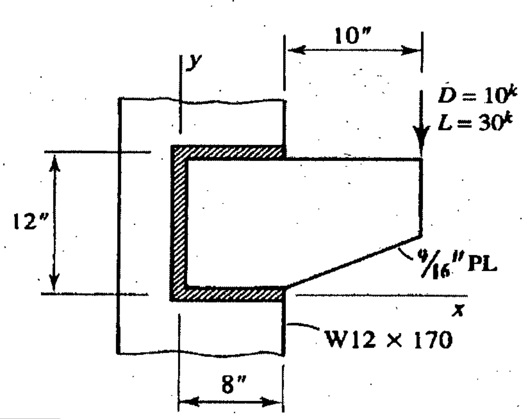
1. (a) Select the lightest W section of A992 ($F_y = 50$ ksi) steel to serve as a column 22'-10" long to carry an axial compression load of 115 kips dead load and 150 kips live load in a braced structure, as shown in Fig. 1. Use ASD approach. **(18)**

Fig.1




(b) Determine the size of fillet weld required for the bracket connection in Fig. 2. The service dead load is 10 kips, and the service live load is 30 kips. Use E70 electrodes and assume that the bracket and the column are OK as base metal. Follow elastic vector analysis and LRFD approach. **(17)**

Fig.2

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**CE 319**

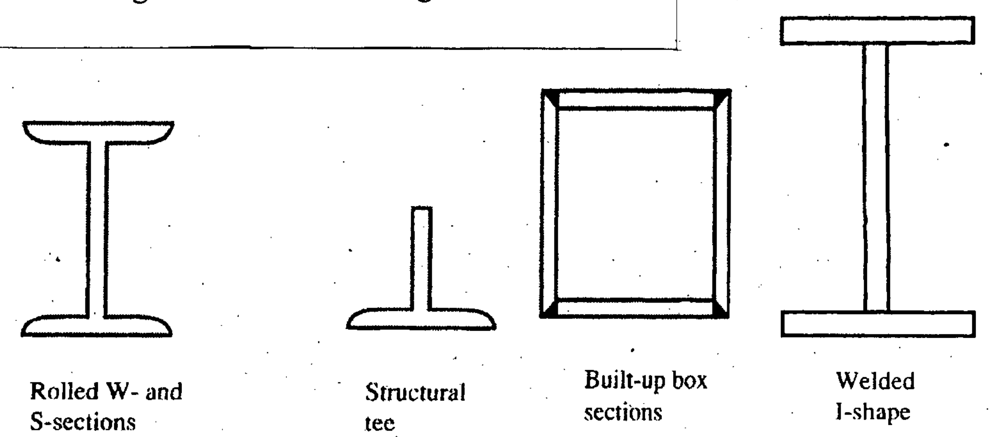
2. (a) A W10 × 112 column transmits an axial compressive live load of 550 kip and dead load of 250 kip on to a concrete base having a top surface area of 36-in. by 60-in. Determine the size and thickness of base plate using A36 materials. The concrete base has $f_c' = 4$ ksi. Follow LRFD method. **(18)**

(b) Select a standard hot-rolled W shape of A992 steel ($F_y$ = 50 ksi) for a simply supported beam of span 20 ft carrying a uniformly distributed live load of 3.4 k/ft and dead load of 1.0 k/ft in addition to its own weight. The beam has continuous lateral support. The maximum permissible live load deflection is $L/240$ where $L$ is the span of the beam. Follow ASD principle. **(17)**

3. (a) (i) Discuss the effect of temperature on the mechanical properties of steel. **(9)**

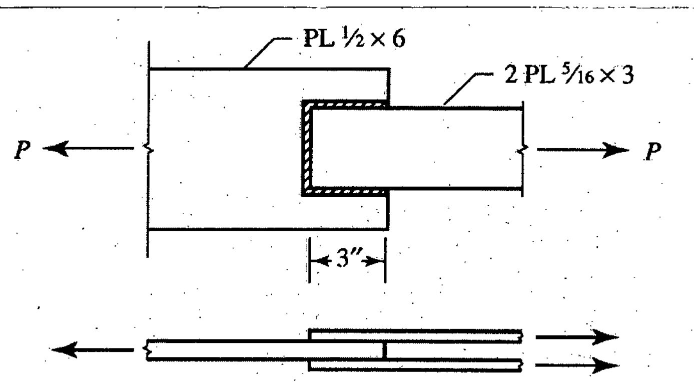
(ii) What is residual stress? Qualitatively draw typical residual stress distribution in the following sections shown in Fig. 3. **(9)**

Fig.3




(b) A tension member splice is made with $\frac{1}{4}$-inch E70 fillet welds as shown in Fig. 4. Each side of the splice is welded as shown. The inner member is a PL $\frac{1}{2}\times 6$ and each outer member is a PL $\frac{5}{16}\times 3$. All steel is A36. Determine the maximum service dead and live load that can be applied if live load is three times the dead load. Follow LRFD principle and consider limit states of welds only. **(17)**

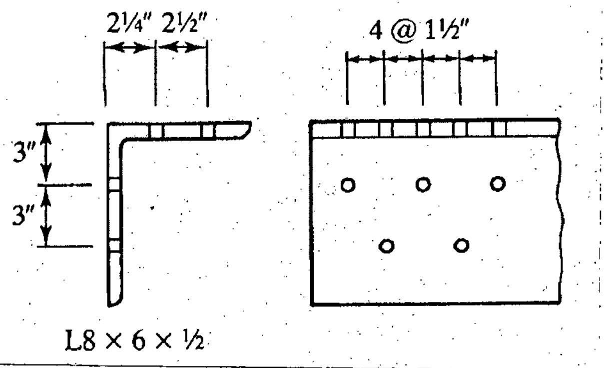
Fig.4



## CE 319

4. (a) An angle L 8 × 6 × $\frac{1}{2}$ as shown in Fig. 5 has five staggered fasteners on each leg. A36 materials is used for the angle and the holes are for $\frac{7}{8}$-in. diameter bolts. Determine the effective net area in tension. **(18)**

Fig.5




(b) A W12×50 section is acted upon by a shear force of 96 kip. Determine the percent of the shear carried by the web and the ratio of the maximum shear stress and the average shear stress. **(17)**

**SECTION – B**

There are **FOUR** questions in this section. Answer any **THREE**.
Assume reasonable values for any missing data. Annexures are provided to facilitate design.

5. (a) With neat sketches describe how different structural steel shapes are designated. **(9)**

(b) Two L7×4×5/8 angles, with their long legs back to back, transmit a tensile load to a $\frac{7}{8}$-in. gusset plate through two lines of six-$\frac{3}{4}$-in. diameter bolts in standard holes as shown in Fig. 6. If the strength of the gusset plate is to be equal to the strength of the angles considering tension limit states of gusset plate and angles only (bolt limit states or block shear strengths for gusset plate or angles are not required to be considered), then determine the necessary width, b of the gusset plate. Angles are made of ASTM A36 steel ($F_y$ = 36 ksi, $F_u$ = 58 ksi) and the gusset plate is of ASTM A992 steel ($F_y$ = 50 ksi, $F_u$ = 65 ksi). Use LRFD method. U for the angles is to be determined from connection details and U for gusset plate is 1. Annexure-3 is provided to facilitate the design. **(26)**

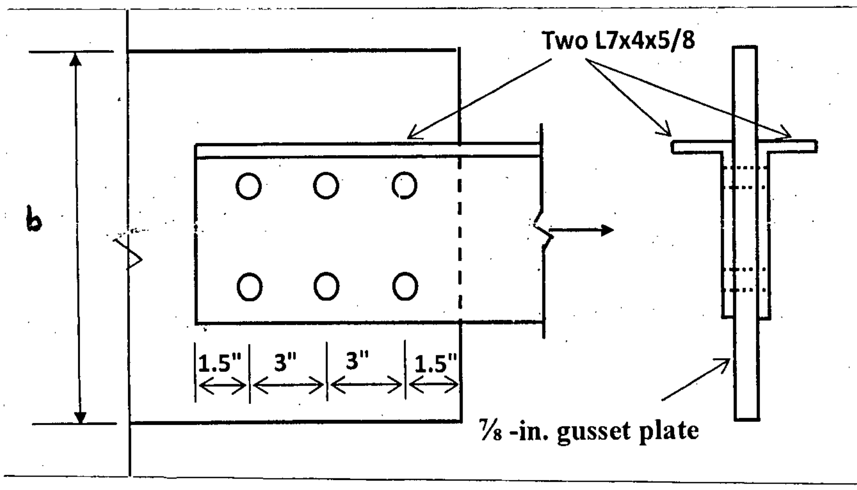



Fig. ~~1~~ 6

**CE 319**

6. (a) Calculate the allowable strength (in ASD) of the bolted connection shown in Fig. 6 based on bolt limit states of shear and bearing only. Bolts are ¾-in. diameter A490 ($F_u^b = 150$ ksi) in standard holes in a bearing type connection with threads included in shear planes. Deformation at the bolt hole at service load is a design consideration. Angles are made of ASTM A36 steel ($F_y = 36$ ksi, $F_u = 58$ ksi) and the gusset plate is of ASTM A992 steel ($F_y = 50$ ksi, $F_u = 65$ ksi). Tension limit states or block shear for gusset plate or angles are not required to be considered. **(17)**

   (b) Determine, the maximum uniformly distributed service live load that may be safely carried by a continuously laterally supported beam on a 24-ft simply supported span based on LRFD moment strength only. It has a wide flange section W14×90 and service dead load including self weight is 0.4 kip/ft. Shear or deflection criteria is not required to be checked. Given: $F_y = 50$ ksi; $E = 29000$ ksi. Annexure-4 is provided to facilitate the design. **(18)**

7. (a) Compute the yield moment and plastic moment capacities and shape factor for major axis bending of the section shown in Fig. 7. Given: $F_y = 42$ ksi. **(17)**

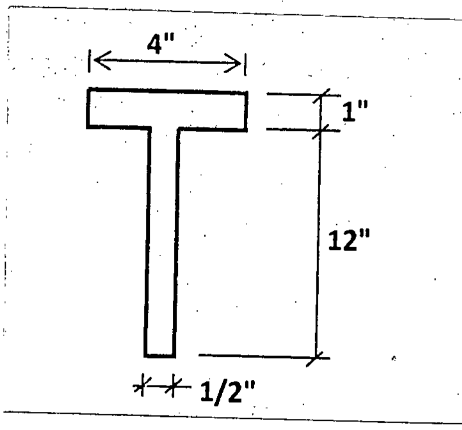



Fig. 7

   (b) Calculate the design strength (in LRFD) of a W14×109 column section with a strong axis unbraced length of 24 ft and weak axis unbraced length of 8 ft. Assume ends of unbraced lengths as pinned. The material is ASTM A36 steel ($F_y = 36$ ksi, $F_u = 58$ ksi); $E = 29000$ ksi. Annexure-4 is provided to facilitate design. **(18)**

Contd .......... P/5

## CE 319

8. (a) Determine the effective length coefficients for the columns AB, CD, DE, FG and GH of the frame shown in Fig. 8. The moments of inertia for members in inch$^4$ are shown alongside the members. The correction factors for beam stiffnesses with far end of the beam hinged are 1/2 with sidesway and 3/2 without sidesway. Column CDE and beam DG are rigidly connected at joint D, while beam BD is hinged at D. Annexure-5 provides necessary nomographs. **(17)**

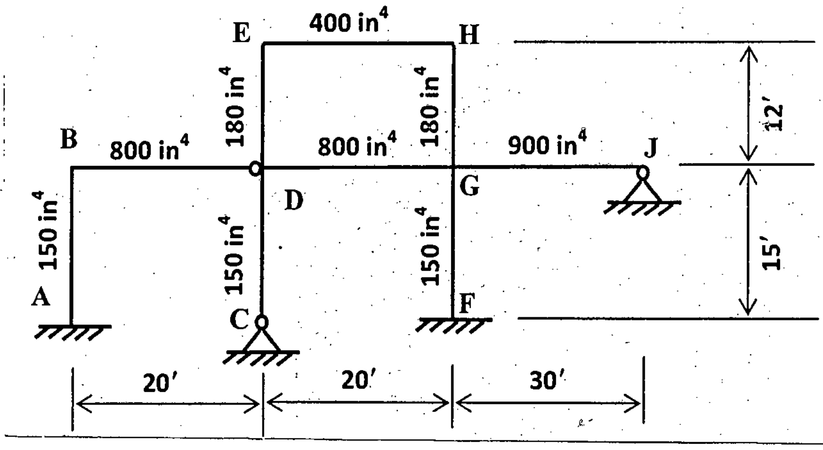



Fig. 8

(b) The residual stress for a 12×1-in. plate to be used as a tension member is shown in Fig. 9. Derive the equation for the stress-strain behaviour in tension of the plate applicable at an imposed tensile strain of 0.0010. What is the average stress and tangent modulus in the section at this strain? Given: $F_y$ = 36 ksi; E = 30000 ksi. **(18)**

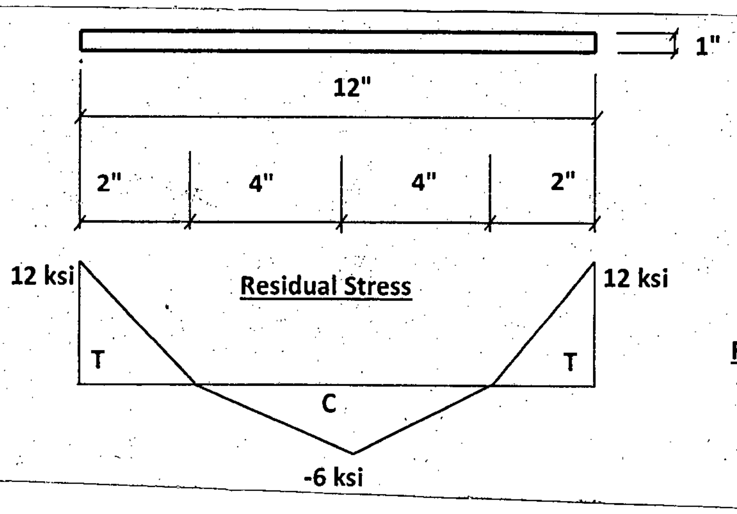



Fig. 9

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Annexure-I

# Table 1-1 (continued)
## W Shapes
### Dimensions

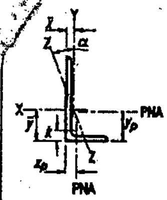
| Shape | Area, A (in.²) | Depth, d (in.) | | Web Thickness, $t_w$ (in.) | | $t_w/2$ (in.) | Flange Width, $b_f$ (in.) | | Flange Thickness, $t_f$ (in.) | | $k_{des}$ (in.) | $k_{det}$ (in.) | $k_1$ (in.) | T (in.) | Workable Gage (in.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W21×201 | 59.2 | 23.0 | 23 | 0.910 | 15/16 | 1/2 | 12.6 | 12 5/8 | 1.63 | 1 5/8 | 2.13 | 2 1/2 | 1 5/16 | 18 | 5 1/2 |
| ×182 | 53.6 | 22.7 | 22 3/4 | 0.830 | 13/16 | 7/16 | 12.5 | 12 1/2 | 1.48 | 1 1/2 | 1.98 | 2 3/8 | 1 1/4 | ↓ | ↓ |
| ×166 | 48.8 | 22.5 | 22 1/2 | 0.750 | 3/4 | 3/8 | 12.4 | 12 3/8 | 1.36 | 1 3/8 | 1.86 | 2 1/4 | 1 3/16 | ↓ | ↓ |
| ×147 | 43.2 | 22.1 | 22 | 0.720 | 3/4 | 3/8 | 12.5 | 12 1/2 | 1.15 | 1 1/8 | 1.65 | 2 | 1 3/16 | ↓ | ↓ |
| ×132 | 38.8 | 21.8 | 21 7/8 | 0.650 | 5/8 | 5/16 | 12.4 | 12 1/2 | 1.04 | 1 1/16 | 1.54 | 1 15/16 | 1 1/8 | ↓ | ↓ |
| ×122 | 35.9 | 21.7 | 21 5/8 | 0.600 | 5/8 | 5/16 | 12.4 | 12 3/8 | 0.960 | 15/16 | 1.46 | 1 13/16 | 1 1/8 | ↓ | ↓ |
| ×111 | 32.7 | 21.5 | 21 1/2 | 0.550 | 9/16 | 5/16 | 12.3 | 12 3/8 | 0.875 | 7/8 | 1.38 | 1 3/4 | 1 1/8 | ↓ | ↓ |
| ×101[c] | 29.8 | 21.4 | 21 3/8 | 0.500 | 1/2 | 1/4 | 12.3 | 12 1/4 | 0.800 | 13/16 | 1.30 | 1 11/16 | 1 1/16 | ↓ | ↓ |
| W21×93 | 27.3 | 21.6 | 21 5/8 | 0.580 | 9/16 | 5/16 | 8.42 | 8 3/8 | 0.930 | 15/16 | 1.43 | 1 5/8 | 15/16 | 18 3/8 | 5 1/2 |
| ×83[c] | 24.3 | 21.4 | 21 3/8 | 0.515 | 1/2 | 1/4 | 8.36 | 8 3/8 | 0.835 | 13/16 | 1.34 | 1 1/2 | 7/8 | ↓ | ↓ |
| ×73[c] | 21.5 | 21.2 | 21 1/4 | 0.455 | 7/16 | 1/4 | 8.30 | 8 1/4 | 0.740 | 3/4 | 1.24 | 1 7/16 | 7/8 | ↓ | ↓ |
| ×68[c] | 20.0 | 21.1 | 21 1/8 | 0.430 | 7/16 | 1/4 | 8.27 | 8 1/4 | 0.685 | 11/16 | 1.19 | 1 3/8 | 7/8 | ↓ | ↓ |
| ×62[c] | 18.3 | 21.0 | 21 | 0.400 | 3/8 | 3/16 | 8.24 | 8 1/4 | 0.615 | 5/8 | 1.12 | 1 5/16 | 13/16 | ↓ | ↓ |
| ×55[c] | 16.2 | 20.8 | 20 3/4 | 0.375 | 3/8 | 3/16 | 8.22 | 8 1/4 | 0.522 | 1/2 | 1.02 | 1 3/16 | 13/16 | ↓ | ↓ |
| ×48[c,f] | 14.1 | 20.6 | 20 5/8 | 0.350 | 3/8 | 3/16 | 8.14 | 8 1/8 | 0.430 | 7/16 | 0.930 | 1 1/8 | 13/16 | ↓ | ↓ |
| W18×71 | 20.8 | 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 | ↓ | ↓ |
| W14×132 | 38.8 | 14.7 | 14 5/8 | 0.645 | 5/8 | 5/16 | 14.7 | 14 3/4 | 1.03 | 1 | 1.63 | 2 5/16 | 1 9/16 | 10 | 5 1/2 |
| ×120 | 35.3 | 14.5 | 14 1/2 | 0.590 | 9/16 | 5/16 | 14.7 | 14 5/8 | 0.940 | 15/16 | 1.54 | 2 1/4 | 1 1/2 | ↓ | ↓ |
| ×109 | 32.0 | 14.3 | 14 3/8 | 0.525 | 1/2 | 1/4 | 14.6 | 14 5/8 | 0.860 | 7/8 | 1.46 | 2 3/16 | 1 1/2 | ↓ | ↓ |
| ×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 | ↓ | ↓ |
| ×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 | ↓ | ↓ |
| 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 1/16 | 10 7/8 | 5 1/2 |
| ×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 | ↓ | ↓ |
| ×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 | ↓ | ↓ |
| ×61 | 17.9 | 13.9 | 13 7/8 | 0.375 | 3/8 | 3/16 | 10.0 | 10 | 0.645 | 5/8 | 1.24 | 1 1/2 | 1 | ↓ | ↓ |
| W14×53 | 15.6 | 13.9 | 13 7/8 | 0.370 | 3/8 | 3/16 | 8.06 | 8 | 0.660 | 11/16 | 1.25 | 1 1/2 | 1 | 10 7/8 | 5 1/2 |
| ×48 | 14.1 | 13.8 | 13 3/4 | 0.340 | 5/16 | 3/16 | 8.03 | 8 | 0.595 | 5/8 | 1.19 | 1 7/16 | 1 | ↓ | ↓ |
| ×43[c] | 12.6 | 13.7 | 13 5/8 | 0.305 | 5/16 | 3/16 | 8.00 | 8 | 0.530 | 1/2 | 1.12 | 1 3/8 | 1 | ↓ | ↓ |
| W12×58 | 17.0 | 12.2 | 12 1/4 | 0.360 | 3/8 | 3/16 | 10.0 | 10 | 0.640 | 5/8 | 1.24 | 1 1/2 | 15/16 | 9 1/4 | 5 1/2 |
| ×53 | 15.6 | 12.1 | 12 | 0.345 | 3/8 | 3/16 | 10.0 | 10 | 0.575 | 9/16 | 1.18 | 1 3/8 | 15/16 | 9 1/4 | 5 1/2 |
| W12×50 | 14.8 | 12.2 | 12 1/4 | 0.370 | 3/8 | 3/16 | 8.08 | 8 1/8 | 0.640 | 5/8 | 1.14 | 1 1/2 | 15/16 | 9 1/4 | 5 1/2 |
| ×45 | 13.1 | 12.1 | 12 | 0.335 | 5/16 | 3/16 | 8.05 | 8 | 0.575 | 9/16 | 1.08 | 1 3/8 | 15/16 | ↓ | ↓ |
| ×40 | 11.7 | 11.9 | 12 | 0.295 | 5/16 | 3/16 | 8.01 | 8 | 0.515 | 1/2 | 1.02 | 1 3/8 | 7/8 | ↓ | ↓ |
| W12×35[c] | 10.3 | 12.5 | 12 1/2 | 0.300 | 5/16 | 3/16 | 6.56 | 6 1/2 | 0.520 | 1/2 | 0.820 | 1 3/16 | 3/4 | 10 1/8 | 3 1/2 |
| ×30[c] | 8.79 | 12.3 | 12 3/8 | 0.260 | 1/4 | 1/8 | 6.52 | 6 1/2 | 0.440 | 7/16 | 0.740 | 1 1/8 | 3/4 | ↓ | ↓ |
| ×26[c] | 7.65 | 12.2 | 12 1/4 | 0.230 | 1/4 | 1/8 | 6.49 | 6 1/2 | 0.380 | 3/8 | 0.680 | 1 1/16 | 3/4 | ↓ | ↓ |
| W12×22[c] | 6.48 | 12.3 | 12 1/4 | 0.260 | 1/4 | 1/8 | 4.03 | 4 | 0.425 | 7/16 | 0.725 | 15/16 | 5/8 | 10 3/8 | 2 1/4[g] |
| ×19[c] | 5.57 | 12.2 | 12 1/8 | 0.235 | 1/4 | 1/8 | 4.01 | 4 | 0.350 | 3/8 | 0.650 | 7/8 | 9/16 | ↓ | ↓ |
| ×16[c] | 4.71 | 12.0 | 12 | 0.220 | 1/4 | 1/8 | 3.99 | 4 | 0.265 | 1/4 | 0.565 | 13/16 | 9/16 | ↓ | ↓ |
| ×14[c,v] | 4.16 | 11.9 | 11 7/8 | 0.200 | 3/16 | 1/8 | 3.97 | 4 | 0.225 | 1/4 | 0.525 | 3/4 | 9/16 | ↓ | ↓ |
| W10×112 | 32.9 | 11.4 | 11 3/8 | 0.755 | 3/4 | 3/8 | 10.4 | 10 3/8 | 1.25 | 1 1/4 | 1.75 | 1 15/16 | 1 | 7 1/2 | 5 1/2 |
| ×100 | 29.4 | 11.1 | 11 1/8 | 0.680 | 11/16 | 3/8 | 10.3 | 10 3/8 | 1.12 | 1 1/8 | 1.62 | 1 13/16 | 1 | ↓ | ↓ |
| ×88 | 25.9 | 10.8 | 10 7/8 | 0.605 | 5/8 | 5/16 | 10.3 | 10 1/4 | 0.990 | 1 | 1.49 | 1 11/16 | 15/16 | ↓ | ↓ |
| ×77 | 22.6 | 10.6 | 10 5/8 | 0.530 | 1/2 | 1/4 | 10.2 | 10 1/4 | 0.870 | 7/8 | 1.37 | 1 9/16 | 7/8 | ↓ | ↓ |
| ×68 | 20.0 | 10.4 | 10 3/8 | 0.470 | 1/2 | 1/4 | 10.1 | 10 1/8 | 0.770 | 3/4 | 1.27 | 1 7/16 | 7/8 | ↓ | ↓ |
| ×60 | 17.6 | 10.2 | 10 1/4 | 0.420 | 7/16 | 1/4 | 10.1 | 10 1/8 | 0.680 | 11/16 | 1.18 | 1 3/8 | 13/16 | ↓ | ↓ |
| ×54 | 15.8 | 10.1 | 10 1/8 | 0.370 | 3/8 | 3/16 | 10.0 | 10 | 0.615 | 5/8 | 1.12 | 1 5/16 | 13/16 | ↓ | ↓ |
| ×49 | 14.4 | 10.0 | 10 | 0.340 | 5/16 | 5/16 | 10.0 | 10 | 0.560 | 9/16 | 1.06 | 1 1/4 | 13/16 | ↓ | ↓ |

# Table 1-1 (continued)
## W Shapes
### Properties

W14 – W12

| Shape | Compact Section Criteria $b_f/2t_f$ | $h/t_w$ | Axis X-X I (in.⁴) | S (in.³) | r (in.) | Z (in.³) | Axis Y-Y I (in.⁴) | S (in.³) | r (in.) | Z (in.³) | $r_{ts}$ (in.) | $h_o$ (in.) | Torsional Properties J (in.⁴) | $C_w$ (in.⁶) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W21×201 | 3.86 | 20.6 | 5310 | 461 | 9.47 | 530 | 542 | 86.1 | 3.02 | 133 | 3.55 | 21.4 | 40.9 | 62000 |
| ×182 | 4.22 | 22.6 | 4730 | 417 | 9.40 | 476 | 483 | 77.2 | 3.00 | 119 | 3.51 | 21.2 | 30.7 | 54400 |
| ×166 | 4.57 | 25.0 | 4280 | 380 | 9.36 | 432 | 435 | 70.0 | 2.99 | 108 | 3.48 | 21.1 | 23.6 | 48500 |
| ×147 | 5.44 | 26.1 | 3630 | 329 | 9.17 | 373 | 376 | 60.1 | 2.95 | 92.6 | 3.45 | 20.9 | 15.4 | 41100 |
| ×132 | 6.01 | 28.9 | 3220 | 295 | 9.12 | 333 | 333 | 53.5 | 2.93 | 82.3 | 3.42 | 20.8 | 11.3 | 36000 |
| ×122 | 6.45 | 31.3 | 2960 | 273 | 9.09 | 307 | 305 | 49.2 | 2.92 | 75.6 | 3.40 | 20.7 | 8.98 | 32700 |
| ×111 | 7.05 | 34.1 | 2670 | 249 | 9.05 | 279 | 274 | 44.5 | 2.90 | 68.2 | 3.37 | 20.6 | 6.83 | 29200 |
| ×101[c] | 7.68 | 37.5 | 2420 | 227 | 9.02 | 253 | 248 | 40.3 | 2.89 | 61.7 | 3.35 | 20.6 | 5.21 | 26200 |
| W21×93 | 4.53 | 32.3 | 2070 | 192 | 8.70 | 221 | 92.9 | 22.1 | 1.84 | 34.7 | 2.24 | 20.7 | 6.03 | 9940 |
| ×83[c] | 5.00 | 36.4 | 1830 | 171 | 8.67 | 196 | 81.4 | 19.5 | 1.83 | 30.5 | 2.21 | 20.6 | 4.34 | 8630 |
| ×73[c] | 5.60 | 41.2 | 1600 | 151 | 8.64 | 172 | 70.6 | 17.0 | 1.81 | 26.6 | 2.19 | 20.5 | 3.02 | 7410 |
| ×68[c] | 6.04 | 43.6 | 1480 | 140 | 8.60 | 160 | 64.7 | 15.7 | 1.80 | 24.4 | 2.17 | 20.4 | 2.45 | 6760 |
| ×62[c] | 6.70 | 46.9 | 1330 | 127 | 8.54 | 144 | 57.5 | 14.0 | 1.77 | 21.7 | 2.15 | 20.4 | 1.83 | 5960 |
| ×55[c] | 7.87 | 50.0 | 1140 | 110 | 8.40 | 126 | 48.4 | 11.8 | 1.73 | 18.4 | 2.11 | 20.3 | 1.24 | 4980 |
| ×48[c,f] | 9.47 | 53.8 | 959 | 93.0 | 8.24 | 107 | 38.7 | 9.52 | 1.66 | 14.9 | 2.05 | 20.2 | 0.803 | 3950 |
| W18×71 | 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 | 17.6 | 2.73 | 4240 |
| ×60[c] | 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[c] | 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[c] | 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 |
| W14×132 | 7.15 | 17.7 | 1530 | 209 | 6.28 | 234 | 548 | 74.5 | 3.76 | 113 | 4.23 | 13.6 | 12.3 | 25500 |
| ×120 | 7.80 | 19.3 | 1380 | 190 | 6.24 | 212 | 495 | 67.5 | 3.74 | 102 | 4.20 | 13.5 | 9.37 | 22700 |
| ×109 | 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] | 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] | 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 | 5.92 | 22.4 | 881 | 123 | 6.05 | 139 | 148 | 29.3 | 2.48 | 44.8 | 2.85 | 13.5 | 5.07 | 6710 |
| ×74 | 6.41 | 25.4 | 795 | 112 | 6.04 | 126 | 134 | 26.6 | 2.48 | 40.5 | 2.82 | 13.4 | 3.87 | 5990 |
| ×68 | 6.97 | 27.5 | 722 | 103 | 6.01 | 115 | 121 | 24.2 | 2.46 | 36.9 | 2.80 | 13.3 | 3.01 | 5380 |
| ×61 | 7.75 | 30.4 | 640 | 92.1 | 5.98 | 102 | 107 | 21.5 | 2.45 | 32.8 | 2.78 | 13.2 | 2.19 | 4710 |
| W14×53 | 6.11 | 30.9 | 541 | 77.8 | 5.89 | 87.1 | 57.7 | 14.3 | 1.92 | 22.0 | 2.22 | 13.3 | 1.94 | 2540 |
| ×48 | 6.75 | 33.6 | 484 | 70.2 | 5.85 | 78.4 | 51.4 | 12.8 | 1.91 | 19.6 | 2.20 | 13.2 | 1.45 | 2240 |
| ×43[c] | 7.54 | 37.4 | 428 | 62.6 | 5.82 | 69.6 | 45.2 | 11.3 | 1.89 | 17.3 | 2.18 | 13.1 | 1.05 | 1950 |
| W12×58 | 7.82 | 27.0 | 475 | 78.0 | 5.28 | 86.4 | 107 | 21.4 | 2.51 | 32.5 | 2.82 | 11.6 | 2.10 | 3570 |
| ×53 | 8.69 | 28.1 | 425 | 70.6 | 5.23 | 77.9 | 95.8 | 19.2 | 2.48 | 29.1 | 2.79 | 11.5 | 1.58 | 3160 |
| W12×50 | 6.31 | 26.8 | 391 | 64.2 | 5.18 | 71.9 | 56.3 | 13.9 | 1.96 | 21.3 | 2.25 | 11.6 | 1.71 | 1880 |
| ×45 | 7.00 | 29.6 | 348 | 57.7 | 5.15 | 64.2 | 50.0 | 12.4 | 1.95 | 19.0 | 2.23 | 11.5 | 1.26 | 1650 |
| ×40 | 7.77 | 33.6 | 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] | 6.31 | 36.2 | 285 | 45.6 | 5.25 | 51.2 | 24.5 | 7.47 | 1.54 | 11.5 | 1.79 | 12.0 | 0.741 | 879 |
| ×30[c] | 7.41 | 41.8 | 238 | 38.6 | 5.21 | 43.1 | 20.3 | 6.24 | 1.52 | 9.56 | 1.77 | 11.9 | 0.457 | 720 |
| ×26[c] | 8.54 | 47.2 | 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] | 4.74 | 41.8 | 156 | 25.4 | 4.91 | 29.3 | 4.66 | 2.31 | 0.848 | 3.66 | 1.04 | 11.9 | 0.293 | 164 |
| ×19[c] | 5.72 | 46.2 | 130 | 21.3 | 4.82 | 24.7 | 3.76 | 1.88 | 0.822 | 2.98 | 1.02 | 11.8 | 0.180 | 131 |
| ×16[c] | 7.53 | 49.4 | 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] | 8.82 | 54.3 | 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 | 4.17 | 10.4 | 716 | 126 | 4.66 | 147 | 236 | 45.3 | 2.68 | 69.2 | 3.07 | 10.1 | 15.1 | 6020 |
| ×100 | 4.62 | 11.6 | 623 | 112 | 4.60 | 130 | 207 | 40.0 | 2.65 | 61.0 | 3.03 | 10.0 | 10.9 | 5150 |
| ×88 | 5.18 | 13.0 | 534 | 98.5 | 4.54 | 113 | 179 | 34.8 | 2.63 | 53.1 | 2.99 | 9.85 | 7.53 | 4330 |
| ×77 | 5.86 | 14.8 | 455 | 85.9 | 4.49 | 97.6 | 154 | 30.1 | 2.60 | 45.9 | 2.95 | 9.73 | 5.11 | 3630 |
| ×68 | 6.58 | 16.7 | 394 | 75.7 | 4.44 | 85.3 | 134 | 26.4 | 2.59 | 40.1 | 2.91 | 9.63 | 3.58 | 3100 |
| ×60 | 7.41 | 18.7 | 341 | 66.7 | 4.39 | 74.6 | 116 | 23.0 | 2.57 | 35.0 | 2.88 | 9.54 | 2.48 | 2640 |
| ×54 | 8.15 | 21.2 | 303 | 60.0 | 4.37 | 66.8 | 103 | 20.6 | 2.56 | 31.3 | 2.86 | 9.48 | 1.82 | 2320 |
| ×49 | 8.93 | 23.1 | 272 | 54.6 | 4.35 | 60.4 | 93.4 | 18.7 | 2.54 | 28.3 | 2.84 | 9.42 | 1.39 | 2070 |

Annexure-2




# Table 1-7 Angles Properties

# Table 1-7 (continued) Angles Properties

L8-L6

| Shape | $k$ | Wt. | Area, $A$ | Axis X-X | | | | | | Flexural-Torsional Properties | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $I$ | $S$ | $r$ | $\bar{y}$ | $Z$ | $y_p$ | $J$ | $C_w$ | $\bar{r}_o$ |
| | in. | lb/ft | in.$^2$ | in.$^4$ | in.$^3$ | in. | in. | in.$^3$ | in. | in.$^4$ | in.$^6$ | in. |
| L8×8×1 1/8 | 1 3/4 | 56.9 | 16.7 | 98.1 | 17.5 | 2.41 | 2.40 | 31.6 | 1.05 | 7.13 | 32.5 | 4.29 |
| ×1 | 1 5/8 | 51.0 | 15.0 | 89.1 | 15.8 | 2.43 | 2.36 | 28.5 | 0.943 | 5.08 | 23.4 | 4.32 |
| ×7/8 | 1 1/2 | 45.0 | 13.2 | 79.7 | 14.0 | 2.45 | 2.31 | 25.3 | 0.832 | 3.46 | 16.1 | 4.36 |
| ×3/4 | 1 3/8 | 38.9 | 11.4 | 69.9 | 12.2 | 2.46 | 2.28 | 22.0 | 0.720 | 2.21 | 10.4 | 4.39 |
| ×5/8 | 1 1/4 | 32.7 | 9.61 | 59.6 | 10.3 | 2.48 | 2.21 | 18.6 | 0.606 | 1.30 | 6.16 | 4.42 |
| ×9/16 | 1 3/16 | 29.6 | 8.68 | 54.2 | 9.33 | 2.49 | 2.19 | 16.8 | 0.548 | 0.961 | 4.65 | 4.43 |
| ×1/2 | 1 1/8 | 26.4 | 7.75 | 48.8 | 8.36 | 2.49 | 2.17 | 15.1 | 0.490 | 0.683 | 3.23 | 4.45 |
| L8×6×1 | 1 1/2 | 44.2 | 13.0 | 80.9 | 15.1 | 2.49 | 2.65 | 27.3 | 1.47 | 4.34 | 16.3 | 3.88 |
| ×7/8 | 1 3/8 | 39.1 | 11.5 | 72.4 | 13.4 | 2.50 | 2.60 | 24.3 | 1.41 | 2.96 | 11.3 | 3.92 |
| ×3/4 | 1 1/4 | 33.8 | 9.94 | 63.5 | 11.7 | 2.52 | 2.55 | 21.1 | 1.34 | 1.90 | 7.28 | 3.95 |
| ×5/8 | 1 1/8 | 28.5 | 8.36 | 54.2 | 9.86 | 2.54 | 2.50 | 17.9 | 1.27 | 1.12 | 4.33 | 3.98 |
| ×9/16 | 1 1/16 | 25.7 | 7.56 | 49.4 | 8.94 | 2.55 | 2.48 | 16.2 | 1.23 | 0.823 | 3.20 | 3.99 |
| ×1/2 | 1 | 23.0 | 6.75 | 44.4 | 8.01 | 2.55 | 2.46 | 14.6 | 1.20 | 0.584 | 2.28 | 4.01 |
| ×7/16 | 15/16 | 20.2 | 5.93 | 39.3 | 7.06 | 2.56 | 2.43 | 12.9 | 1.16 | 0.396 | 1.55 | 4.02 |
| L8×4×1 | 1 1/2 | 37.4 | 11.0 | 69.7 | 14.0 | 2.51 | 3.03 | 24.3 | 2.47 | 3.68 | 12.9 | 3.75 |
| ×7/8 | 1 3/8 | 33.1 | 9.73 | 62.6 | 12.5 | 2.53 | 2.99 | 21.7 | 2.41 | 2.51 | 8.69 | 3.78 |
| ×3/4 | 1 1/4 | 28.7 | 8.44 | 55.0 | 10.9 | 2.55 | 2.94 | 18.9 | 2.34 | 1.61 | 5.75 | 3.80 |
| ×5/8 | 1 1/8 | 24.2 | 7.11 | 47.0 | 9.20 | 2.56 | 2.89 | 16.1 | 2.27 | 0.955 | 3.42 | 3.83 |
| ×9/16 | 1 1/16 | 21.9 | 6.43 | 42.9 | 8.34 | 2.57 | 2.86 | 14.6 | 2.23 | 0.704 | 2.53 | 3.84 |
| ×1/2 | 1 | 19.6 | 5.75 | 38.6 | 7.48 | 2.58 | 2.84 | 13.1 | 2.20 | 0.501 | 1.80 | 3.86 |
| ×7/16 | 15/16 | 17.2 | 5.06 | 34.2 | 6.59 | 2.59 | 2.81 | 11.6 | 2.16 | 0.340 | 1.22 | 3.87 |
| L7×4×3/4 | 1 1/4 | 26.2 | 7.69 | 37.8 | 8.39 | 2.21 | 2.50 | 14.8 | 1.87 | 1.47 | 3.97 | 3.31 |
| ×5/8 | 1 1/8 | 22.1 | 6.48 | 32.4 | 7.12 | 2.23 | 2.45 | 12.5 | 1.80 | 0.868 | 2.37 | 3.34 |
| ×1/2 | 1 | 17.9 | 5.25 | 26.6 | 5.79 | 2.25 | 2.40 | 10.2 | 1.74 | 0.456 | 1.25 | 3.37 |
| ×7/16 | 15/16 | 15.7 | 4.62 | 23.6 | 5.11 | 2.26 | 2.38 | 9.03 | 1.70 | 0.310 | 0.851 | 3.38 |
| ×3/8 | 7/8 | 13.6 | 3.98 | 20.5 | 4.42 | 2.27 | 2.35 | 7.81 | 1.67 | 0.198 | 0.544 | 3.40 |
| L6×6×1 | 1 1/2 | 37.4 | 11.0 | 35.4 | 8.55 | 1.79 | 1.86 | 15.4 | 0.918 | 3.68 | 9.24 | 3.18 |
| ×7/8 | 1 3/8 | 33.1 | 9.75 | 31.9 | 7.61 | 1.81 | 1.81 | 13.7 | 0.813 | 2.51 | 6.41 | 3.21 |
| ×3/4 | 1 1/4 | 28.7 | 8.46 | 28.1 | 6.64 | 1.82 | 1.77 | 11.9 | 0.705 | 1.61 | 4.17 | 3.24 |
| ×5/8 | 1 1/8 | 24.2 | 7.13 | 24.1 | 5.64 | 1.84 | 1.72 | 10.1 | 0.594 | 0.955 | 2.50 | 3.28 |
| ×9/16 | 1 1/16 | 21.9 | 6.45 | 22.0 | 5.12 | 1.85 | 1.70 | 9.18 | 0.538 | 0.704 | 1.85 | 3.29 |
| ×1/2 | 1 | 19.6 | 5.77 | 19.9 | 4.59 | 1.86 | 1.67 | 8.22 | 0.481 | 0.501 | 1.32 | 3.31 |
| ×7/16 | 15/16 | 17.2 | 5.08 | 17.6 | 4.06 | 1.86 | 1.65 | 7.25 | 0.423 | 0.340 | 0.899 | 3.32 |
| ×3/8 | 7/8 | 14.9 | 4.38 | 15.4 | 3.51 | 1.87 | 1.62 | 6.27 | 0.365 | 0.218 | 0.575 | 3.34 |
| ×5/16 | 13/16 | 12.4 | 3.67 | 13.0 | 2.95 | 1.88 | 1.60 | 5.26 | 0.306 | 0.129 | 0.338 | 3.35 |

| Shape | Axis Y-Y | | | | | | Axis Z-Z | | | | $Q_s$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I$ | $S$ | $r$ | $\bar{x}$ | $Z$ | $x_p$ | $I$ | $S$ | $r$ | Tan $\alpha$ | $F_y$ = 36 ksi |
| | in.$^4$ | in.$^3$ | in. | in. | in.$^3$ | in. | in.$^4$ | in.$^3$ | in. | | |
| L8×8×1 1/8 | 98.1 | 17.5 | 2.41 | 2.40 | 31.6 | 1.05 | 40.9 | 7.23 | 1.56 | 1.00 | 1.00 |
| ×1 | 89.1 | 15.8 | 2.43 | 2.36 | 28.5 | 0.943 | 36.8 | 6.51 | 1.56 | 1.00 | 1.00 |
| ×7/8 | 79.7 | 14.0 | 2.45 | 2.31 | 25.3 | 0.832 | 32.7 | 5.78 | 1.57 | 1.00 | 1.00 |
| ×3/4 | 69.9 | 12.2 | 2.46 | 2.26 | 22.0 | 0.720 | 28.5 | 5.04 | 1.57 | 1.00 | 1.00 |
| ×5/8 | 59.6 | 10.3 | 2.48 | 2.21 | 18.6 | 0.606 | 24.2 | 4.27 | 1.58 | 1.00 | 0.997 |
| ×9/16 | 54.2 | 9.33 | 2.49 | 2.19 | 16.8 | 0.548 | 22.0 | 3.88 | 1.58 | 1.00 | 0.959 |
| ×1/2 | 48.8 | 8.36 | 2.49 | 2.17 | 15.1 | 0.490 | 19.7 | 3.49 | 1.59 | 1.00 | 0.912 |
| L8×6×1 | 38.8 | 8.92 | 1.72 | 1.65 | 16.2 | 0.816 | 21.3 | 4.84 | 1.28 | 0.542 | 1.00 |
| ×7/8 | 34.9 | 7.94 | 1.74 | 1.60 | 14.4 | 0.721 | 18.9 | 4.31 | 1.28 | 0.546 | 1.00 |
| ×3/4 | 30.8 | 6.92 | 1.75 | 1.56 | 12.5 | 0.624 | 16.5 | 3.78 | 1.29 | 0.550 | 1.00 |
| ×5/8 | 26.4 | 5.88 | 1.77 | 1.51 | 10.5 | 0.526 | 14.1 | 3.22 | 1.29 | 0.554 | 0.997 |
| ×9/16 | 24.1 | 5.34 | 1.78 | 1.49 | 9.52 | 0.476 | 12.8 | 2.94 | 1.30 | 0.556 | 0.959 |
| ×1/2 | 21.7 | 4.79 | 1.79 | 1.46 | 8.52 | 0.425 | 11.5 | 2.64 | 1.30 | 0.557 | 0.912 |
| ×7/16 | 19.3 | 4.23 | 1.80 | 1.44 | 7.50 | 0.374 | 10.2 | 2.35 | 1.31 | 0.559 | 0.850 |
| L8×4×1 | 11.6 | 3.94 | 1.03 | 1.04 | 7.73 | 0.691 | 7.87 | 2.15 | 0.844 | 0.247 | 1.00 |
| ×7/8 | 10.5 | 3.51 | 1.04 | 0.997 | 6.77 | 0.612 | 7.01 | 1.93 | 0.846 | 0.252 | 1.00 |
| ×3/4 | 9.37 | 3.07 | 1.05 | 0.949 | 5.82 | 0.531 | 6.13 | 1.70 | 0.850 | 0.257 | 1.00 |
| ×5/8 | 8.11 | 2.62 | 1.06 | 0.902 | 4.86 | 0.448 | 5.24 | 1.47 | 0.856 | 0.262 | 0.997 |
| ×9/16 | 7.44 | 2.38 | 1.07 | 0.878 | 4.39 | 0.405 | 4.79 | 1.34 | 0.859 | 0.264 | 0.959 |
| ×1/2 | 6.75 | 2.15 | 1.08 | 0.854 | 3.91 | 0.363 | 4.32 | 1.22 | 0.863 | 0.266 | 0.912 |
| ×7/16 | 6.03 | 1.90 | 1.09 | 0.829 | 3.42 | 0.320 | 3.84 | 1.09 | 0.867 | 0.268 | 0.850 |
| L7×4×3/4 | 9.00 | 3.01 | 1.08 | 1.00 | 5.60 | 0.550 | 5.64 | 1.71 | 0.855 | 0.324 | 1.00 |
| ×5/8 | 7.79 | 2.56 | 1.10 | 0.958 | 4.69 | 0.464 | 4.80 | 1.47 | 0.860 | 0.329 | 1.00 |
| ×1/2 | 6.48 | 2.10 | 1.11 | 0.910 | 3.77 | 0.376 | 3.95 | 1.21 | 0.866 | 0.334 | 0.965 |
| ×7/16 | 5.79 | 1.86 | 1.12 | 0.886 | 3.31 | 0.331 | 3.50 | 1.08 | 0.869 | 0.337 | 0.912 |
| ×3/8 | 5.06 | 1.61 | 1.12 | 0.861 | 2.84 | 0.286 | 3.05 | 0.942 | 0.873 | 0.339 | 0.840 |
| L6×6×1 | 35.4 | 8.55 | 1.79 | 1.86 | 15.4 | 0.918 | 15.0 | 3.53 | 1.17 | 1.00 | 1.00 |
| ×7/8 | 31.9 | 7.61 | 1.81 | 1.81 | 13.7 | 0.813 | 13.3 | 3.13 | 1.17 | 1.00 | 1.00 |
| ×3/4 | 28.1 | 6.64 | 1.82 | 1.77 | 11.9 | 0.705 | 11.6 | 2.73 | 1.17 | 1.00 | 1.00 |
| ×5/8 | 24.1 | 5.64 | 1.84 | 1.72 | 10.1 | 0.594 | 9.83 | 2.32 | 1.17 | 1.00 | 1.00 |
| ×9/16 | 22.0 | 5.12 | 1.85 | 1.70 | 9.17 | 0.538 | 8.94 | 2.11 | 1.18 | 1.00 | 1.00 |
| ×1/2 | 19.9 | 4.59 | 1.86 | 1.67 | 8.22 | 0.481 | 8.04 | 1.89 | 1.18 | 1.00 | 1.00 |
| ×7/16 | 17.6 | 4.06 | 1.86 | 1.65 | 7.25 | 0.423 | 7.11 | 1.68 | 1.18 | 1.00 | 0.973 |
| ×3/8 | 15.4 | 3.51 | 1.87 | 1.62 | 6.28 | 0.365 | 6.17 | 1.45 | 1.19 | 1.00 | 0.912 |
| ×5/16 | 13.0 | 2.95 | 1.88 | 1.60 | 5.26 | 0.306 | 5.20 | 1.23 | 1.19 | 1.00 | 0.826 |

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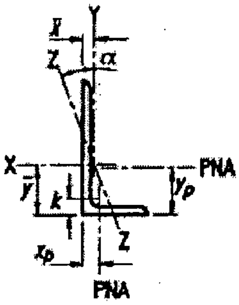
ANNEXURE-~~1~~ 3




# Table 1–7
# Angles
## Properties

| Shape | k | Wt. | Area, A | Axis X-X: I | S | r | $\bar{y}$ | Z | $y_p$ | Flexural-Torsional Properties: J | $C_w$ | $\bar{r}_o$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | in. | lb/ft | in.$^2$ | in.$^4$ | in.$^3$ | in. | in. | in.$^3$ | in. | in.$^4$ | in.$^6$ | in. |
| L8×8×1 1/8 | 1 3/4 | 56.9 | 16.7 | 98.1 | 17.5 | 2.41 | 2.40 | 31.6 | 1.05 | 7.13 | 32.5 | 4.29 |
| ×1 | 1 5/8 | 51.0 | 15.0 | 89.1 | 15.8 | 2.43 | 2.36 | 28.5 | 0.943 | 5.08 | 23.4 | 4.32 |
| ×7/8 | 1 1/2 | 45.0 | 13.2 | 79.7 | 14.0 | 2.45 | 2.31 | 25.3 | 0.832 | 3.46 | 16.1 | 4.36 |
| ×3/4 | 1 3/8 | 38.9 | 11.4 | 69.9 | 12.2 | 2.46 | 2.26 | 22.0 | 0.720 | 2.21 | 10.4 | 4.39 |
| ×5/8 | 1 1/4 | 32.7 | 9.61 | 59.6 | 10.3 | 2.48 | 2.21 | 18.6 | 0.606 | 1.30 | 6.16 | 4.42 |
| ×9/16 | 1 3/16 | 29.6 | 8.68 | 54.2 | 9.33 | 2.49 | 2.19 | 16.8 | 0.548 | 0.961 | 4.55 | 4.43 |
| ×1/2 | 1 1/8 | 26.4 | 7.75 | 48.8 | 8.36 | 2.49 | 2.17 | 15.1 | 0.490 | 0.683 | 3.23 | 4.45 |
| L8×6×1 | 1 1/2 | 44.2 | 13.0 | 80.9 | 15.1 | 2.49 | 2.65 | 27.3 | 1.47 | 4.34 | 16.3 | 3.88 |
| ×7/8 | 1 3/8 | 39.1 | 11.5 | 72.4 | 13.4 | 2.50 | 2.60 | 24.3 | 1.41 | 2.96 | 11.3 | 3.92 |
| ×3/4 | 1 1/4 | 33.8 | 9.94 | 63.5 | 11.7 | 2.52 | 2.55 | 21.1 | 1.34 | 1.90 | 7.28 | 3.95 |
| ×5/8 | 1 1/8 | 28.5 | 8.36 | 54.2 | 9.86 | 2.54 | 2.50 | 17.9 | 1.27 | 1.12 | 4.33 | 3.98 |
| ×9/16 | 1 1/16 | 25.7 | 7.56 | 49.4 | 8.94 | 2.55 | 2.48 | 16.2 | 1.23 | 0.823 | 3.20 | 3.99 |
| ×1/2 | 1 | 23.0 | 6.75 | 44.4 | 8.01 | 2.55 | 2.46 | 14.6 | 1.20 | 0.584 | 2.28 | 4.01 |
| ×7/16 | 15/16 | 20.2 | 5.93 | 39.3 | 7.06 | 2.56 | 2.43 | 12.9 | 1.16 | 0.396 | 1.55 | 4.02 |
| L8×4×1 | 1 1/2 | 37.4 | 11.0 | 69.7 | 14.0 | 2.51 | 3.03 | 24.3 | 2.47 | 3.68 | 12.9 | 3.75 |
| ×7/8 | 1 3/8 | 33.1 | 9.73 | 62.6 | 12.5 | 2.53 | 2.99 | 21.7 | 2.41 | 2.51 | 8.89 | 3.78 |
| ×3/4 | 1 1/4 | 28.7 | 8.44 | 55.0 | 10.9 | 2.55 | 2.94 | 18.9 | 2.34 | 1.61 | 5.75 | 3.80 |
| ×5/8 | 1 1/8 | 24.2 | 7.11 | 47.0 | 9.20 | 2.56 | 2.89 | 16.1 | 2.27 | 0.955 | 3.42 | 3.83 |
| ×9/16 | 1 1/16 | 21.9 | 6.43 | 42.9 | 8.34 | 2.57 | 2.86 | 14.6 | 2.23 | 0.704 | 2.53 | 3.84 |
| ×1/2 | 1 | 19.6 | 5.75 | 38.6 | 7.48 | 2.58 | 2.84 | 13.1 | 2.20 | 0.501 | 1.80 | 3.86 |
| ×7/16 | 15/16 | 17.2 | 5.06 | 34.2 | 6.59 | 2.59 | 2.81 | 11.6 | 2.16 | 0.340 | 1.22 | 3.87 |
| L7×4×3/4 | 1 1/4 | 26.2 | 7.69 | 37.8 | 8.39 | 2.21 | 2.50 | 14.8 | 1.87 | 1.47 | 3.97 | 3.31 |
| ×5/8 | 1 1/8 | 22.1 | 6.48 | 32.4 | 7.12 | 2.23 | 2.45 | 12.5 | 1.80 | 0.868 | 2.37 | 3.34 |
| ×1/2 | 1 | 17.9 | 5.25 | 26.6 | 5.79 | 2.25 | 2.40 | 10.2 | 1.74 | 0.456 | 1.25 | 3.37 |
| ×7/16 | 15/16 | 15.7 | 4.62 | 23.6 | 5.11 | 2.26 | 2.38 | 9.03 | 1.70 | 0.310 | 0.851 | 3.38 |
| ×3/8 | 7/8 | 13.6 | 3.98 | 20.5 | 4.42 | 2.27 | 2.35 | 7.81 | 1.67 | 0.198 | 0.544 | 3.40 |

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ANNEXURE 1 (Contd.)

# Table 1–7 (continued)
## Angles
### Properties

L8-L6

| Shape | Axis Y-Y | | | | | | Axis Z-Z | | | | $Q_s$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I$ | $S$ | $r$ | $\bar{x}$ | $Z$ | $x_p$ | $I$ | $S$ | $r$ | Tan $\alpha$ | $F_y=36$ ksi |
| | in.⁴ | in.³ | in. | in. | in.³ | in. | in.⁴ | in.³ | in. | | |
| L8×8×1⅛ | 98.1 | 17.5 | 2.41 | 2.40 | 31.6 | 1.05 | 40.9 | 7.23 | 1.56 | 1.00 | 1.00 |
| ×1 | 89.1 | 15.8 | 2.43 | 2.36 | 28.5 | 0.943 | 36.8 | 6.51 | 1.56 | 1.00 | 1.00 |
| ×7/8 | 79.7 | 14.0 | 2.45 | 2.31 | 25.3 | 0.832 | 32.7 | 5.78 | 1.57 | 1.00 | 1.00 |
| ×3/4 | 69.9 | 12.2 | 2.46 | 2.26 | 22.0 | 0.720 | 28.5 | 5.04 | 1.57 | 1.00 | 1.00 |
| ×5/8 | 59.6 | 10.3 | 2.48 | 2.21 | 18.6 | 0.606 | 24.2 | 4.27 | 1.58 | 1.00 | 0.997 |
| ×9/16 | 54.2 | 9.33 | 2.49 | 2.19 | 16.8 | 0.548 | 22.0 | 3.88 | 1.58 | 1.00 | 0.959 |
| ×1/2 | 48.8 | 8.36 | 2.49 | 2.17 | 15.1 | 0.490 | 19.7 | 3.49 | 1.59 | 1.00 | 0.912 |
| L8×6×1 | 38.8 | 8.92 | 1.72 | 1.65 | 16.2 | 0.816 | 21.3 | 4.84 | 1.28 | 0.542 | 1.00 |
| ×7/8 | 34.9 | 7.94 | 1.74 | 1.60 | 14.4 | 0.721 | 18.9 | 4.31 | 1.28 | 0.546 | 1.00 |
| ×3/4 | 30.8 | 6.92 | 1.75 | 1.56 | 12.5 | 0.624 | 16.5 | 3.78 | 1.29 | 0.550 | 1.00 |
| ×5/8 | 26.4 | 5.88 | 1.77 | 1.51 | 10.5 | 0.526 | 14.1 | 3.22 | 1.29 | 0.554 | 0.997 |
| ×9/16 | 24.1 | 5.34 | 1.78 | 1.49 | 9.52 | 0.476 | 12.8 | 2.94 | 1.30 | 0.556 | 0.959 |
| ×1/2 | 21.7 | 4.79 | 1.79 | 1.46 | 8.52 | 0.425 | 11.5 | 2.64 | 1.30 | 0.557 | 0.912 |
| ×7/16 | 19.3 | 4.23 | 1.80 | 1.44 | 7.50 | 0.374 | 10.2 | 2.35 | 1.31 | 0.559 | 0.850 |
| L8×4×1 | 11.6 | 3.94 | 1.03 | 1.04 | 7.73 | 0.691 | 7.87 | 2.15 | 0.844 | 0.247 | 1.00 |
| ×7/8 | 10.5 | 3.51 | 1.04 | 0.997 | 6.77 | 0.612 | 7.01 | 1.93 | 0.846 | 0.252 | 1.00 |
| ×3/4 | 9.37 | 3.07 | 1.05 | 0.949 | 5.82 | 0.531 | 6.13 | 1.70 | 0.850 | 0.257 | 1.00 |
| ×5/8 | 8.11 | 2.62 | 1.06 | 0.902 | 4.86 | 0.448 | 5.24 | 1.47 | 0.856 | 0.262 | 0.997 |
| ×9/16 | 7.44 | 2.38 | 1.07 | 0.878 | 4.39 | 0.405 | 4.79 | 1.34 | 0.859 | 0.264 | 0.959 |
| ×1/2 | 6.75 | 2.15 | 1.08 | 0.854 | 3.91 | 0.363 | 4.32 | 1.22 | 0.863 | 0.266 | 0.912 |
| ×7/16 | 6.03 | 1.90 | 1.09 | 0.829 | 3.42 | 0.320 | 3.84 | 1.09 | 0.867 | 0.268 | 0.850 |
| L7×4×3/4 | 9.00 | 3.01 | 1.08 | 1.00 | 5.60 | 0.550 | 5.64 | 1.71 | 0.855 | 0.324 | 1.00 |
| ×5/8 | 7.79 | 2.56 | 1.10 | 0.958 | 4.69 | 0.464 | 4.80 | 1.47 | 0.860 | 0.329 | 1.00 |
| ×1/2 | 6.48 | 2.10 | 1.11 | 0.910 | 3.77 | 0.376 | 3.95 | 1.21 | 0.866 | 0.334 | 0.965 |
| ×7/16 | 5.79 | 1.86 | 1.12 | 0.886 | 3.31 | 0.331 | 3.50 | 1.08 | 0.869 | 0.337 | 0.912 |
| ×3/8 | 5.06 | 1.61 | 1.12 | 0.861 | 2.84 | 0.286 | 3.05 | 0.942 | 0.873 | 0.339 | 0.840 |

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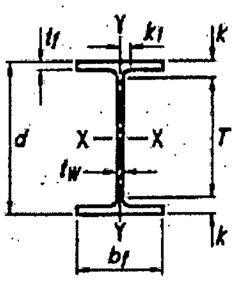
ANNEXURE-~~2~~ 4



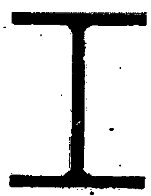
# Table 1-1 (continued)
## W Shapes
### Dimensions

| 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 $k$: $k_{det}$ | $k_1$ | $T$ | Workable Gage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | in.$^2$ | in. | | in. | | in. | in. | | in. | | in. | in. | in. | in. | in. |
| W14×132 | 38.8 | 14.7 | 14 5/8 | 0.645 | 5/8 | 5/16 | 14.7 | 14 3/4 | 1.03 | 1 | 1.63 | 2 5/16 | 1 9/16 | 10 | 5 1/2 |
| ×120 | 35.3 | 14.5 | 14 1/2 | 0.590 | 9/16 | 5/16 | 14.7 | 14 5/8 | 0.940 | 15/16 | 1.54 | 2 1/4 | 1 1/2 | ↓ | ↓ |
| ×109 | 32.0 | 14.3 | 14 3/8 | 0.525 | 1/2 | 1/4 | 14.6 | 14 5/8 | 0.860 | 7/8 | 1.46 | 2 3/16 | 1 1/2 | | |
| ×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 | | |
| ×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 | | |

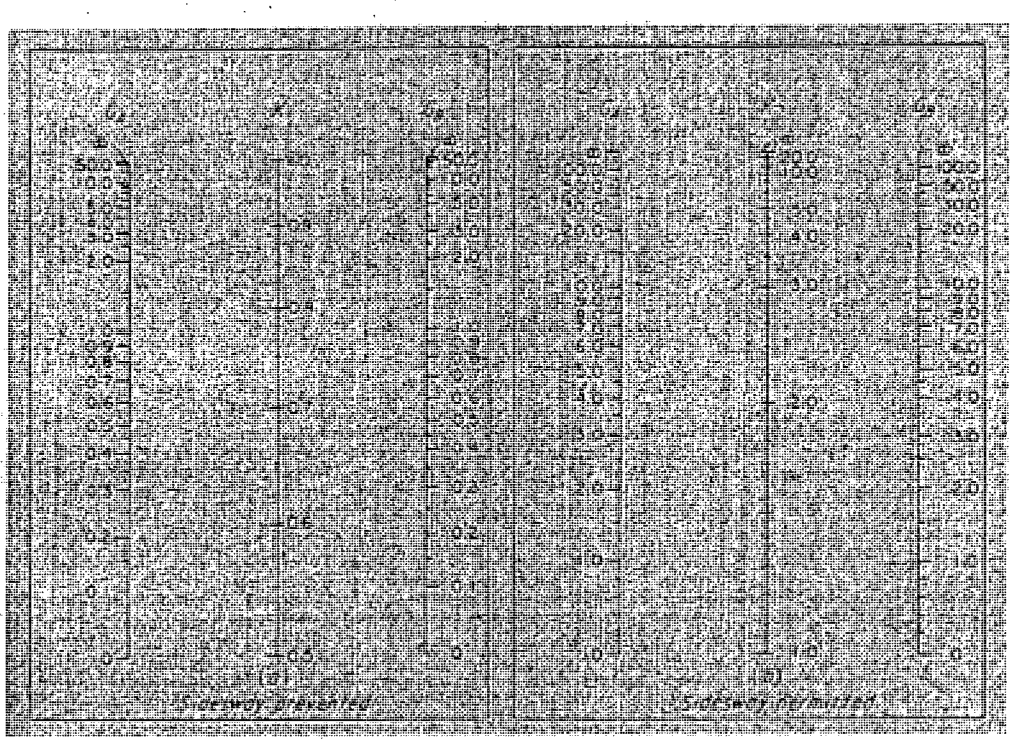
# Table 1-1 (continued)
## W Shapes
### Properties

W14 – W12

| | 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.$^6$ |
| W14x | 132 | 7.15 | 17.7 | 1530 | 209 | 6.28 | 234 | 548 | 74.5 | 3.76 | 113 | 4.23 | 13.6 | 12.3 | 25500 |
| | 120 | 7.80 | 19.3 | 1380 | 190 | 6.24 | 212 | 495 | 67.5 | 3.74 | 102 | 4.20 | 13.5 | 9.37 | 22700 |
| | 109 | 8.49 | 21.7 | 1240 | 173 | 6.22 | 192 | 447 | 61.2 | 3.73 | 92.7 | 4.17 | 13.5 | 7.12 | 20200 |
| | 99 | 9.34 | 23.5 | 1110 | 157 | 6.17 | 173 | 402 | 55.2 | 3.71 | 83.6 | 4.14 | 13.4 | 5.37 | 18000 |
| | 90 | 10.2 | 25.9 | 999 | 143 | 6.14 | 157 | 362 | 49.9 | 3.70 | 75.6 | 4.11 | 13.3 | 4.06 | 16000 |



ANNEXURE-5



Nomograph for effective length of columns.

L-3/T-2/CE Date : 31/01/2016

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2013-2014

Sub : **CE 351** (Transportation Engineering I)

Full Marks: 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

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## SECTION – A

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

1. (a) What is meant by "Transportation Planning"? Show with a neat sketch the basic elements of Transportation Planning. **(11)**

(b) Explain schematically the relationship between access and movement function of street. **(12)**

(c) Calculate the inter zonal trips using a simple gravity model from the following data. Assume the exponent of travel time as 0.6. **(12)**

| Production Zone i | Employment Zone | Employments | Travel time from Zone i |
|---|---|---|---|
| $T_i$ = 450 work trips | 1 | 750 | 9 minutes |
| | 2 | 400 | 5 minutes |
| | 3 | 300 | 7 minutes |

2. (a) What is the difference between the terms "Accident" and "Crash" in road safety study. Show the following with a collision diagram: **(11)**

(i) Rear-end, (ii) Right angle, (iii) Sideswipes and (iv) Head-on

(b) Explain the factors involved in transportation crashes. **(12)**

(c) A driver moving at a speed of 65 mph on a 3 percent upgrade section of a highway sights an object 500 ft away on the highway and applied the brake. If the coefficient of friction for the pavement is 0.29 and acceleration due to gravity is 32.2 ft/sec$^2$, would the driver be able to stop the car before hitting the object? **(12)**

3. (a) State the advantages and disadvantages of a rotary inter section. **(11)**

(b) Show diagrammatically the method of attaining superelevation considering pavement revolved about the centre line. **(12)**

(c) Show with neat sketches the minimum passing sight distance for a two-lane two-way highway in Bangladesh. **(12)**

4. (a) Discuss five key problems and challenges of transportation system. Also explain three ideal city formats. **(8)**

(b) Explain emerging transportation technologies with names of new tools/technologies. **(9)**

(c) Explain the components of urban public transport service design. Also, explain various public transport network structure with labeled diagrams. **(9)**

(d) Explain the driving factors behind the popularly emerging public transport modes such as light rail or bus rapid transit modes. Explain the important features of Bus Rapid Transit (BRT). **(9)**

Contd .......... P/2

**CE 351**

## SECTION – B

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

5. (a) Explain different components, dimensions and interdisciplinary breadth of transportation system with figures. **(15)**

   (b) Explain the justification of road hierarchy in the light of accessibility and mobility need with facts and figures. Also discuss the state of road hierarchy in Dhaka city. **(10)**

   (c) How can you measure efficiency of transport system? Explain the performance measuring criteria with examples of various transportations modes. **(10)**

6. (a) Write down eight key points of transportation system with relevant discussion. Define design vehicle, terminal, depot, workshop, PCU and PIEV. **(8+6)**

   (b) When to carry out the following studies: **(10)**

   (i) Volume (ii) Speed (iii) Origin - destination (iv) Speed - delay

   (c) Following data was collected while conducting spot speed studies at certain stretch of a road within the urban area. **(11)**

| Speed range (kmph) | Frequency (f) |
|---|---|
| 0 – 5 | 0 |
| 5 – 10 | 12 |
| 10 – 15 | 25 |
| 15 – 20 | 40 |
| 20 – 25 | 100 |
| 25 – 30 | 205 |
| 30 – 35 | 240 |
| 35 – 40 | 110 |
| 40 – 45 | 45 |
| 45 – 50 | 25 |
| 50 – 55 | 11 |
| 55 – 60 | 6 |
| 60 – 65 | 3 |
| 65 – 70 | 0 |

Determine:

(i) Average speed of traffic stream.

(ii) Modal speed and pace of traffic stream.

(iii) Upper and lower speed limits.

(iv) Design speed.

Contd .......... P/3

**CE 351**

7. (a) List the tools that are available to the Traffic Engineers in managing roadway congestion and safety problems? Why Traffic Engineering is so essential now-a-days especially in our country? What are the benefits of providing street lighting? **(8+3+3)**

(b) Mention the locations where parking should be prohibited. What steps should be undertaken for systematic development of parking facilities? Write down the types of parking facilities and method of parking. **(3+3+4)**

(c) 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. Assume reasonable value for any missing data. **(4)**

$U_1 = 35.0$ kmph　　$U_2 = 39.2$ kmph

$S_1 = 6.5$ kmph　　$S_2 = 8.8$ kmph

$n_1 = 261$ nos.　　$n_2 = 270$ nos.

(d) An urban secondary street with 65 ft pavement width having a reflectance of 20%, carries a maximum of 1750 vph at night time in both directions. Design the street lighting system of the road considering mercury light as a source with mounting height of 30 ft and a maintenance factor of 0.75. Draw the lighting layout. Necessary information are given in Tables 1 to 4 and in Figure 1. **(7)**

8. (a) Name the functional classification of traffic signs and give two examples for each. Differentiate between traffic signs and markings. Very briefly discuss about the new trend of roadway signs, marking and signal. Write down the importance of retro-reflective marking. **(4+4+4+3)**

(b) Which UN convention standardized the uniform design of traffic control devices? At what circumstances all-red period is considered in traffic signal design? List different types of signal controllers and differentiate between simultaneous and progressive signal controllers. **(2+3+5)**

(c) Design a two-phase signal of an isolated cross-junction for the following data. Assume reasonable value for any missing data. Draw the phase and cycle time bar diagram. **(10)**

| | N-S phase | E-W phase |
|---|---|---|
| ALL RED period | 0 sec | 3 sec |
| Initial and final lost time | 2 sec | 3 sec |

| | North | South | East | West |
|---|---|---|---|---|
| Flow (pcu/hr) | 650 | 450 | 860 | 750 |
| Saturation flow (pcu/hr) | 2050 | 1900 | 2100 | 2080 |

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**FOR Q. 7(d)**

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 |

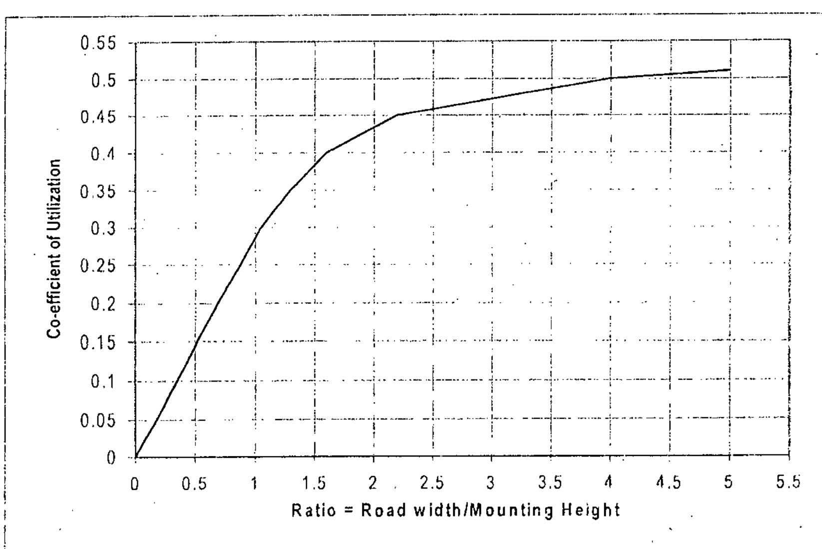
TABLE 3 LIGHTING SOURCE CHARACTERISTICS

| 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 (i.e. taken as 80%). [redacted]

**L-3/T-2/CE** **Date : 06/02/2016**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2013-2014

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.

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## SECTION – A

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

1. (a) Define: (i) Celerity, (ii) Hydraulic smooth boundary, (iii) Relative roughness and (iv) Compound section. **(10)**

   (b) Water flows at a depth of 2 m and velocity of 4 m/s in a circular channel whose diameter is 2.5 m. Compute the discharge and determine the state of flow. **(10)**

   (c) Deduce the expression for normal depth in a triangular channel using the Chezy formula. **(10)**

   (d) A trapezoidal channel having side slopes of 2H:1V, n = 0.02 and $S_0 = 0.0001$ carries a discharge of 25 $m^3/s$ at a normal depth of 2 m. Compute bottom width. **($16\frac{2}{3}$)**

2. (a) Prove that A1 profile is not physically possible. **(5)**

   (b) Explain the behavior of a flow profile when $h \rightarrow \infty$. **(5)**

   (c) A rectangular channel 6 m wide and having n = 0.025 has three reaches arranged serially. The bottom slopes of the three reaches are 0.0064, 0.015 and 0.0016 respectively. For a discharge of 20 $m^3/s$ through this channel, sketch the resulting flow profiles. **($12\frac{2}{3}$)**

   (d) Draw the possible flow profiles in the following serial arrangement of channels: **(24)**

   (i) critical - steep - mild - free overfall
   (ii) steep - critical - mild (with a sluice gate)
   (iii) mild - critical - horizontal
   (iv) mild - adverse - horizontal
   (v) critical-adverse-steep (with a weir)
   (vi) steep - steeper - mild.

3. (a) Derive the equation $u^* = \sqrt{ghS_0}$ for a wide channel where the notations have their usual meaning. **(10)**

   (b) Derive the equation $U = CR^{1/2}S_f^{1/2}$ where the notations have their usual meaning. **(10)**

   (c) A trapezoidal channel has a bottom width of 6 m, side slopes of 2H:1V and n = 0.025. Determine the critical slope when the discharge is 20 $m^3/s$ and $\alpha = 1.2$. **(10)**

Contd .......... P/2

**WRE 311**

**Contd... Q. No. 3**

(d) An irrigation canal is trapezoidal with bottom width of 6 m, side slopes of 2H:1V and a depth of flow of 2 m. The longitudinal slope of the canal is 0.0005. Considering uniform flow, compute discharge carried by the canal if; **(16⅔)**

(i) when only the bottom is lined, and

(ii) when only the sides are lined.

Given, n = 0.025 for unlined part and n = 0.013 for the lined part.

4. (a) Deduce the expression for the length of the flow profile between two sections in a horizontal channel. **(10)**

(b) A dam raises the water level to 3 m at the end of a wide rectangular channel. The normal depth and critical depth for the flow are 1.5 m and 2 m respectively. The longitudinal slope for the channel is 0.0001. Compute the length of the resulting flow profile between the dam site and the location where the depth is 2.8 m. **(10)**

Given, $\varphi = \frac{1}{6}\ln\frac{u^2+u+1}{(u-1)^2} - \frac{1}{\sqrt{3}}\tan^{-1}\left(\frac{\sqrt{3}}{2u+1}\right)$

(c) Drive the hydraulic exponent for uniform flow computation for triangular channel regarding Manning formula. **(10)**

(d) A rectangular channel with b = 6 m, n = 0.025 and $S_0$ = 0.0025 carries a discharge of 40 $m^3/s$. At a section A of the channel the depth of flow is 2 m. How far upstream or downstream from this section will the depth be 2.25 m? Use direct step method. **(16⅔)**

## SECTION – B

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

5. (a) Define Prismatic, Non-prismatic, Natural and Artificial channels. **(6)**

(b) Why velocity distribution coefficients are used in open channel flow problems?. **(4⅔)**

(c) Show that for a channel with large slope the pressure distribution is less than the hydrostatic pressure. **(6)**

(d) The velocity distribution is a very wide river 3.0 m deep is found to be approximately in accordance with the equation $v = 1 + 2(y/y_0)^{1/2}$, where, $y_0$ = depth of river and v is the velocity at depth y. Calculate α and β. **(15)**

Contd .......... P/3

**WRE 311**

**Contd... Q. No. 5**

(e) The following data were obtained in a stream gauging operation. A current meter with a calibration equation, $v = 0.3n+0.03$ where n = revolutions per second, was used to measure the velocity at 0.6 depth. Calculate the discharge. **(15)**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance, m | 0 | 2 | 4 | 6 | 9 | 12 | 15 | 18 | 20 | 22 | 23 | 24 |
| Depth, m | 0 | 0.5 | 1.2 | 1.9 | 2.3 | 1.8 | 1.7 | 1.6 | 1.5 | 1.2 | 0.8 | 0 |
| No.of revolution | 0 | 75 | 80 | 125 | 140 | 120 | 110 | 105 | 90 | 85 | 70 | 0 |
| Time, s | 0 | 150 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 150 | 0 |

6. (a) Define section factor and control. **(6)**

(b) Find out the critical depth for a triangular channel. **(4⅔)**

(c) Discuss the characteristics of specific energy curve with a neat sketch. **(6)**

(d) Compute the critical depth and velocity in a (i) wide rectangular channel with $q = 4$ $m^2/s$, (ii) rectangular channel with $b = 6$ m and $Q = 35$ $m^3/s$, (iii) triangular channel with $s = 1$ and $Q = 5$ $m^3/s$. In all cases assume $\alpha = 1.12$. **(15)**

(e) Water is flowing at a velocity of 2 m/s and a depth of 2.5 m in a long rectangular channel 6 m wide. Compute (i) the contraction in width of the channel for producing critical flow, and (ii) the depth and change in water level produced by (i) a smooth contraction in width to 5 m, (ii) a smooth contraction in width to 3 m and (iii) a smooth expansion in width to 8 m. In all cases, neglect energy losses and take $\alpha = 1.0$. **(15)**

7. (a) What is stilling basin? What are the purposes of providing stilling basin? Write down the various appurtenances of stilling basin. **(1+2+3=6)**

(b) Describe the different types of hydraulic jumps that occur in horizontal sloping channel with neat sketches. **(4⅔)**

(c) Derive the equation of sequent depth for hydraulic jump in a horizontal rectangular channel. **(6)**

(d) Design a USBR stilling basin II for the overflow spillway section having a crest length of 76 m, the design discharge is 2265 cumec. The channel floor elevation is at 4 m from mean sea level. The velocity of flow at the toe of the spillway is 24 m/s and the tailwater elevation is at 15 m from mean sea level. Draw a neat sketch for the final designed basin. **(18)**

Contd .......... P/4

**WRE 311**

**Contd... Q. No. 7**

(e) The values of variables in connection with two hydraulic jumps in horizontal rectangular channel are given in the following table. Compute the values of the other variables in the table. **(12)**

| | $y_1$ (m) | $V_1$ (m/s) | $y_2$ (m) | $V_2$ (m/s) | q ($m^2$/s) | $F_{r1}$ | $F_{r2}$ | $h_L$ | $L_j$ |
|---|---|---|---|---|---|---|---|---|---|
| Jump | | 12.9 | | 1.21 | | | | | |

8. (a) Show that the best hydraulic trapezoidal section is one half of a regular hexagon. **(6)**

(b) What is the difference between Kennedy's and Lacey's approach in alluvial channel design? **(4⅔)**

(c) What is lining? What are the purposes of lining? What are the lining materials? **(6)**

(d) A channel lined with concrete is to be laid on a slope of 1 in 3500. The side slope of the channel is to be maintained at 1.5 H: 1 V and the lining material is expected to give a roughness value of 0.014. Design the channel for a discharge of 100 $m^3$/s and a maximum permissible velocity of 2.5 m/s. **(15)**

(e) Design a stable alluvial channel by Lacey's method carrying a discharge of 30 $m^3$/s through 0.2 mm sand. **(15)**

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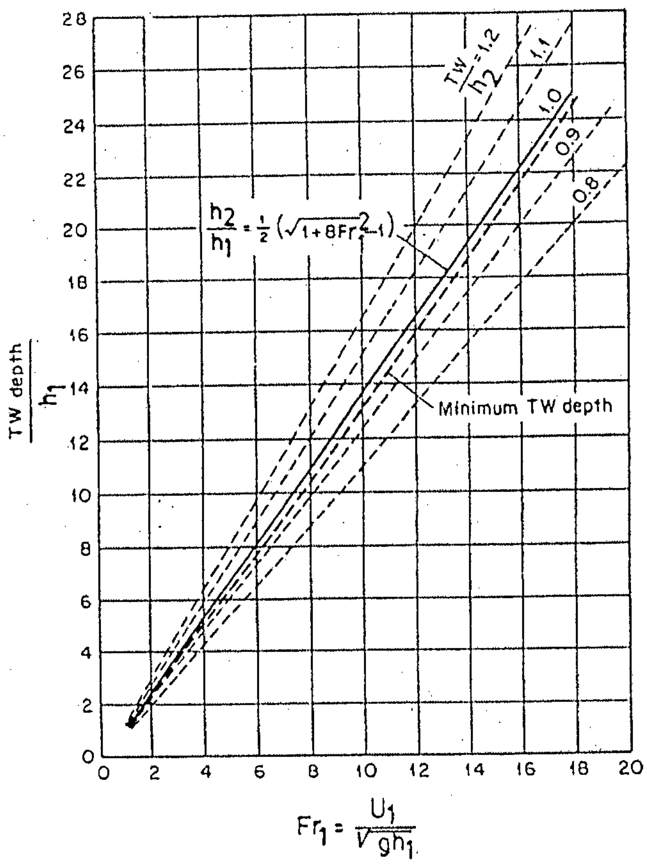


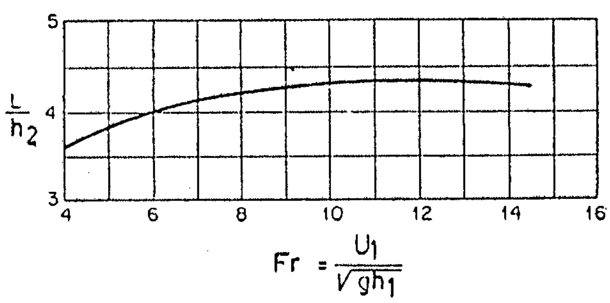


Figure for Q. 7(d)