BENGAL ENGINEERING AND SCIENCE UNIVERSITY, SHIBPUR
B.E., 6TH SEMESTER (CE) FINAL EXAMINATIONS, April 2013
Design of Steel Structures (CE-601)

Full Marks: 70 **Time: 3 hours**

Use separate answer script for each half. *<u>Use of IS:800-2007 is not allowed in the examination hall.</u>* *Answer any six questions, taking* ***three from each half.*** *All questions are of equal value. Two marks are reserved for neatness in each half. Assume any data reasonably, if required. All the notations used have their usual meanings. Consider E250 (Fe410) steel conforming to IS 2062. E=200 GPa.*

<u>First Half</u>

1. A cross-section of a laterally supported beam of span 6.5m, made with ISMB 250 @37.3 kg/m (a= 47.55 cm^2, b_f=125 mm, t_f=12.5 mm, t_w=6.9 mm, I_{xx}=5131.6 cm^4, I_{yy}=334.5 cm^4, r_{xx}=10.39 cm, r_{yy}=2.65 cm, Z_{px}=465.71cm^3) is subjected to factored shear force of 200 kN and factored bending moment of 125 kN-m. Check the adequacy of the section in flexure and shear. Consider the section to be plastic. Given, $M_{dv} = M_d - \beta(M_d - M_{fd}); \beta = [2(V/V_d)-1]^2$.

2. A simply supported welded plate girder of span 28 m is made with flange plate 500 mm x 40 mm and web plate of 1000 mm x 10 mm. The girder carries a factored udl of 50 kN/m, inclusive of self-weight. Design the end-bearing stiffener. Check for buckling, bearing and torsional restraint. Given, $I_s \geq 0.34\alpha_s D^3 t_{cf}$, where $\alpha_s = 30/(kL/r_y)^2$; For (kL/r)=10, 20, f_{cd}=227 and 224 MPa, respectively.

3. A gantry girder of simply supported span 7.5 m, is composed of ISMB 600 @1.23 kN/m and ISMC 300 @ 0.363 kN/m. Check the adequacy of the section in overall buckling for the following data: i) Static wheel load=120 kN, ii) Wheel base =2.2 m, iii) Height of rail =150 mm, iv) χ_{LT} =0.74, v) Z_{px} of overall section =4279.79 cm^3, vi) Z_{py}=719.5 cm^3 for top flange of overall section., vii)Z_{ex}= 3310 cm^3 of overall section, viii) Z_{ey}= 532.4 cm^3 for top flange of overall section, ix)Lateral surge=6 kN per wheel, x) longitudinal surge = 5 kN per wheel. Consider the section to be plastic. Assume 2 kN/m for weight of rail and gantry girder. Calculations and checks for shear capacity, longitudinal drag force, reduction of moment capacity due to shear force, local capacity, weld design, web buckling, web bearing, deflection and fatigue are not asked.

4. Calculate the safe compressive and tensile load carried by a single angle welded discontinuous truss member made with ISA 50x50x6 (a=5.68 cm^2, C_{zz}=C_{yy}=1.45 cm, I_{zz}= I_{yy}=12.9 cm^4, r_{zz}=r_{yy}=1.51 cm, g= 28 mm, r_1= 6 mm) with one leg connected to 8 mm thick gusset plate. Consider the maximum connection length as 120 mm. Check for block shear failure and design of connection are not asked. Given, k_1, k_2, k_3, α =0.7, 0.6, 5 and 0.49, respectively.

$$T_{dn} = 0.9A_{nc}f_u/\gamma_{m1} + \beta A_{g0}f_y/\gamma_{m0}, \beta = 1.4 - 0.076(w/t)(f_y/f_u)(b_s/L_c) \leq (f_u\gamma_{m0}/f_y\gamma_1) \geq 0.7$$

$$\phi = 0.5[1+\alpha(\lambda-0.2)+\lambda^2], \quad f_{cd} = \frac{f_y/\gamma_{m0}}{\phi+\left[\phi^2-\lambda^2\right]^{0.5}},$$

$$\lambda_e = \sqrt{k_1 + k_2\lambda_{vv}^2 + k_3\lambda_\varphi^2} \qquad \lambda_{vv} = \frac{\left(\frac{l}{r_{vv}}\right)}{\varepsilon\sqrt{\frac{\pi^2 E}{250}}} \text{ and } \lambda_\varphi = \frac{(b_1+b_2)/2t}{\varepsilon\sqrt{\frac{\pi^2 E}{250}}}$$

5. Determine the design strength in flexure of ISMB 600@ 1202.7N/m (h=600mm, b_f=210mm, t_f=20.8mm, t_w=12mm, r= 20mm, Iz=91813×$10^4$$mm^4$, Iy=2651×$10^4$$mm^4$, Z_{pz}=3510×$10^3$$mm^3$, Z_{ez}=3060×$10^3$$mm^3$) used in 4 m simply supported laterally unsupported span. The beam is subjected to a maximum bending moment (unfactored)=525 kN-m. Imperfection factor, α_{LT}=0.21 for rolled section.

$$M_{cr} = \sqrt{\frac{\pi^2 EI_y}{L_{LT}^2}\left(GI_t + \frac{\pi^2 EI_w}{L_{LT}^2}\right)} \qquad I_w = (1-\beta_f)\beta_f I_y h_f^2 \text{ where } \beta_f = \frac{I_{fc}}{I_{fc}+I_{ft}}; \; \lambda_{LT} = \sqrt{\beta_b Z_p f_y / M_{cr}}$$

$$\phi_{LT} = 0.5[1+\alpha_{LT}(\lambda_{LT}-0.2)+\lambda_{LT}^2]; \qquad \chi_{LT} = \frac{1}{\{\phi_{LT}+[\phi_{LT}^2-\lambda_{LT}^2]^{0.5}\}}$$

Second Half

6. A Laced column of effective length 7.5 m, consists of 2-ISMC 200, placed toe-to-toe. The properties of 1 –ISMC 200 are a=28.21 cm^2, b_f =75 mm, t_f=11.4 mm, t_w=6.1 mm, C_{yy}=2.17 cm, I_{zz}=1819.3 cm^4, I_{yy}= 140.4 cm^4, r_{zz}= 8.08 cm, r_{yy}=2.23 cm, g=40 mm, g1=60 mm. Calculate their spacing and permissible compressive load. Given, for KL_z/r_z=(50, 100 and 150), f_{cd}=(183, 107 and 59 MPa). Design a suitable single lacing system for the above column when subjected to a factored load of 80% of the column capacity. Check whether the lacing bars are safe from axial tension and compression. Design of tie plate and connection are not required.

7. Determine tensile strength of a tie made with 1-ISMC 200 (properties given in Q.6). The tie is connected to a 8 mm thick gusset plate with its web. Consider M 20 bolts, placed in 2 rows, with 4 bolts in each row. Edge distance and pitch are 35 mm and 50 mm, respectively.
Given, $T_{dn} = 0.9A_{nc}f_u / \gamma_{ml} + \beta A_{g0}f_y / \gamma_{m0}$, $\beta = 1.4 - 0.076(w/t)(f_y / f_u)(b_s / L_c) \le (f_u \gamma_{m0} / f_y \gamma_{ml}) \ge 0.7$

   $T_{dn} = [A_{vg}f_y / \sqrt{3}\gamma_{m0} + 0.9A_{tn}f_u / \gamma_{ml}]$ or $[0.9A_{vn}f_u / \sqrt{3}\gamma_{ml} + 0.9A_{tg}f_y / \gamma_{m0}]$.

8. A beam column of length 8.5m is subjected to factored axial load of 200 kN with top and bottom factored moment of 10 kN-m and 80 kN-m, respectively, both about major axis. The moment is linearly varying. The factored maximum shear force is 40 kN. Check the adequacy of ISHB 450@ 92.5 kg/m (a=11789 mm2, b=250 mm, t_f=13.7 mm, t_w= 11.3 mm, r_{zz}=185 mm, r_{yy}=50.8 mm; r_l=13.7 mm, Z_{ez}=1793.3 cm^3, Z_{ey}=242.1 cm^3, I_y=3045 cm^3, Z_{pz}= 1931870 mm^3) as the column section if the bottom end of the column is fixed and the top end is restrained from translations but free to rotate. Given, i) the section is plastic, ii) M_{ndz}=1.11xM_{dz}(1-n)$\le M_{dz}$, iii) $\left(\frac{M_y}{M_{ndy}}\right)^{\alpha_1} + \left(\frac{M_z}{M_{ndz}}\right)^{\alpha_2} \le 1.0$, α_2=2, iv) χ_{LT}=0.879, λ_{LT} = 0.831, v) for buckling strength about major axis: for KL_z/r_z=(30 and 50), f_{cd}=(220 and 205 MPa), for buckling about minor axis KL_y/r_y= (100 and 150), f_{cd}=(118 and 64 MPa), vi) $K_z = 1 + (\lambda_z - 0.2)n_z \le 1 + 0.8n_z$, $n_z = P_{uz} / P_{dz}$, C_{mz}=C_{mLT}=$0.6 + 0.4\varphi$,

$$K_{LT} = 1 - \frac{0.1\lambda_{LT} n_y}{(C_{mLT} - 0.25)} \ge 1 - \frac{0.1 n_y}{(C_{mLT} - 0.25)}.$$

9. Design a column base for the column in Q.8. The concrete grade at foundation is M30. τ_{bd} =1.5 MPa, given, tensile strength of 20 mm bolts of grade 4.6 is 51.7 kN. The size of the base plate should not exceed 1m.

10. Design a bracket connection (Fig. Q.10) using field weld for a factored load of 150 kN is acting vertically at a distance of 700 mm from the column. The column is ISHB 450 (properties given in Q.8).

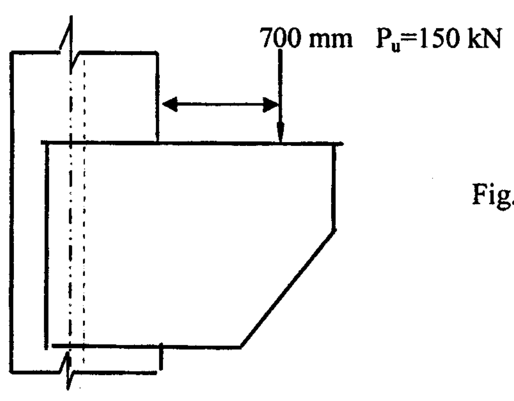

Fig. Q.10