

**DESIGN OF STEEL STRUCTURES**  
(CIVL 3201)

Time Allotted : 2½ hrs

Full Marks : 60

*Figures out of the right margin indicate full marks.*

*Candidates are required to answer Group A and  
any 4 (four) from Group B to E, taking one from each group.*

*Candidates are required to give answer in their own words as far as practicable.*

**USE OF IS CODES ARE ALLOWED IN THE EXAMINATION HALL**

**Group – A**

1. Answer any twelve:

12 × 1 = 12

*Choose the correct alternative for the following*

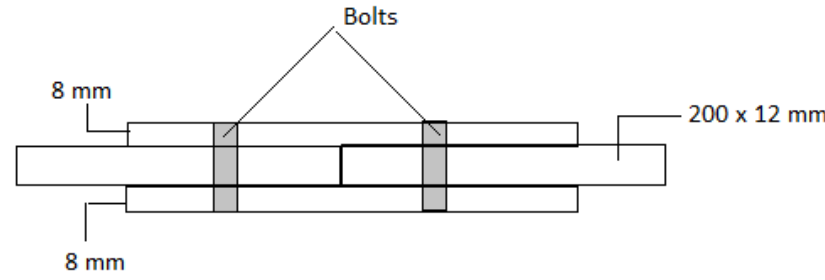
- (i) When the load line coincides with the c.g. of the bolt group, then the bolts are subjected to  
(a) only shear (b) only tension  
(c) only bending (d) both shear and tension
- (ii) High strength bolts are designed on the basis of  
(a) friction (b) tension (c) compression (d) shear
- (iii) The shear strength of the bolt can be written as  $f_s A_n$ , where  $f_s$  is given by  
(a)  $f_y / (\sqrt{3} \times 1.25)$  (b)  $f_{ub} / (\sqrt{3} \times 1.25)$   
(c)  $f_y / (\sqrt{3} \times 1.10)$  (d)  $f_u / (\sqrt{3} \times 1.10)$
- (iv) For block shear failure of a tension member, the failure occurs along a path through the connection involving  
(a) tension on the two perpendicular planes  
(b) tension on one plane and shear on the other perpendicular plane  
(c) shear on two perpendicular planes  
(d) tension on the plane of connection and compression on the other perpendicular plane
- (v) The slenderness ratio of a single-angle single bolted strut should be less than  
(a) 180 (b) 250 (c) 300 (d) 350
- (vi) Shear buckling of web in plate girder is prevented by using  
(a) Vertical intermediate stiffener (b) Horizontal stiffener at neutral axis  
(c) Bearing stiffener (d) All of (a), (b) & (c)
- (vii) Gantry girders are usually designed as  
(a) Laterally supported beams  
(b) Laterally unsupported beams  
(c) For combination of vertical loads and either of the lateral and longitudinal force  
(d) both (b) and (c)
- (viii) Which one of the following is mode of failure in a fillet weld material?  
(a) Tension (b) Shear (c) Bearing (d) Crushing.
- (ix) Beam should be designed for  
(a) Flexural strength (b) Lateral buckling stiffness  
(c) Local buckling (d) All of (a), (b) & (c)
- (x) Web crippling in steel beam occurs due to  
(a) Column action of compression flange (b) Failure of web under concentrated load  
(c) Excessive bending moment (d) Secondary bending moment.

*Fill in the blanks with the correct word*

- (xi) The slenderness ratio of lacing bar should not exceed \_\_\_\_\_.
- (xii) A beam section is classed as low shear case when the factored shear force is less than \_\_\_\_\_.
- (xiii) The effective cross sectional area in the threaded portion of the bolt is called the \_\_\_\_\_ at the threaded section.
- (xiv) The surge load is assumed to be resisted by the \_\_\_\_\_.
- (xv) The impact allowance for horizontal force transverse to the rail (surge load) for an EOT crane is \_\_\_\_\_.

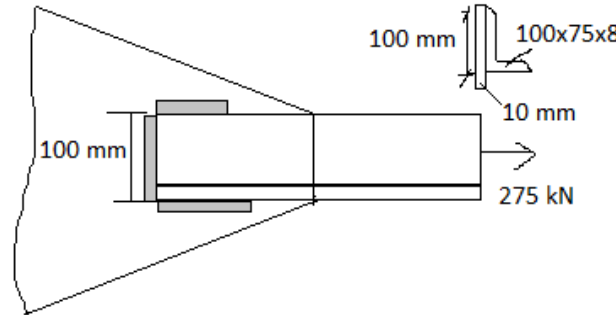
### Group - B

2. (a) Two plates of 200×12 are to be connected by a double cover butt joint with 20 mm diameter bolts as shown in the Fig. 1. The factored tensile force on the plates is 500 kN. Design the bolted connection. [[CO1](Create/HOCQ)]



**Fig. 1**

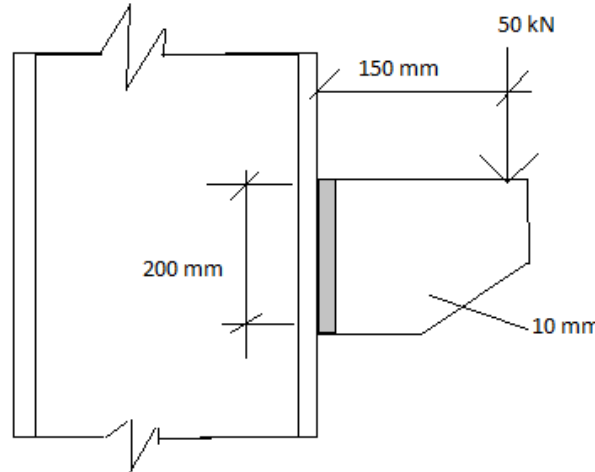
- (b) A tie member of a roof truss consists of ISA 100×75×8 of Fe 410 grade is welded to a 10 mm gusset plate (refer Fig.2). Design the welded connection to transmit load of 275 kN. Assume connections are made in the workshop. [[CO1](Create/HOCQ)]



**Fig. 2**

**5 + 7 = 12**

3. Design the following welded connections to connect a 10 mm thick bracket to the flange of a column as shown in the Fig. 3 below. (i) Fillet weld (ii) Groove weld. [[CO1](Create/HOCQ)]

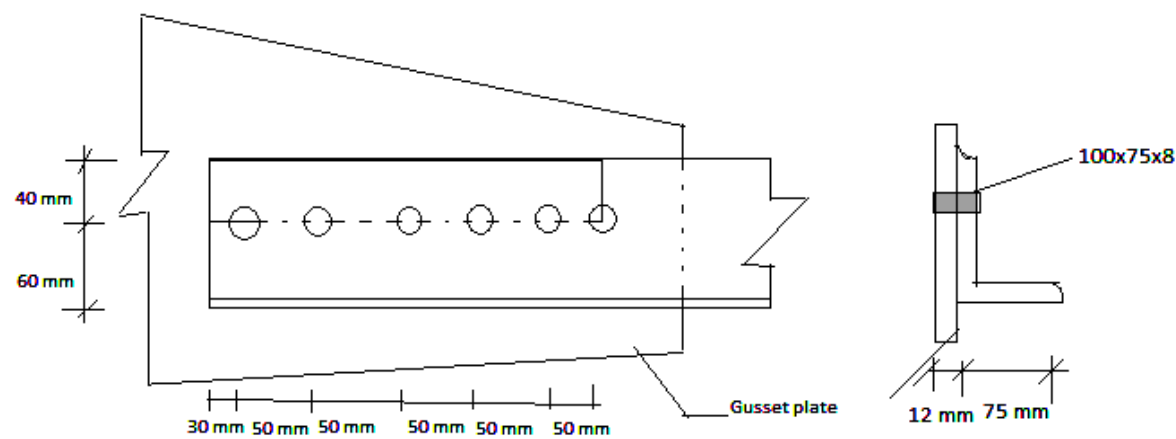


**Fig. 3**

**12**

### Group - C

4. (a) A single unequal angle 100×75×8 mm is connected to a 12 mm thick gusset plate at the ends with 6 numbers of 20 mm diameter bolts to transfer tension as shown in Fig. 4. Determine the design tensile strength of the angle if the gusset is connected to the 100 mm leg. The yield strength and ultimate strength of the steel used are 250 MPa and 400 MPa.



**Fig. 4**

- (b) Calculate the design load carrying capacity of a compound column consisting of ISHB 250@ 500.31N/m with one cover plate of 320×20 mm on each flange as shown in Fig. 5. The length of column is 4m and assume that its one end is fixed and other end is hinged. Assume  $f_y = 250 \text{ N/mm}^2$ . The properties of ISHB @ 500.31 N/m are:  $A = 6496 \text{ mm}^2$ ,  $I_{xx} = 77.365 \times 10^6 \text{ mm}^4$ ,  $I_{yy} = 19.613 \times 10^6 \text{ mm}^4$ ,  $r_{xx} = 109.1 \text{ mm}$ ,  $r_{yy} = 54.9 \text{ mm}$ . [[CO2](Evaluate/HOCQ)]

[[CO2,C04](Evaluate/HOCQ)]

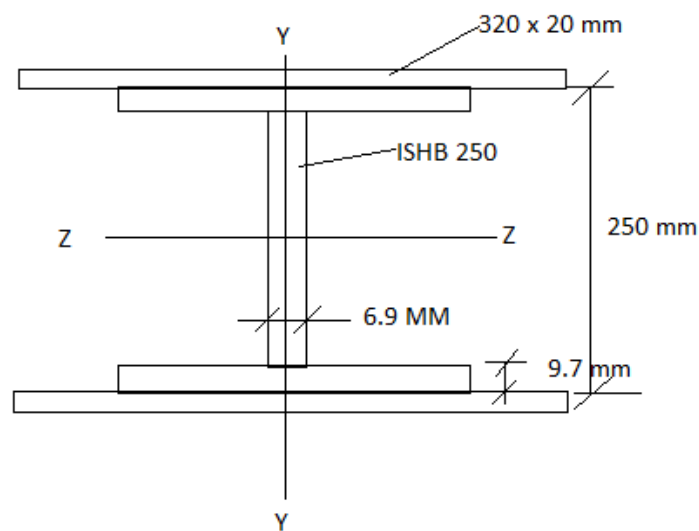


Fig. 5

6 + 6 = 12

5. (a) Design the single lacing system with bolted connection for a 9 m long columns fixed at both ends with 2 Nos. ISMC 350 @ 413 N/m placed back to back carrying a factored axial load of 1200 kN. Properties of ISMC 350 @ 413 N/m are  
 $A = 5366 \text{ mm}^2$ ,  $h = 350 \text{ mm}$ ,  $b_w = 100 \text{ mm}$ ,  $t_f = 13.5 \text{ mm}$ ,  $t_w = 8.1 \text{ mm}$ ,  
 $I_{xx} = I_{zz} = 100.88 \times 10^6 \text{ mm}^4$ ,  $I_{yy} = 4.306 \times 10^6 \text{ mm}^4$ ,  $r_{xx} = r_{zz} = 136.60 \text{ mm}$ ,  
 $r_{yy} = 28.3 \text{ mm}$ ,  $c_{yy} = 24.4 \text{ mm}$ . [[CO4](Create/HOCQ)]
- (b) Design the base plate for a column made of ISHB 250 @ 51.10 kg/m to carry a compressive load of 780 kN. The grade of concrete used is M20. Assume Fe410 grade steel. Properties of ISHB 250 @ 51.10 kg/m are  
 $A = 6496 \text{ mm}^2$ ,  $h = 250 \text{ mm}$ ,  $b = 250 \text{ mm}$ ,  $t_f = 9.7 \text{ mm}$ ,  $t_w = 6.9 \text{ mm}$ ,  
 $I_{xx} = 7736.5 \text{ cm}^4$ ,  $I_{yy} = 1961.3 \text{ cm}^4$ ,  $r_{zz} = 10.91 \text{ cm}$ ,  $r_{yy} = 5.49 \text{ cm}$ . [[CO4](Create/HOCQ)]

8 + 4 = 12

### Group - D

6. Design a laterally unrestrained beam to carry a uniformly distributed load of 50 kN/m. The beam is unsupported for a length of 1.5 m and is simply placed on longitudinal beams at its ends. Consider  $f_y = 250 \text{ N/mm}^2$ ,  $f_u = 410 \text{ N/mm}^2$ ,  $E = 2 \times 10^5 \text{ N/mm}^2$ . Choose a section of ISMB 175 @ 0.19 kN/m  
The relevant properties of the section are:  
Overall depth  $D = 175 \text{ mm}$   
Width of flange  $b_f = 90 \text{ mm}$   
Thickness of flange  $t_f = 8.6 \text{ mm}$   
Thickness of web  $t_w = 5.5 \text{ mm}$   
Radius as root  $r = 10 \text{ mm}$   
Depth of web  $d = D - 2(t_f + r) = 175 - 2 \times (8.6 + 10) = 137.8 \text{ mm}$   
Moment of inertia  $I_z = 1270.6 \times 10^4 \text{ mm}^4$ ,  $I_y = 85.1 \times 10^4 \text{ mm}^4$   
Elastic section modulus  $Z_{ez} = 145.2 \times 10^3 \text{ mm}^3$   
Plastic section modulus  $Z_{pz} = 161.65 \times 10^3 \text{ mm}^3$   
Minimum radius of gyration  $r_y = 18.6 \text{ mm}$ . [[CO3,CO5](analyze/IOCQ)]
7. Design a welded plate girder of 20 m span and laterally supported throughout. It has to support a uniform load of 80 kN/m throughout the span exclusive of self weight. Design the plate girder without intermediate vertical stiffeners. Consider  $f_y = 250 \text{ N/mm}^2$ ,  $f_u = 410 \text{ N/mm}^2$ . Connections need not be designed. [[CO3, CO5](Create/HOCQ)]

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### Group - E

8. Determine the moments and forces due to the vertical and horizontal loads acting on a simply-supported gantry girder given the following data:  
1. Simply-supported span = 6 m  
2. Crane's wheel centres = 3.6 m  
3. Self-weight of the girder (say) = 1.6 kN/m  
4. Maximum crane wheel load (static) = 220 kN  
5. Weight of crab/trolley = 60 kN  
6. Maximum hook load = 200 kN  
Calculate also the serviceability deflection (working load) assuming ISMB 600. Consider  $f_y = 250 \text{ N/mm}^2$ ,  $f_u = 410 \text{ N/mm}^2$ ,  $E = 2 \times 10^5 \text{ N/mm}^2$ .  
The properties of ISMB 600 @ 122.6 kg/m are given as follows:  
Sectional area ( $A$ ) of I – section =  $156.21 \text{ cm}^2$ , radius at root ( $r$ ) = 20 mm, width of flange ( $b_f$ ) = 210 mm, thickness of flange ( $t_f$ ) = 20.8 mm, thickness of web ( $t_w$ ) = 12 mm,  $I_{zz} = 91813 \text{ cm}^4$ ,  $I_{yy} = 2651.0 \text{ cm}^4$ , Radii of Gyration ( $r_{zz}$ ) = 24.24 cm, ( $r_{yy}$ ) = 4.12 cm, Section Modulus ( $Z_{zz}$ ) =  $3060.4 \text{ cm}^3$ , ( $Z_{yy}$ ) =  $252.5 \text{ cm}^3$ . [[CO6](Evaluate/HOCQ)]

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9. A welded gantry girder, without lateral restraint along its span, to be used in an industrial building carrying an overhead travelling crane is fabricated using ISMB 550 @103.7kg/m with a channel ISMC 300 @ 35.8 kg/m at the top. Centre-to-centre distance between columns (i.e. span of gantry girder) =7 m. Calculate the moment capacity and buckling resistance of the gantry girder. Consider  $f_y = 250 \text{ N/mm}^2$ ,  $f_u = 410 \text{ N/mm}^2$ ,  $E = 2 \times 10^5 \text{ N/mm}^2$ .

The properties of ISMB 550 @ @103.7kg/m are given as follows:

Sectional area ( $A$ ) = 132.11cm<sup>2</sup>, Depth of section ( $h$ ) = 550mm, Width of flange ( $b$ ) =190mm, Thickness of flange ( $t_f$ ) =19.3 mm, Thickness of web ( $t_w$ ) = 11.2mm, Radii of Gyration ( $r_z$ ) = 22.16 cm, ( $r_y$ ) = 3.73cm, Moment of inertia ( $I_{zz}$ ) = 64893.6 cm<sup>4</sup>, Moment of inertia ( $I_{yy}$ ) = 1833.8 cm<sup>4</sup>.

The properties of ISMC 300 @ 35.8 kg/m are given as follows:

Sectional area  $a=4564 \text{ mm}^2$ , Depth of section ( $h$ ) = 300 mm, Width of flange ( $b_f$ ) =90 mm, Thickness of flange ( $t_f$ ) =13.6 mm, Thickness of web ( $t_w$ ) = 7.6 mm, Radii of Gyration ( $r_z$ ) = 11.81 cm, ( $r_y$ ) = 2.61 cm, Moment of inertia ( $I_{zz}$ ) = 6362.6×10<sup>4</sup> mm<sup>4</sup>, Moment of inertia ( $I_{yy}$ ) = 310.8×10<sup>4</sup> mm<sup>4</sup>.

[[CO6](Evaluate/HOCQ)]

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Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	0	12.5	87.5

#### Course Outcome (CO):

After the completion of the course students will be able to

1. Familiar with the material properties of structural steel, analyse the different bolted and welded connections and design them for concentric and eccentric loads.
2. Design different steel sections subjected to axial compression and tension following Indian codes of practices.
3. Comprehend the differences between laterally supported and unsupported flexure members and design of the flexure members using Indian codes of practice.
4. Analyse and design rolled and built up compression members along with base connection subjected to axial compression, bending and tension.
5. Calculate shear force and bending moment on rolled and built up girders and design it following Indian standard design guidelines.
6. Identify different components of gantry system, calculate lateral and vertical loads acting on the system and design them.

\*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.