# UNIVERSITY OF RUHUNA

## Faculty of Engineering

End-Semester 5 Examination in Engineering: October 2019

**Module Number**: CE5201 **Module Name**: Design of Steel Structures

Time allowed: Three Hours

Answer all questions, each question carries equal marks

*European Standards EC3-1-1, EC3-1-5, and EC3-1-8 are provided*

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Q1. Steel portal frame building as a warehouse is proposed to be built in Galle area. Plan view and elevation view of the proposed building are shown in Fig. Q1 (a) and Fig. Q1(b), respectively. ABC is a reputed design company being selected to award the tender for design and construction of above steel building. Suppose you are recruited as a young structural engineer for the ABC company recently and assign to this building project. Your senior structural engineer requests you to conduct the preliminary structural analysis and structural design of this steel building. He has idealized the roof bracing system for a half of the end bay and it is shown in Fig. Q1 (c). During the long wind condition, wind pressure build up on the end wall is transferred to the roof bracing system as nodal loads. The calculated nodal loads are as shown in the idealized bracing system.

a) Show that the member AE is subjected to a **compression** force of magnitude 43 kN. Check the adequacy of hot-finished rectangular hollow section of size 120x80x5 in Grade S275 for the member AE. Assume that the end connections are pinned about both major and minor axes. [9 Marks]

b) Proving that the member AF is subjected to a **tension** force of magnitude 35 kN, check the adequacy of the same section used in Part (a) for the member AF. Assume that the end connections of member AF are made by weld. [6 Marks]

Q2. A timber floor of an office building is supported on a steel beam grid as shown in Fig. Q2. The timber floor is rested on the secondary beams and the secondary beams are rested on the main beams. The main beams are connected to the columns at both ends using flexible joints. The secondary beams provide lateral restraints to the main beam at their crossing points. Unfactored permanent and variable loads transferred through the secondary beams to the main beam are as follows.

Permanent loads

Uniformly Distributed Load (self-weight) $g = 1.6$ kN/m

Concentrated loads at B and C $G_B = 50$ kN, $G_C = 25$ kN

Variable loads

Concentrated loads at B and C $Q_B = 60$ kN, $Q_C = 30$ kN

a) Plot the bending moment and shear force diagrams for the main beam and identify the design bending moment and design shear force to verify the adequacy of cross section resistance of a selected section. [2 Marks]

b) Verify the adequacy of 533x210x101 UB section made in Grade S275 steel for the main beam in terms of the following design criteria.

i) Local buckling by cross-section classification [2 Marks]

ii) Shear buckling and shear yielding resistance [2 Marks]

iii) Bending resistance [2 Marks]

iv) Web resistance to transverse load at the support. Take the stiff bearing length $s_s$=75mm and end distance c = 0. [2 Marks]

c) Using the bending moment diagram plotted in Part (a) and the geometrical configurations provided in Fig. Q2, check the adequacy of 533x210x101 UB section for the lateral torsional buckling of segment BC. Critical buckling resisting moment $M_{cr}$ for segment BC is 1895 kNm. [5 Marks]

Q3. Portal truss frames in a warehouse building are spaced at equal intervals. A portal truss frame consists of two columns and a roof truss as shown in Fig. Q3(a). The roof truss is rested on cap-plate connected on the column top. Fig. Q3(b) shows an idealized column in a typical portal truss indicating the compression force transferred by the roof truss and the variation of major axis bending moment due to lateral loads. Assess the suitability of 254x254x73 UC section (Grade S275) to be used as a column of a portal truss under the following design criteria.

a) Classify the cross section for combined bending and axial compression status.
[Hint: For the beam web classification, you may assume either entire web is under uniform compression or use $\alpha = 0.5\left[1 + \left(\frac{N_{ED}}{f_y t_w d}\right)\right]$]. [2 Marks]

b) Check whether allowance needs to be made for the effect of axial force on moment capacity about y-y and z-z axis. [4 Marks]

c) Check the member buckling resistance of the column under bending and axial compression. Use Annex B to determine interaction factors, $k_{ij}$. Use $M_{cr} = 1034$ kNm with pinned end support conditions at both ends about both axes. [9 Marks]

Q4. Fig. Q4 shows a beam-column flexible connection made by using fin-plates. Two fin-plates of size 230x110x10 mm (Grade S275) have been welded to the column flange using 8 mm fillet weld. The fin-plates are then connected to the beam web using 3 M20 Grade 8.8 bolts. The connection requires to transfer 300 kN reaction force from the beam to the column through bolt and weld connection.

a) Check the adequacy of bolt connection between the beam web and the fin-plates. Take tensile stress area of M20 bolt is 245 $mm^2$. [6 Marks]

b) Assess the adequacy of 8 mm fillet weld to resist the applied reaction force. [6 Marks]

c) Check whether the given distances for end, edge and spacing are adequate for the minimum and maximum requirement of the bolt group. [3 Marks]

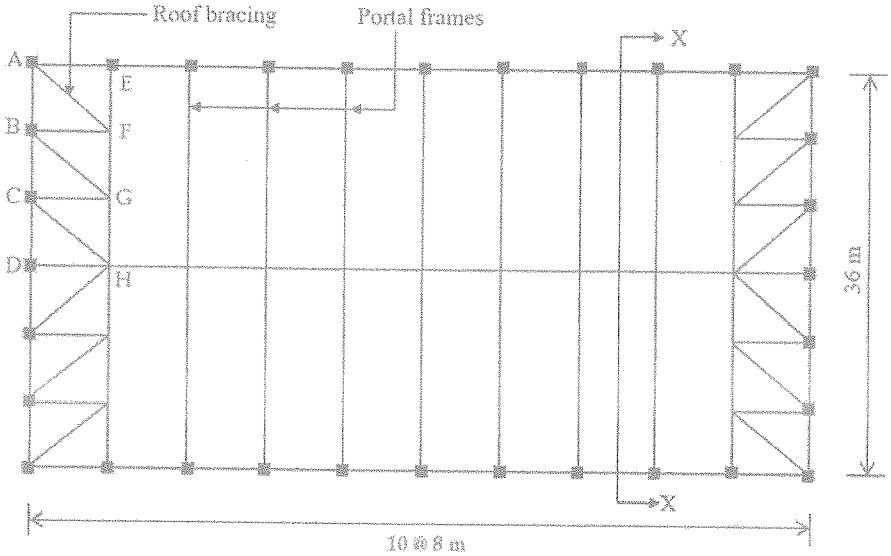


Fig. Q1(a)

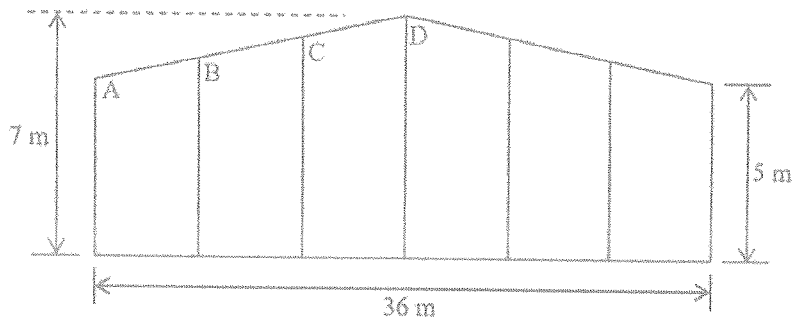


Fig. Q1(b)

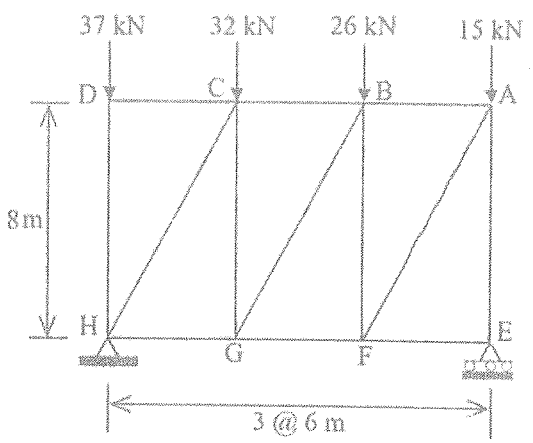


Fig. Q1(c)

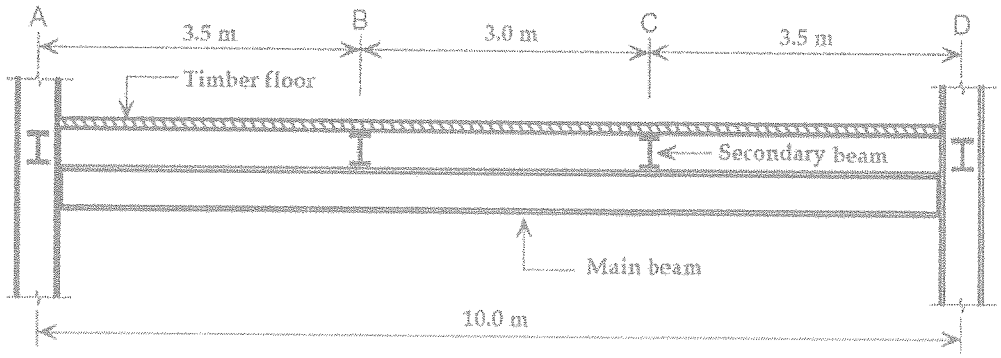


Fig. Q2

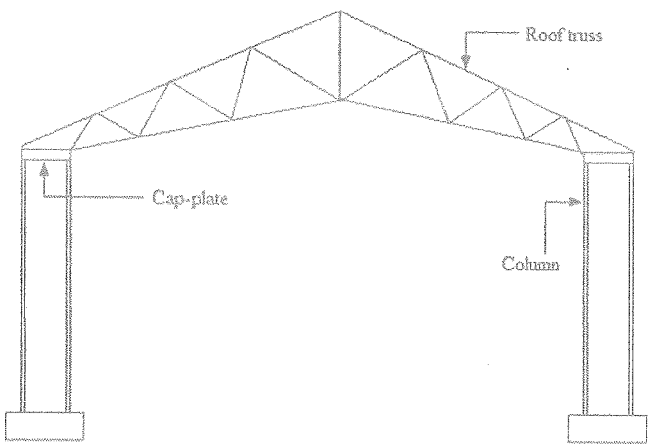


Fig. Q3 (a)

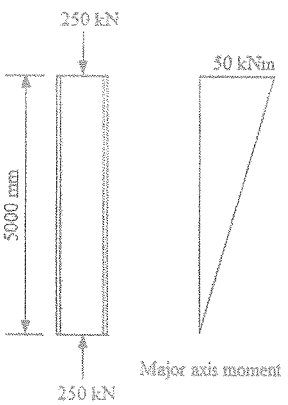


Fig. Q3(b)

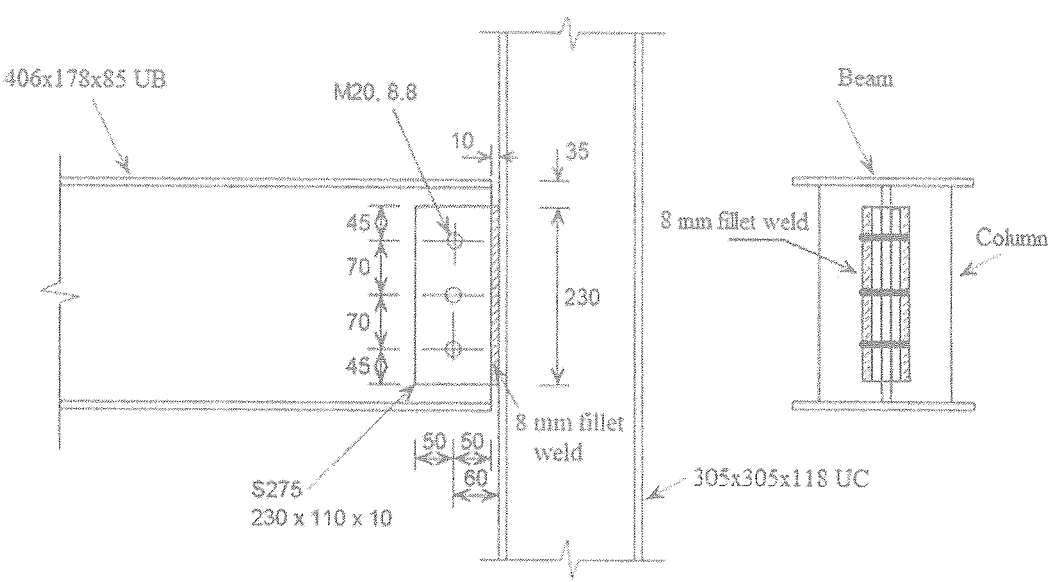


Fig. Q4

## Section Property Table - RHS Sections

| Section designation DxBxt | Mass per meter | Area | Ratios for local buckling | | Second moment of area | | Radius of Gyration | | Elastic Modulus | | Plastic Modulus | | Torsional Constants | | Surface area of section | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | A | $c_w/t$ | $c_f/t$ | Axis y-y | Axis z-z | Axis y-y | Axis z-z | Axis y-y | Axis z-z | Axis y-y | Axis z-z | J | C | Per meter | Per tonne |
| | kg/m | $cm^2$ | | | $cm^4$ | $cm^4$ | cm | cm | $cm^3$ | $cm^3$ | $cm^3$ | $cm^3$ | $cm^4$ | $cm^3$ | $m^2$ | $m^2$ |
| 120x80x5 | 14.7 | 18.7 | 21 | 13 | 365 | 193 | 4.42 | 3.21 | 60.9 | 48.2 | 74.6 | 56.1 | 401 | 77.9 | 0.387 | 26.3 |

## Section Property Table - I, H Sections

| Designation DxBxM | Mass per m | Depth of Section | Width of Section | Thickness of | | Root Radius | Depth between Fillets | Area of Section | Local buckling ratio | | Second Moment Area | | Radius of Gyration | | Section (Elastic) Modulus | | Plastic Modulus | | Buckling parameter | Torsional Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Web | Flange | | | | | | Axis y-y | Axis z-z | Axis y-y | Axis z-z | Axis y-y | Axis z-z | Axis y-y | Axis z-z | | |
| | M | h | b | $t_w$ | $t_f$ | r | d | A | $C_f/t_f$ | $C_w/t_w$ | Iy | Iz | iy | iz | $Z_y$ | $Z_y$ | Wy | Wz | u | x |
| | kg/m | mm | mm | mm | mm | mm | mm | $cm^2$ | | | $cm^4$ | $cm^4$ | cm | cm | $cm^3$ | $cm^3$ | $cm^3$ | $cm^3$ | | |
| 533x210x101 | 101 | 536.7 | 210.0 | 10.8 | 17.4 | 12.7 | 476.5 | 129 | 4.99 | 44.1 | 61500 | 2690 | 21.9 | 4.57 | 2290 | 256 | 2610 | 399 | 0.874 | 33.2 |
| 254x254x73 | 73.1 | 254.1 | 254.6 | 8.6 | 14.2 | 12.7 | 200.3 | 93.1 | 7.77 | 23.3 | 11400 | 3910 | 11.1 | 6.48 | 898 | 307 | 992 | 465 | 0.849 | 17.3 |