



CVX7640/CVX6832 - Structural Design

FINAL EXAMINATION - 2022/2023

Time Allowed: Four (04) Hours

Date: 2024 - 02 - 06 (Tuesday)

Time: 0930 - 1330 hrs.

Paper consists of five (05) questions. Answer any four (04) questions.
You may use the booklet named "Extracts From Relevant Standards" provided to you with the course material, which also contain concrete design charts & steel sectional properties
You may assume and state reasonable values for any factors not provided.

Q1. Figure 1 shows the loads on the 3rd floor (including beam self-weight) of a four storey steel office building which needs to be designed according to BS5950-1:2000. Assume all the beams in the building are fixed at the connections and laterally restrained. UB 406 × 140 × 39 steel sections are used for the primary beams. Take $P_y = 275 \text{ N/mm}^2$. (You have to mention the relevant clauses and tables of BS5950-1:2000 near your calculation steps.) Sectional properties of UB 406 × 140 × 39 steel sections are given in Table 1. at the end of the Paper.

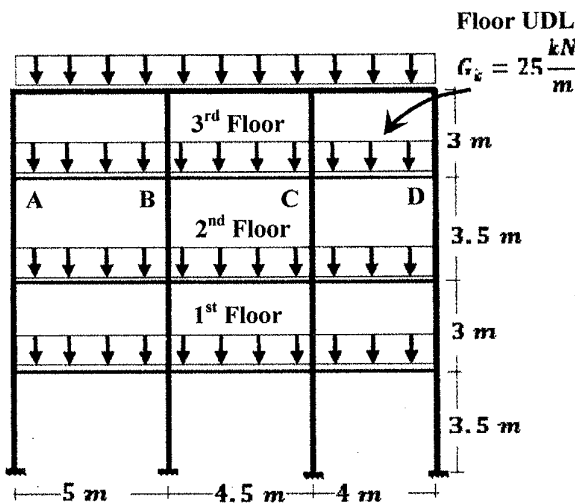


Figure 1

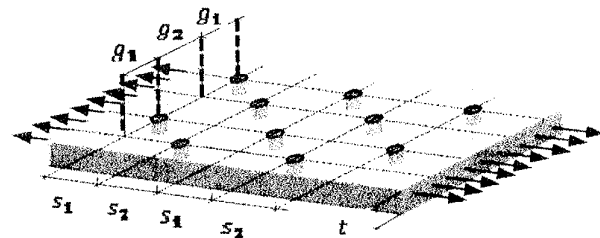


Figure 2

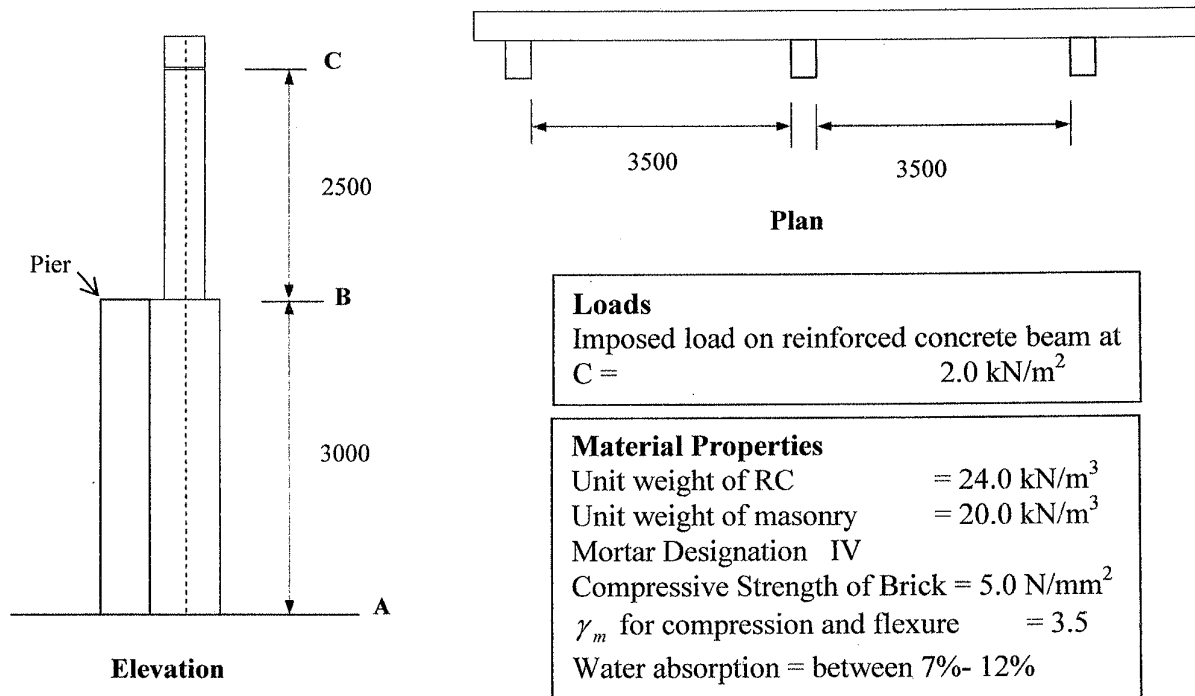
- Calculate the design loads and draw the bending moment and the shear force diagrams for beam AB (in 3rd Floor). [06 Marks]
- Do the section classification and identify the class of the steel section which is being used for Beam AB. [04 Marks]
- Check the adequacy of the given steel section for shear capacity and for moment capacity. [06 Marks]
- Check the adequacy of the given steel section for deflection (see annex for deflection calculation formula) and web bearing. Take $b_1 = 25 \text{ mm}$, $b_s = 5 \text{ mm}$, and $n = 2 + \frac{0.6b_s}{k}$.
Where $k = T + r$ for rolled I-sections. [04 Marks]

- Figure 2 shows a 250 mm wide steel plate ($p_y = 275 \text{ N/mm}^2$) subjected to tension and it is connected to another steel plate using 16 mm diameter bolts. The steel plate thickness (t) is 16 mm and consider $s_1 = 45 \text{ mm}$, $s_2 = 65 \text{ mm}$, $g_1 = 45 \text{ mm}$, $g_2 = 60 \text{ mm}$.
Determine the effective net area (A_s) and the tension capacity (P_t) of the steel plate. [05 Marks]



A new masonry wall has to be constructed around the boundary of a certain airport of Sri Lanka. The wall is to be designed as a load bearing wall. The piers are 300mm*300mm in size and provide an enhanced resistance to the wall from level A to B. There is a reinforced concrete beam on top of the wall at C. The height of the reinforced concrete beam is 300mm.

You have been assigned as the design engineer of the project. Using BS5628 Part I -1992 design code, perform the required design work of the masonry wall.



- (i) Determine the **effective length** and the **effective thickness** of wall panel from A to B. (02 Marks)
- (ii) Evaluate **characteristic dead and imposed loads** acting in the ground level per meter length of the wall at the ground level (At A). (02 Marks)
- (iii) Find **design load** per meter length at the ground level (At A). (02 Marks)
- (iv) Determine the **slenderness ratio** of the wall (From A to B) and compare with its permissible value. (02 Marks)
- (v) Write down the equation for the vertical load resistance, defining all terms. (02 Marks)
- (vi) Check whether the wall (from A to B) is able to carry the design compressive load considering vertical load resistance of the wall. (02 Marks)

- (i) Draw a figure showing boundary conditions for the wall panel A to B. (02 Marks)
- (ii) Determine the **characteristic flexural strength** values. (02 Marks)
- (iii) Determine the **orthogonal ratio** and the **bending moment coefficient**. (02 Marks)
- (iv) Determine the **bending moments parallel and perpendicular to the bed joint** if it is subjected a lateral load of 10.0 kN/m^2 from A to B. (04 Marks)
- (v) Check the safety of the wall panel under the given lateral load considering moment failure. (03 Marks)

Q3.

The 16th century, 'Bogoda Bridge' which is supposed to be the oldest surviving timber bridge in Sri Lanka is shown in the photograph.

It is a double span timber bridge with dual central support piers, constructed over 'Gallanda Oya' for pedestrian traffic. Dual timber bridge girders are supported on a rock pads at the bank sides of the stream and on a cross beam at the center support. A planked deck is supported on the two girders and timber handrails and clay tiled roof are supported on runners at the edges of the deck.

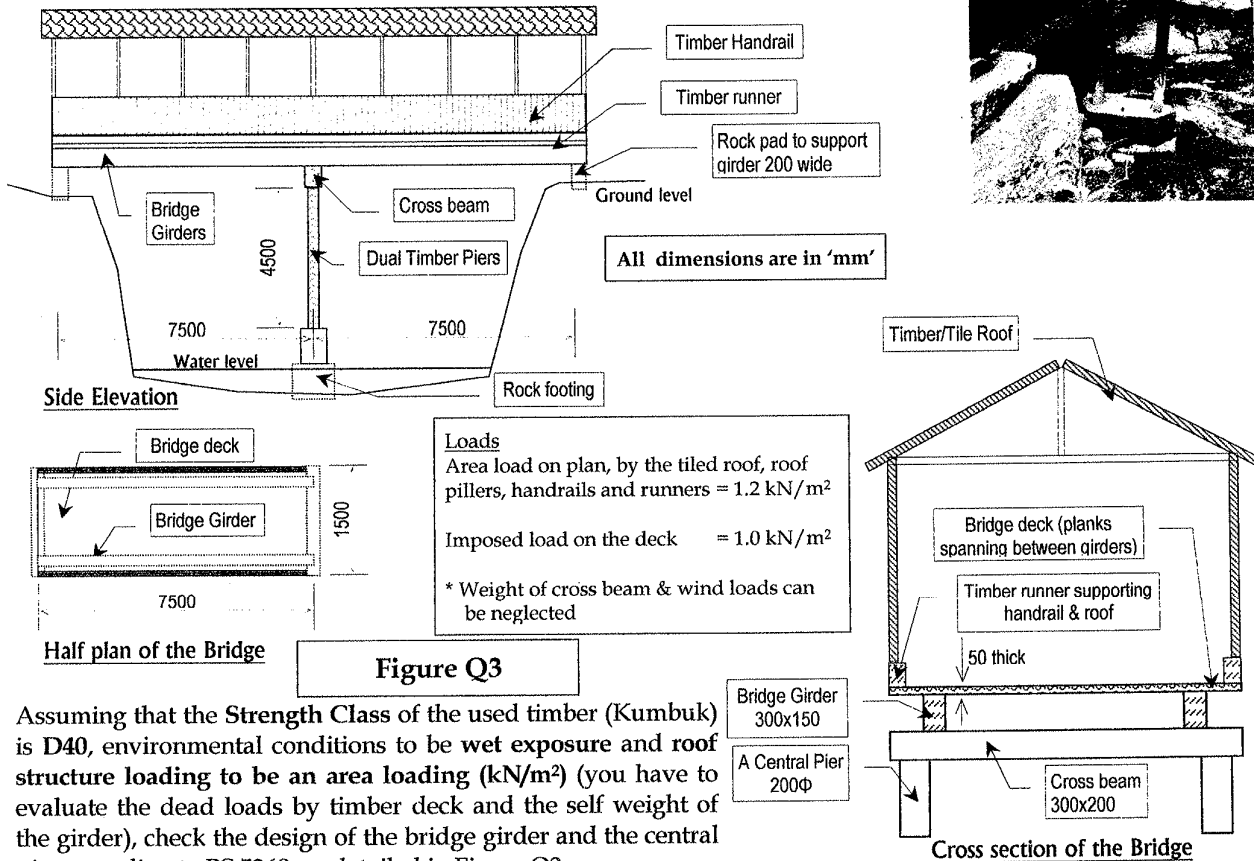


Figure Q3

Assuming that the **Strength Class** of the used timber (Kumbuk) is **D40**, environmental conditions to be **wet exposure** and **roof structure loading** to be an **area loading (kN/m²)** (you have to evaluate the dead loads by timber deck and the self weight of the girder), check the design of the bridge girder and the central pier according to BS 5268, as detailed in Figure Q3.

Section A Use following steps in checking adequacy of a bridge girder (Assuming simply supported).

- Evaluate the loading on the girder due to dead and live loads and check against lateral stability criteria. (03 marks)
- Compute the applied bending stress at the critical section for both load combinations (DL only & DL + IL conditions) and check whether they are within the permissible limits. (03 marks)
- For DL + IL condition check whether the maximum allowable deflection is within the permissible limit (0.003L). (03 marks)
- For DL + IL condition check whether the girder is safe against failure due to shear. (03 marks)
- For DL + IL condition check whether applied bearing stress by the girder supporting on the cross beam is within the permissible limit. (03 marks)

Section B Use following steps in checking the adequacy of a pier.

- Evaluate the axial load & critical moment on a pier due to dead & live load combination. (03 marks)
- Compute the applied maximum compressive stress in the pier and check whether this is within the permissible limit. (03 marks)
- Check the pier for combined compressive stress and flexural stress due to nominal eccentricity created by load transfer. (04 marks)



Q4.

A typical floor plan and a sectional view of a three storied commercial building are shown in Figure Q4 (a) and (b) respectively. The beams along the gridlines as shown are cast monolithically with the floor slab.

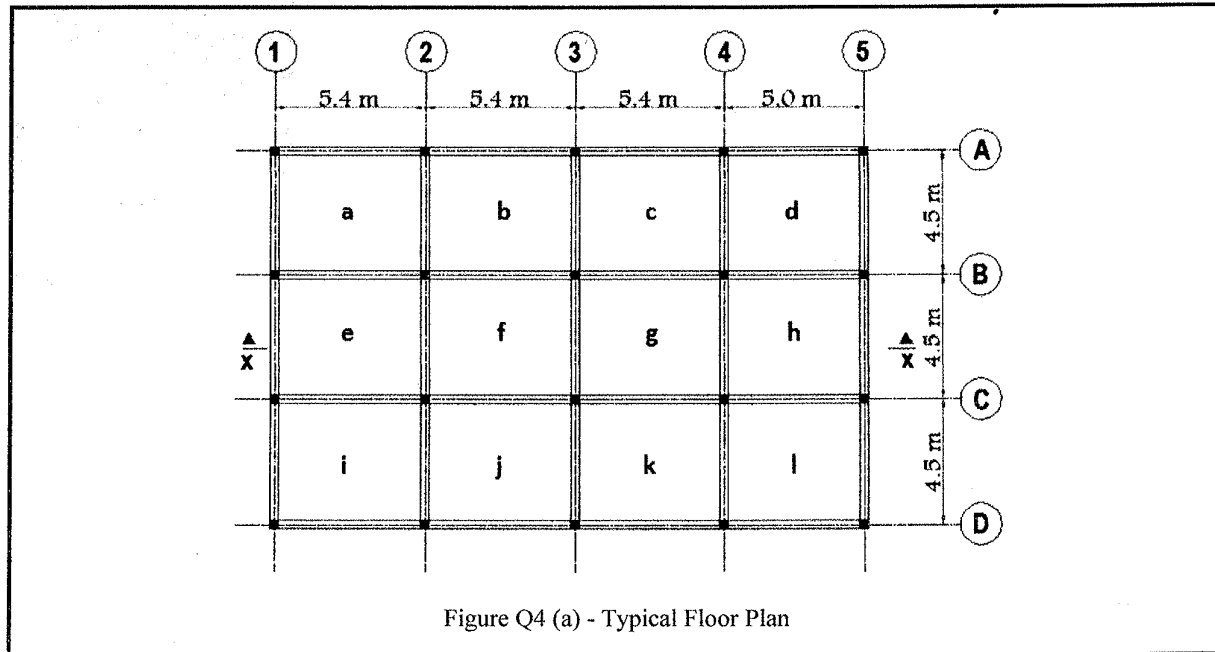
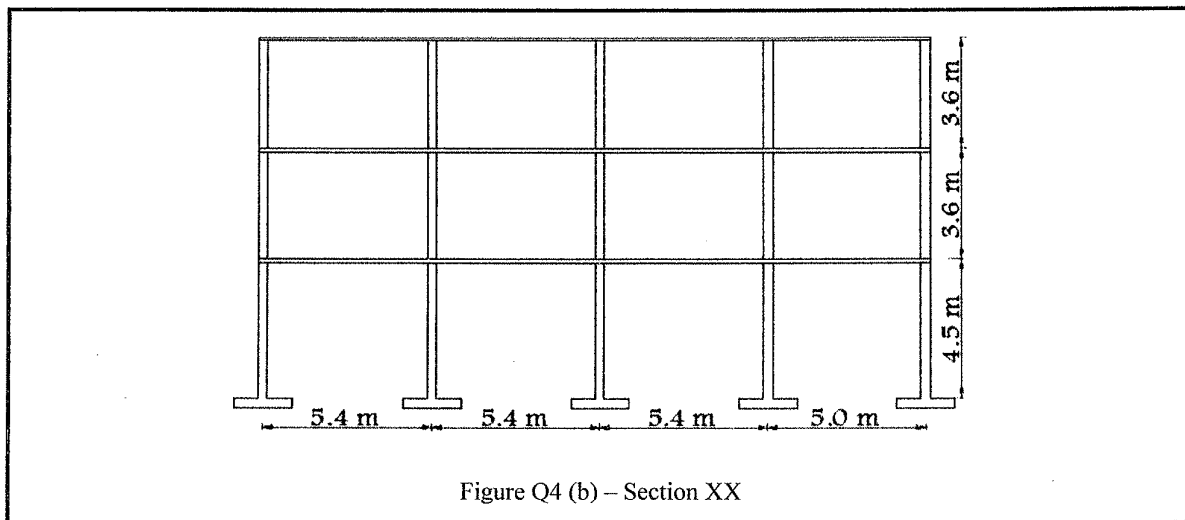


Figure Q4

Loads on the structure;

Imposed load on the roof	= 1.0 kN/m ²
Dead load by finishes on floors & roof	= 1.0 kN/m ²
Imposed load on floors	= 3.0 kN/m ²
** You may neglect the effects of Wind	

Thickness of floor & roof slabs	= 125 mm
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Weights of materials

Unit weight of RC	= 24.0 kN/m ³
Unit weight of Masonry	= 20.0 kN/m ³

Strength of materials;

Grade of concrete	= 25
Characteristic strength of steel	
Main r/f	= 460 N/mm ²
Shear r/f	= 250 N/mm ²

Nominal cover for reinforcement	= 20 mm
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Order of floors – Ground, 1st, 2nd, Roof

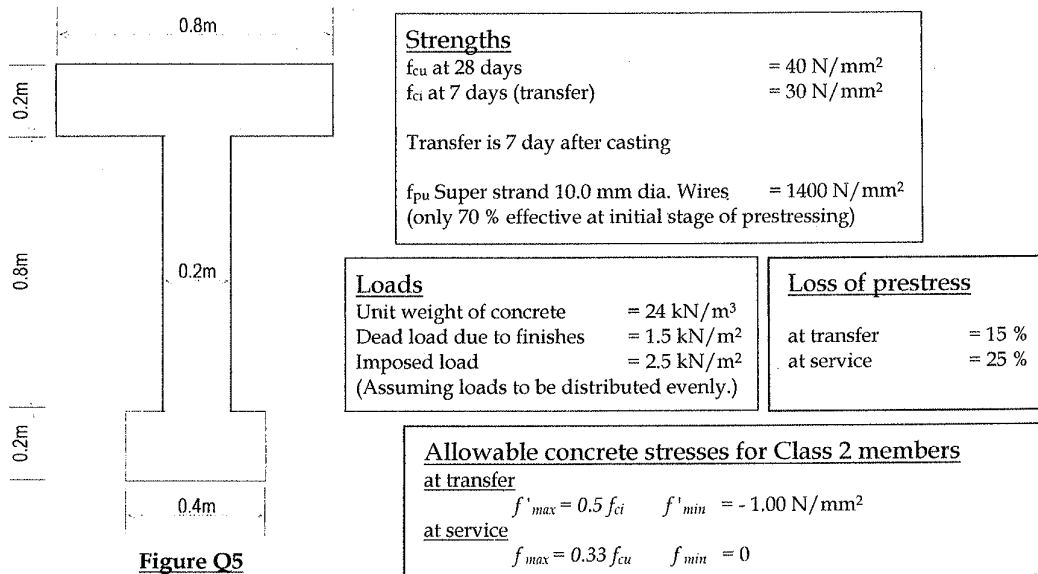
* Required design charts are provided *



- i.) Identify the most critical slab panel giving reasons for your choice. (03 Marks)
- ii.) Evaluate the design ultimate load acting on the 1st floor slab and compute the bending moments acting on the short direction of slab panel "g" using the bending moment coefficients from the code. Design reinforcements only for the short direction of this panel to satisfy code requirements and draw a typical plan showing the reinforcement detail for slab panel "g". Indicate curtailment of reinforcements without dimensions. (06 Marks)
- iii.) Evaluate the design ultimate load acting on the beam on grid 3, 350x300 mm (you may assume that a 225mm thick masonry wall is supported on top of the beam and take a uniformly distributed load along its span to simplify the analysis) and calculate the ultimate bending moments at critical locations when all spans are loaded with the ultimate load using the design formula given in BS8110-1:1997 for uniformly loaded continuous beams. (06 Marks)
- iv.) Draw the bending moment diagram for the beam on grid 3 using the bending moments computed above. Design the required reinforcements for the span BC to resist bending at critical locations and indicate how you would curtail reinforcements (without dimensions) within span BC in the bending moment diagram. (06 Marks)
- v.) Explain with a neat sketch what is meant by "punching shear" failure of a pad footing. Explain the procedure you would follow to make sure that the footing is safe against ULS direct shear failure. (04 Marks)

A pre tensioned concrete beam (having an unsymmetrical I – Section) is proposed to be used for supporting a 75 mm thick first-floor slab of a pavilion. The beam is simply supported at both ends and the effective span is 15 m and spacing of the beams is 4 m (center to center). The beam carries only its own weight at transfer. The beam is type 2.

The proposed section of the prestress beam, material properties and the loading on the beam are as follows.



You may use following inequalities (in standard notation) for your calculations

$$Z_t \geq (\alpha M_s - \beta M_i) / (\alpha f_{\max} - \beta f'_{\min})$$

$$Z_b \geq (\alpha M_s - \beta M_i) / (\beta f'_{\max} - \alpha f_{\min})$$

$$P_i \geq (Z_{tf}'_{\min} - M_i) / \alpha(Z_t/A_c - e)$$

$$P_i \leq (Z_b f'_{\max} + M_i) / \alpha(Z_b/A_c + e)$$

$$P_i \leq (Z_{tf \max} - M_s) / \beta (Z_t / A_c - e)$$

$$P_i \geq (Z_b f_{\min} + M_s) / \beta (Z_b / A_c + e)$$

$$e \leq (M_i - Z_t f'_{\min}) / \alpha P_i + Z_t / A_c$$

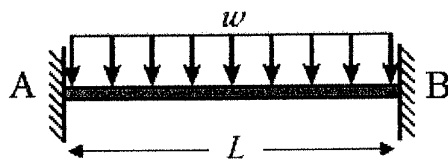
$$e \leq (M_i + Z_b f'_{\max}) / \alpha P_i - Z_b / A_c$$

$$e \geq (M_s - Z_t f_{\max}) / \beta P_i + Z_t / A_c$$

$$e \geq (M_s + Z_b f_{\min}) / \beta P_i - Z_b / A_c$$

- i). Find the required sectional properties of the given section for the Prestress concrete design. (04 Marks)
- ii). Evaluate the dead and imposed loads on the beam at **transfer** and in **service** and calculate the critical bending moments at the two instances for critical sagging moment. (04 Marks)
- iii). Check the adequacy of the section in carrying the stresses at **transfer** and at **service** (03 Marks)
- iv). After the design process one structural engineer proposed the following arrangement.
Number of 5mm diameter wires = 15
Number of tendon rows = 1 , along the mid height of the lower flange.
Equal Spacing of tendons
Cover - 30 mm
Shear Links - 10 mm diameter
Check whether the above given arrangement is suitable for the section with the most critical sagging moment. (05 Marks)
- v) Check whether the proposed tendon arrangement is suitable at the supports of the beam. If mid span arrangement is not suitable for the supports, design the solution for the support. (02 Marks)
- vi). Check the given tendon arrangement is appropriate by considering the spacing of the wires. (01 Mark)
- vii). Check the suitability of the section with respect to Ultimate Moment capacity and state whether additional reinforcement is required. (Numerical calculation for additional r/f is not required). (03 Marks)
- viii). Check the shear reinforcements are required to resist the critical Shear Force at the supports. (Numerical calculation for shear reinforcement is not required) (03 Marks)

Supplementary Information
For Question Q1

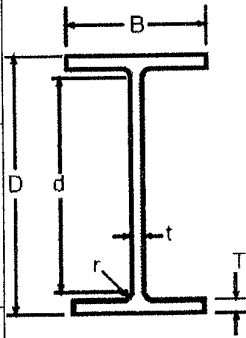


$$M_{fBA} = M_{fAB} = \frac{wL^2}{12}$$

$$M_{midspan} = \frac{wL^2}{24}$$

$$\text{Deflection at midspan} = \frac{wL^4}{384EI}$$

Table 1 – Sectional Properties of UB 406 × 140 × 39 steel section

Section Designation	Mass per meter [kg/m]	Depth of section (D) [mm]	Width of section (B) [mm]	Thickness of web (t) [mm]	Thickness of Flange (T) [mm]	Root radius (r) [mm]	Depth between fillets (d) [mm]	Ratios for local buckling		Second moment of area		Radius of gyration	
								Flange (B/2T)	Web (d/t)	Axis x-x [cm ⁴]	Axis y-y [cm ⁴]	Axis x-x [cm]	Axis y-y [cm]
406 x 140 x 39	39.0	398.0	141.8	6.4	8.6	10.2	360.4	8.24	56.3	12508	410	15.9	2.87
Section Designation	Elastic modulus		Plastic modulus		Buckling parameter (u)	Torsional index (x)	Warping constant (H) [dm ⁶]	Torsional constant (J) [cm ⁴]	Area of section [cm ²]	Indicative values for Advance275			
	Axis x-x [cm ³]	Axis y-y [cm ³]	Axis x-x [cm ³]	Axis y-y [cm ³]						M _{cx} [kNm]	P _{cy} for L _e =3.5 [kN]		
406 x 140 x 39	629	58	724	91	0.858	47.5	0.155	10.7	49.7	199	523		