# University of Asia Pacific
# Department of Civil Engineering
# Final Examination Spring 2012
# Program: B.Sc Engineering (Civil)

Course Title: Structural Engineering VI (Design of Steel Structures) Course Code: CE 417
Time: 2 hours Full Marks: 50

The figures in the margin indicate full marks.
Assume reasonable values for any missing data. Annexures are provided to facilitate design.
**There are EIGHT questions. Answer any SIX questions**

1. Calculate the probable net areas for the tension splice shown in Fig.1 and hence find the net area that governs the splice design. All material is A36 steel. Bolts are 5/8-in. A325 in standard holes. Also determine the effective net area if U=0.85. 8 ⅓

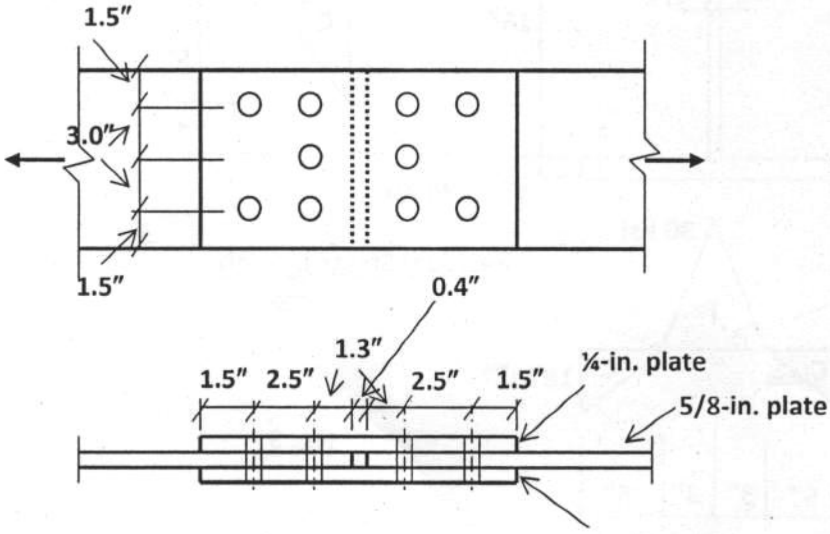



**Fig. 1**

2. The residual stress for a 20x2-in. plate to be used as a tension member is shown in Fig. 2. Write the equation for the stress-strain behaviour in tension of the plate at an imposed tensile strain of 0.0008. What is the average stress in the section at a strain of 0.0014? Given: $F_y$=42 ksi; E=30000 ksi. 8 ⅓

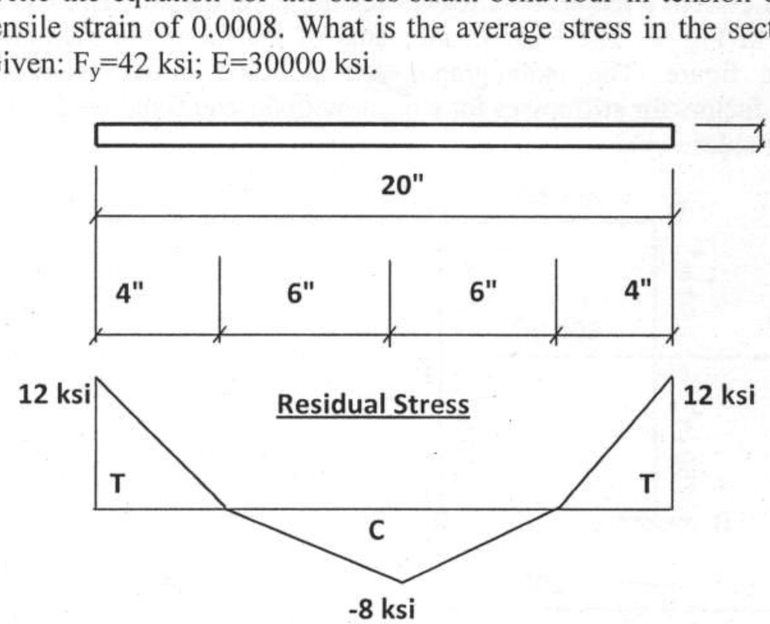



**Fig. 2**

3. The equation for the stress-strain curve for the cross section with the residual stresses shown in Fig. 3 was determined as $\sigma = -15{,}625{,}000\varepsilon^2 + 48{,}750\varepsilon - 5.625$ for a range of compressive strain $-0.0006 \leq \varepsilon \leq -0.0012$. Determine the values of stress and tangent modulus, if a column with the given section is subjected to an imposed uniform compressive strain of 0.0010 in./in. What is the corresponding slenderness ratio L/r according to tangent modulus $E_t$, if the column buckles at this compressive strain. Compressive strain 0.0010 is to be taken as positive in the above stress-strain equation. 8 ⅓

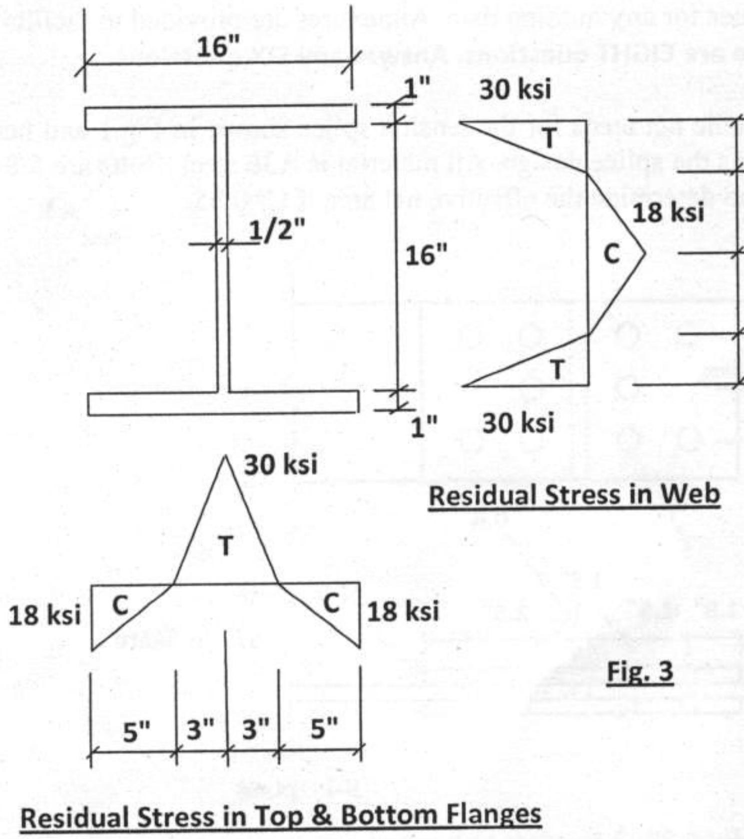



Fig. 3

4. Determine the effective length coefficients for the columns BC, EF, CD and FG of the frame shown in Fig. 4. The relevant moments of inertia of the members in $inch^4$ are shown in the figure. The Nomographs are provided in Annexure-1. Given: The multiplication factors for stiffnesses for a beam with far end fixed are 2/3 (with sidesway) and 2 (without sidesway). 8 ⅓

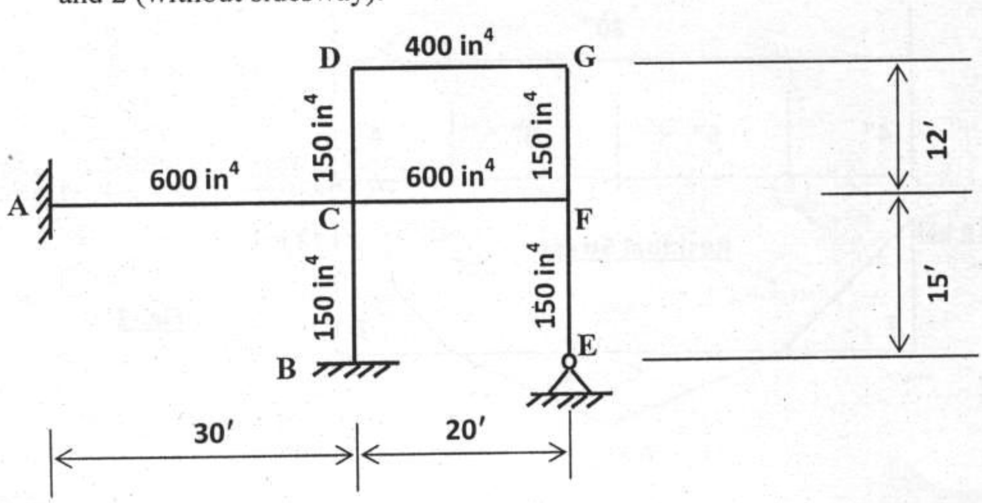



Fig. 4

5. Compute the yield moment and plastic moment capacities and shape factor for major axis bending of the section shown in Fig. 5. Given: $F_y = 42$ ksi. 8 ⅓

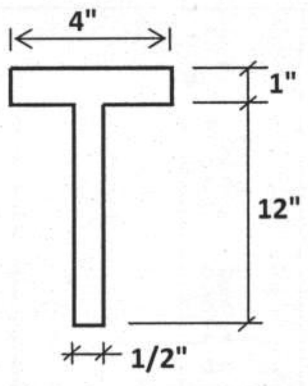



Fig. 5

6. A W12x58 section as shown in Fig.6 is used for a 22 ft. long column. The section has an area of 17 $in^2$ and a radius of gyration, $r_x = 5.28$ in. and $r_y = 2.51$ in. about the strong axis X and the weak axis Y respectively. If effective length factor for buckling about major axis X is $K_x = 1$ and that for buckling about minor axis Y is $K_y = 0.7$, calculate the allowable load P for the column using AISC/ASD method. Given: $F_y = 36$ ksi and E = 29000 ksi. See Annexure-2. 8 ⅓

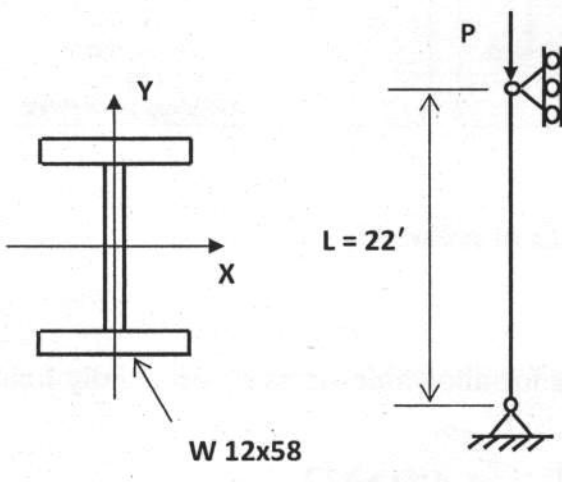
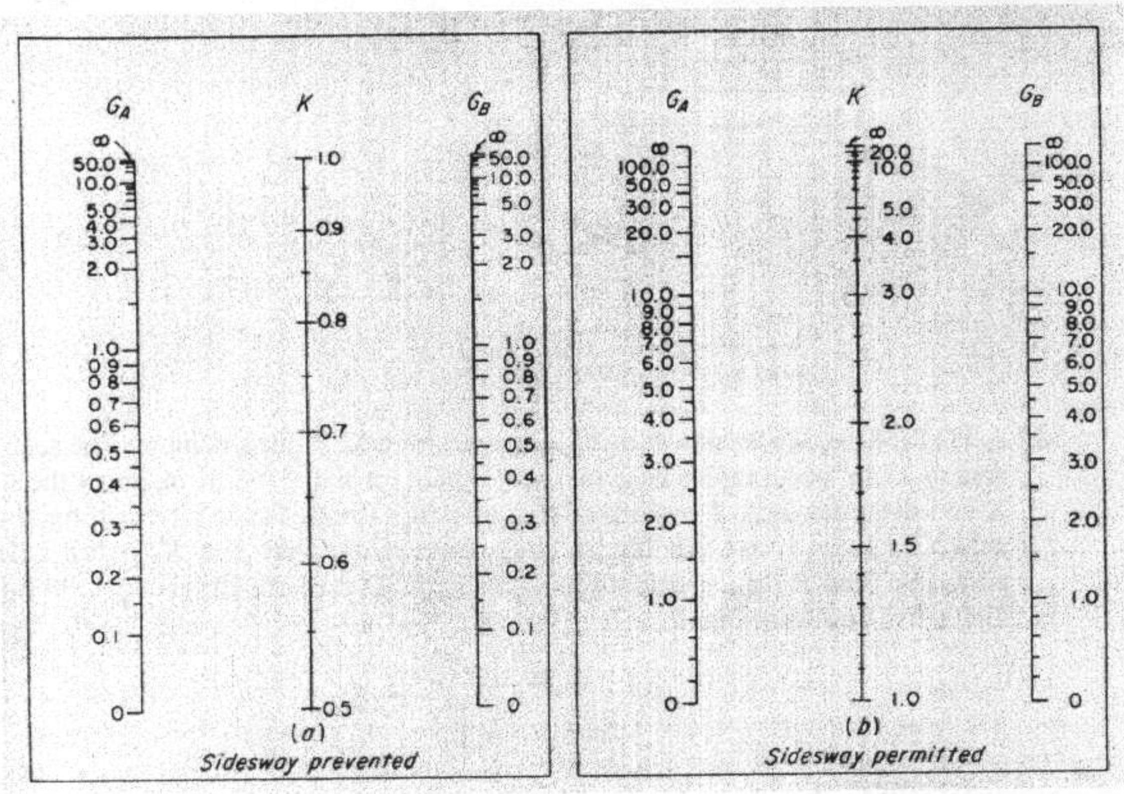



Fig. 6

7. Using LRFD method, calculate the design strength of a W10x45 section for a 22 ft. long column. The section has an area of 13.3 $in^2$ and a radius of gyration, $r_x = 4.32$ in. and $r_y = 2.01$ in. about the strong axis X and the weak axis Y respectively. Given: Effective length factor for buckling about major axis X is $K_x = 2$ and that for buckling about minor axis Y is $K_y = 1$; $F_y = 36$ ksi and E = 29000 ksi. See Annexure-3. 8 ⅓

8. Assuming that the beam will be braced to satisfy compact-section requirements, select the lightest W section to carry a uniformly distributed live load of 1.5 kips/ft and a dead load (not including the weight of the beam) of 0.50 kips/ft on a 30-ft simply supported span. What will be the least spacing of lateral bracings to satisfy the compact section requirements? Also check whether the deflection criterion is satisfied or not. Given: $F_y = 36$ ksi. See Annexures-4 & 5. 8 ⅓

## ANNEXURE-1




**Nomograph for effective length of columns.**

## ANNEXURE-2

The AISC/ASD formulas for allowable stress $F_a$ on axially loaded compression members are

$$F_a = \begin{cases} \dfrac{F_y\left[1-\dfrac{1}{2}\left(\dfrac{KL/r}{C_c}\right)^2\right]}{\dfrac{5}{3}+\dfrac{3}{8}\dfrac{KL/r}{C_c}-\dfrac{1}{8}\left(\dfrac{KL/r}{C_c}\right)^3} & \dfrac{KL}{r} \le C_c \quad (4\text{-}17) \\[2ex] \dfrac{12\pi^2 E}{23(KL/r)^2} = \dfrac{149{,}000}{(KL/r)^2} & \dfrac{KL}{r} \ge C_c \quad (4\text{-}18) \end{cases}$$

where $K$ is the effective-length coefficient (Art. 4-5) and

$$C_c = \pi\sqrt{\frac{2E}{F_y}}$$

**ANNEXURE-3**

The AISC/LRFD design strength of columns is $\phi_c P_n$, where $\phi_c = 0.85$ and $P_n = A_g F_{cr}$, with $F_{cr}$ given by

$$F_{cr} = \begin{cases} 0.658^{\lambda_c^2} F_y & 0 \le \lambda_c < 1.5 \qquad (4\text{-}27) \\ \dfrac{0.877}{\lambda_c^2} F_y & \lambda_c > 1.5 \qquad (4\text{-}28) \end{cases}$$

in which

$$\lambda_c = \frac{KL}{r\pi}\sqrt{\frac{F_y}{E}}$$

**ANNEXURE-4**

## Specification Formulas

**AISC/ASD.** The allowable bending stress $F_b$ for channels and I-shaped members of steels with $F_y \le 65$ ksi, supported against lateral buckling and bent about the major axis, are as follows:

Compact section: $F_b = 0.66F_y$ (5-16*a*)

Noncompact section: $F_b = 0.60F_y$ (5-16*b*)

If $65/\sqrt{F_y} \le b_f/2t_f \le 95/\sqrt{F_y}$:

$$F_b = \begin{cases} F_y\left(0.79 - 0.002\dfrac{b_f}{2t_f}\sqrt{F_y}\right) & \text{(rolled shapes)} \qquad \text{5-16}c) \\ F_y\left(0.79 - 0.002\dfrac{b_f}{2t_f}\sqrt{\dfrac{F_y}{k_c}}\right) & \text{(built-up members)} \qquad (\text{5-16}d) \end{cases}$$

where

$$k_c = \begin{cases} 1 & \text{if } \dfrac{h}{t} \le 70 \\ \dfrac{4.05}{(h/t)^{0.46}} & \text{if } \dfrac{h}{t} > 70 \end{cases}$$

Notation in Eqs. (5-16) is as follows:

$b_f$ = flange width
$t_f$ = flange thickness
$h$ = distance between adjacent lines of fasteners, or clear distance between flanges if welds are used
$t$ = web thickness

**ANNEXURE-4 (Contd.)**

Lateral support may be continuous, as for a beam which is the direct support of a floor, or by bracing members. Lateral-support spacing for beams designed for $F_b = 0.66F_y$ must not exceed the smaller of the values of $L_c$ given by the following:

$$L_c = \frac{76b_f}{\sqrt{F_y}} \tag{5-17a}$$

$$L_c = \frac{20{,}000}{F_y d/A_f} \tag{5-17b}$$

# DESIGN FOR LIMITED DEFLECTION

$$\frac{L}{d} = \frac{480}{F_b} \tag{5-13}$$

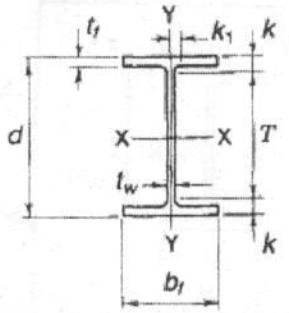
**ANNEXURE-5**

## ALLOWABLE STRESS DESIGN SELECTION TABLE
For shapes used as beams

$S_x$

| $F_y$ = 50 ksi | | | | | | | $F_y$ = 36 ksi | | |
|---|---|---|---|---|---|---|---|---|---|
| $L_c$ | $L_u$ | $M_R$ | $S_x$ | Shape | Depth $d$ | $F'_y$ | $L_c$ | $L_u$ | $M_R$ |
| Ft | Ft | Kip-ft | In.$^3$ | | In. | Ksi | Ft | Ft | Kip-ft |
| 8.1 | 8.6 | 464 | **176** | **W 24× 76** | **23⅞** | — | **9.5** | **11.8** | **348** |
| 9.3 | 20.2 | 481 | 175 | W 16×100 | 17 | — | 11.0 | 28.1 | 347 |
| 13.1 | 29.2 | 476 | 173 | W 14×109 | 14⅜ | 58.6 | 15.4 | 40.6 | 343 |
| 7.5 | 10.9 | 470 | 171 | W 21× 83 | 21⅜ | — | 8.8 | 15.1 | 339 |
| 9.9 | 15.5 | 457 | 166 | W 18× 86 | 18⅜ | — | 11.7 | 21.5 | 329 |
| 13.0 | 26.7 | 432 | 157 | W 14× 99 | 14⅛ | 48.5 | 15.4 | 37.0 | 311 |
| 9.3 | 18.0 | 426 | 155 | W 16× 89 | 16¾ | — | 10.9 | 25.0 | 307 |
| 7.4 | 8.5 | 424 | **154** | **W 24× 68** | **23¾** | — | **9.5** | **10.2** | **305** |
| 7.4 | 9.6 | 415 | 151 | W 21× 73 | 21¼ | — | 8.8 | 13.4 | 299 |
| 9.9 | 13.7 | 402 | 146 | W 18× 76 | 18¼ | 64.2 | 11.6 | 19.1 | 289 |
| 13.0 | 24.5 | 393 | 143 | W 14× 90 | 14 | 40.4 | 15.3 | 34.0 | 283 |
| 7.4 | 8.9 | 385 | **140** | **W 21× 68** | **21⅛** | — | **8.7** | **12.4** | **277** |
| 9.2 | 15.8 | 369 | 134 | W 16× 77 | 16½ | — | 10.9 | 21.9 | 265 |
| 5.8 | 6.4 | 360 | **131** | **W 24× 62** | **23¾** | — | **7.4** | **8.1** | **259** |
| 7.4 | 8.1 | 349 | **127** | **W 21× 62** | **21** | — | **8.7** | **11.2** | **251** |
| 6.8 | 11.1 | 349 | 127 | W 18× 71 | 18½ | — | 8.1 | 15.5 | 251 |
| 9.1 | 20.2 | 338 | 123 | W 14× 82 | 14¼ | — | 10.7 | 28.1 | 244 |
| 10.9 | 26.0 | 325 | 118 | W 12× 87 | 12½ | — | 12.8 | 36.2 | 234 |
| 6.8 | 10.4 | 322 | 117 | W 18× 65 | 18⅜ | — | 8.0 | 14.4 | 232 |
| 9.2 | 13.9 | 322 | 117 | W 16× 67 | 16⅜ | — | 10.8 | 19.3 | 232 |

ANNEXURE-5 (Contd.)

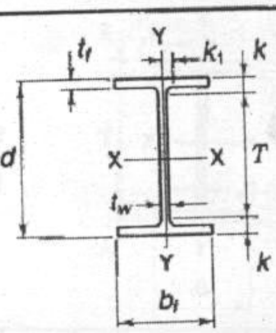



## W SHAPES
### Dimensions

| Designation | Area $A$ | Depth $d$ | | Web Thickness $t_w$ | | Web $\frac{t_w}{2}$ | 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 21×402[h] | 118.0 | 26.02 | 26 | 1.730 | 1 3/4 | 7/8 | 13.405 | 13 3/8 | 3.130 | 3 1/8 | 18 1/4 | 3 7/8 | 1 7/16 |
| ×364[h] | 107.0 | 25.47 | 25 1/2 | 1.590 | 1 9/16 | 13/16 | 13.265 | 13 1/4 | 2.850 | 2 7/8 | 18 1/4 | 3 5/8 | 1 3/8 |
| ×333[h] | 97.9 | 25.00 | 25 | 1.460 | 1 7/16 | 3/4 | 13.130 | 13 1/8 | 2.620 | 2 5/8 | 18 1/4 | 3 3/8 | 1 5/16 |
| ×300[h] | 88.2 | 24.53 | 24 1/2 | 1.320 | 1 5/16 | 11/16 | 12.990 | 13 | 2.380 | 2 3/8 | 18 1/4 | 3 1/8 | 1 1/4 |
| ×275[h] | 80.8 | 24.13 | 24 1/8 | 1.220 | 1 1/4 | 5/8 | 12.890 | 12 7/8 | 2.190 | 2 3/16 | 18 1/4 | 3 | 1 3/16 |
| ×248[h] | 72.8 | 23.74 | 23 3/4 | 1.100 | 1 1/8 | 9/16 | 12.775 | 12 3/4 | 1.990 | 2 | 18 1/4 | 2 3/4 | 1 1/8 |
| ×223 | 65.4 | 23.35 | 23 3/8 | 1.000 | 1 | 1/2 | 12.675 | 12 5/8 | 1.790 | 1 13/16 | 18 1/4 | 2 9/16 | 1 1/16 |
| ×201 | 59.2 | 23.03 | 23 | 0.910 | 15/16 | 1/2 | 12.575 | 12 5/8 | 1.630 | 1 5/8 | 18 1/4 | 2 3/8 | 1 |
| ×182 | 53.6 | 22.72 | 22 3/4 | 0.830 | 13/16 | 7/16 | 12.500 | 12 1/2 | 1.480 | 1 1/2 | 18 1/4 | 2 1/4 | 1 |
| ×166 | 48.8 | 22.48 | 22 1/2 | 0.750 | 3/4 | 3/8 | 12.420 | 12 3/8 | 1.360 | 1 3/8 | 18 1/4 | 2 1/8 | 15/16 |
| ×147 | 43.2 | 22.06 | 22 | 0.720 | 3/4 | 3/8 | 12.510 | 12 1/2 | 1.150 | 1 1/8 | 18 1/4 | 1 7/8 | 1 1/16 |
| ×132 | 38.8 | 21.83 | 21 7/8 | 0.650 | 5/8 | 5/16 | 12.440 | 12 1/2 | 1.035 | 1 1/16 | 18 1/4 | 1 13/16 | 1 |
| ×122 | 35.9 | 21.68 | 21 5/8 | 0.600 | 5/8 | 5/16 | 12.390 | 12 3/8 | 0.960 | 15/16 | 18 1/4 | 1 11/16 | 1 |
| ×111 | 32.7 | 21.51 | 21 1/2 | 0.550 | 9/16 | 5/16 | 12.340 | 12 3/8 | 0.875 | 7/8 | 18 1/4 | 1 5/8 | 15/16 |
| ×101 | 29.8 | 21.36 | 21 3/8 | 0.500 | 1/2 | 1/4 | 12.290 | 12 1/4 | 0.800 | 13/16 | 18 1/4 | 1 9/16 | 15/16 |
| W 21× 93 | 27.3 | 21.62 | 21 5/8 | 0.580 | 9/16 | 5/16 | 8.420 | 8 3/8 | 0.930 | 15/16 | 18 1/4 | 1 11/16 | 1 |
| × 83 | 24.3 | 21.43 | 21 3/8 | 0.515 | 1/2 | 1/4 | 8.355 | 8 3/8 | 0.835 | 13/16 | 18 1/4 | 1 9/16 | 15/16 |
| × 73 | 21.5 | 21.24 | 21 1/4 | 0.455 | 7/16 | 1/4 | 8.295 | 8 1/4 | 0.740 | 3/4 | 18 1/4 | 1 1/2 | 15/16 |
| × 68 | 20.0 | 21.13 | 21 1/8 | 0.430 | 7/16 | 1/4 | 8.270 | 8 1/4 | 0.685 | 11/16 | 18 1/4 | 1 7/16 | 7/8 |
| × 62 | 18.3 | 20.99 | 21 | 0.400 | 3/8 | 3/16 | 8.240 | 8 1/4 | 0.615 | 5/8 | 18 1/4 | 1 3/8 | 7/8 |

**ANNEXURE-5 (Contd.)**

# W SHAPES
## Properties




| Nominal Wt. per Ft | Compact Section Criteria | | | | $r_T$ | $\frac{d}{A_f}$ | Elastic Properties | | | | | | Plastic Modulus | | Designation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\frac{b_f}{2t_f}$ | $F_y'$ | $\frac{d}{t_w}$ | $F_y'''$ | | | Axis X-X | | | Axis Y-Y | | | $Z_x$ | $Z_y$ | |
| | | | | | | | $I$ | $S$ | $r$ | $I$ | $S$ | $r$ | | | |
| Lb. | | Ksi | | Ksi | In. | | In.$^4$ | In.$^3$ | In. | In.$^4$ | In.$^3$ | In. | In.$^3$ | In.$^3$ | |
| 402 | 2.1 | — | 15.0 | — | 3.63 | 0.62 | 12200 | 937 | 10.2 | 1270 | 189 | 3.27 | 1130 | 296 | W 21×402 |
| 364 | 2.3 | — | 16.0 | — | 3.59 | 0.67 | 10800 | 846 | 10.0 | 1120 | 168 | 3.23 | 1010 | 263 | ×364 |
| 333 | 2.5 | — | 17.1 | — | 3.55 | 0.73 | 9610 | 769 | 9.91 | 994 | 151 | 3.18 | 915 | 237 | ×333 |
| 300 | 2.7 | — | 18.6 | — | 3.51 | 0.78 | 8480 | 692 | 9.81 | 873 | 134 | 3.15 | 816 | 210 | ×300 |
| 275 | 2.9 | — | 19.8 | — | 3.48 | 0.85 | 7620 | 632 | 9.73 | 785 | 122 | 3.12 | 741 | 189 | ×275 |
| 248 | 3.2 | — | 21.6 | — | 3.45 | 0.94 | 6760 | 569 | 9.63 | 694 | 109 | 3.09 | 663 | 169 | ×248 |
| 223 | 3.5 | — | 23.4 | — | 3.41 | 1.02 | 5950 | 510 | 9.54 | 609 | 96.1 | 3.06 | 589 | 149 | ×223 |
| 201 | 3.9 | — | 25.3 | — | 3.38 | 1.12 | 5310 | 461 | 9.47 | 542 | 86.1 | 3.02 | 530 | 133 | ×201 |
| 182 | 4.2 | — | 27.4 | — | 3.36 | 1.23 | 4730 | 417 | 9.40 | 483 | 77.2 | 3.00 | 476 | 119 | ×182 |
| 166 | 4.6 | — | 30.0 | — | 3.34 | 1.33 | 4280 | 380 | 9.36 | 435 | 70.1 | 2.98 | 432 | 108 | ×166 |
| 147 | 5.4 | — | 30.6 | — | 3.34 | 1.53 | 3630 | 329 | 9.17 | 376 | 60.1 | 2.95 | 373 | 92.6 | ×147 |
| 132 | 6.0 | — | 33.6 | 58.6 | 3.31 | 1.70 | 3220 | 295 | 9.12 | 333 | 53.5 | 2.93 | 333 | 82.3 | ×132 |
| 122 | 6.5 | — | 36.1 | 50.6 | 3.30 | 1.82 | 2960 | 273 | 9.09 | 305 | 49.2 | 2.92 | 307 | 75.6 | ×122 |
| 111 | 7.1 | — | 39.1 | 43.2 | 3.28 | 1.99 | 2670 | 249 | 9.05 | 274 | 44.5 | 2.90 | 279 | 68.2 | ×111 |
| 101 | 7.7 | — | 42.7 | 36.2 | 3.27 | 2.17 | 2420 | 227 | 9.02 | 248 | 40.3 | 2.89 | 253 | 61.7 | ×101 |
| 93 | 4.5 | — | 37.3 | 47.5 | 2.17 | 2.76 | 2070 | 192 | 8.70 | 92.9 | 22.1 | 1.84 | 221 | 34.7 | W 21× 93 |
| 83 | 5.0 | — | 41.6 | 38.1 | 2.15 | 3.07 | 1830 | 171 | 8.67 | 81.4 | 19.5 | 1.83 | 196 | 30.5 | × 83 |
| 73 | 5.6 | — | 46.7 | 30.3 | 2.13 | 3.46 | 1600 | 151 | 8.64 | 70.6 | 17.0 | 1.81 | 172 | 26.6 | × 73 |
| 68 | 6.0 | — | 49.1 | 27.4 | 2.12 | 3.73 | 1480 | 140 | 8.60 | 64.7 | 15.7 | 1.80 | 160 | 24.4 | × 68 |
| 62 | 6.7 | — | 52.5 | 24.0 | 2.10 | 4.14 | 1330 | 127 | 8.54 | 57.5 | 13.9 | 1.77 | 144 | 21.7 | × 62 |

# University of Asia Pacific
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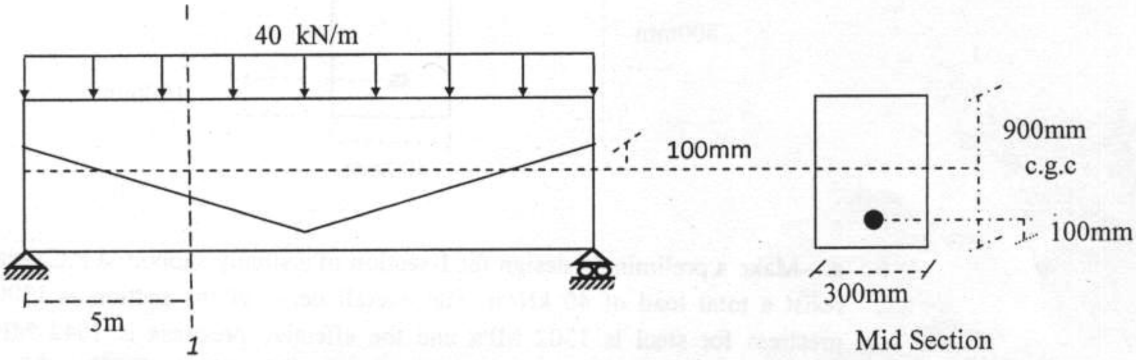
# Final Examination Spring 2012
# Program: B.Sc Engineering (Civil)

Course Title: Structural Engineering V — Course #: CE 415
Time : 2 Hr — Full Marks: 50

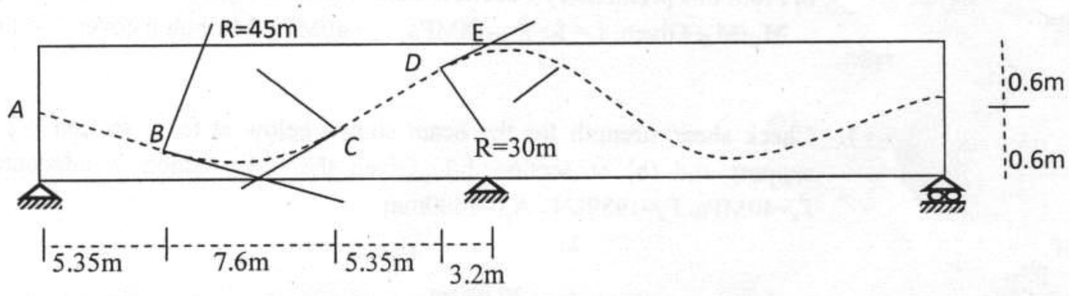
There are seven questions. Answer any **Five**. (5X10=50)

1. **a.** Draw a net sketch of the variation of steel stress with load in P.C. beam.

   **b.** A prestressed-concrete rectangular beam of 300 mm by 900 mm has a simple span of 15m and is loaded by a uniform load of 40 kN/m **excluding self-weight**. The effective prestress is 1620 kN. Compute the fiber stress in concrete at section 1-1 using **3rd concept**.




2. A prestressed concrete continuous beam with curved tendon is shown in figure below. Compute the percent of loss due to friction from A to E. Assume $\alpha$=0.4 and K=0.0026 per meter. Use segmental approximate method.




3. **a.** Write down the name of different types of loss that occur in P.C. beam.

   **b.** An I-shaped beam is prestressed with 2350 mm$^2$ steel with an effective prestress of 1100 MPa is given below. Find the ultimate moment capacity of the section for design following the **ACI code**. Given: $f_{pu}$=1860 MPa , $f'_c$=48MPa.