

**CONTINUING PROFESSIONAL DEVELOPMENT - NOTES FOR PARTICIPANTS
ENGINEERS AUSTRALIA - 22 APRIL 2010**

RAPID DESIGN OF STEELWORK TRUSSES

WORKED SOLUTIONS TO TUTORIAL QUESTIONS

Question 1:

A steel truss (with horizontal top and bottom booms) is urgently required to give temporary support to a roof structure which has been damaged by severe weather. The truss spans 40 metres and is subjected to an imposed vertical load of 8 kN/metre span, in addition to its own self-weight, which can be assumed to be 0.45 kN/metre span.

The space available for construction is limited, and the maximum overall height of the truss must not exceed 2.2 metres. If the maximum permissible axial stress within the truss must not exceed 205MPa, and the maximum allowable deflection under imposed load is restricted to **span/350**:

- i) provide a sketch of the shape of the truss you would recommend, bearing in mind the immediate requirement for the steelwork and the need for economic design;
- ii) use suitable calculations to determine a structural square hollow steel section which you would recommend to be used for the fabrication of the truss;
- iii) estimate the cost of the truss, given that the overall cost of erected steelwork can be estimated as A\$1800 per tonne.

The value of Young's Modulus for steel can be assumed to be 200×10^3 MPa ($= 200 \times 10^6$ kN/m²).

The truss will be considered as a 10-panel statically determinate framework acting as a simply-supported beam structure.

The total distributed load is $8.45 \text{ kN/m} \times 40 \text{ m} (= 338 \text{ kN})$, and the maximum value of bending moment M_{MAX} (which occurs at mid-span) is given by

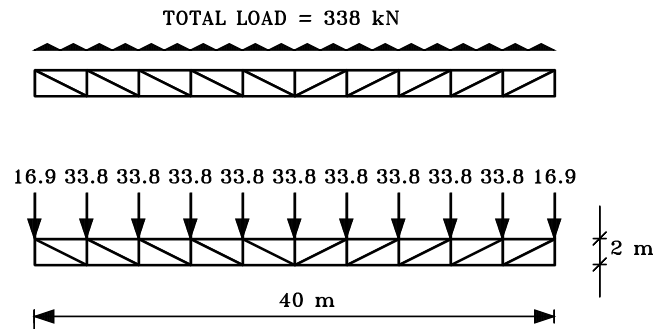


Figure 1

$$M_{MAX} = \frac{w L^2}{8} = \frac{(8 + 0.45) \text{ kN/m} \times (40 \text{ m})^2}{8} = 1690 \text{ kNm}$$

The effective depth (d) will be assumed to be 2.0 m, taking note of the restriction in **overall depth**. The axial load in the top and bottom booms is

$$P = \frac{M_{MAX}}{d} = \frac{1690 \text{ kNm}}{2 \text{ m}} = 845 \text{ kN}$$

If the maximum permissible stress for the steel is 205MPa, the required cross-sectional area A of the truss to limit the stress to this value is

$$A \geq \frac{845 \times 10^3 \text{ N}}{205 \text{ MPa}} = 4122.0 \text{ mm}^2$$

If the maximum deflection of the truss under the action of the imposed load is restricted to span/350 (= 114.3 mm), then

$$\frac{L}{350} \geq \frac{5 w_L L^4}{384 E I} = \frac{5 \times w_L \times L^4}{384 \times E \times \frac{A \times d^2}{2}}$$

$$\Rightarrow A \geq \frac{3500 \times w_L \times L^3}{384 \times E \times d^2} = \frac{3500 \times 8 \text{ kN/m} \times (40 \text{ m})^3}{384 \times (200 \times 10^6) \times (2 \text{ m})^2}$$

$$A \geq 5.8333 \times 10^{-3} \text{ m}^2 = \mathbf{5833.3 \text{ mm}^2}$$

This value for A (5833.3 mm²) is significantly greater than that obtained by considering maximum stress, and therefore it is this higher value that must be taken as the required cross-sectional area for the truss members. Using the OneSteel Cold Formed Structural Hollow Sections and Profiles Catalogue, the square hollow section with the nearest cross-sectional area greater than this area is **200 × 200 × 9 mm SHS** with an area of 6600 mm², which has a mass of 51.8 kg/m.

The total length of steel section in one truss is approximately

$$2 \times 40 \text{ m} + 11 \times 2 \text{ m} + 10 \times \sqrt{4^2 + 2^2} \text{ m} = 146.7 \text{ m}$$

Thus the total weight of steel in the truss is

$$146.7 \text{ m} \times 51.8 \text{ kg/m} = 7599.1 \text{ kg}$$

and if the cost of erected steelwork is A\$1800 per tonne, the total cost of the truss is

$$7.5991 \text{ T} \times \text{A\$1800/T} = \mathbf{\text{A\$13678}}$$

Question 2:

A steel truss (with horizontal top and bottom booms) is required to span 25 metres and is subjected to an imposed vertical load of 5 kN/metre span, in addition to its own self-weight, which can be assumed to be 0.35 kN/metre span.

The space available for construction is limited, and the maximum height of the truss must not exceed 1.5 metres. If Steel Grade 350 is to be used (maximum permissible axial stress within the truss is 205MPa), and the maximum allowable deflection under imposed load is restricted to **span/350**:

- provide a sketch of the shape of the truss you would recommend;
- use suitable calculations to determine a steel section which you would recommend to be used for the fabrication of the truss. You should consider SHS, RHS and CHS section, and your recommendation should be based on achieving minimum weight while still meeting all the above design criteria;
- estimate the cost of the truss, given that the overall cost of erected steelwork can be estimated as A\$1880 per tonne.

The value of Young's Modulus for steel can be assumed to be $200 \times 10^3 \text{ MPa}$ (= $200 \times 10^6 \text{ kN/m}^2$).

The truss will be considered as a 8-panel statically determinate framework acting as a simply-supported beam structure. The total distributed load is $5.35 \text{ kN/m} \times 25 \text{ m}$ (= 133.75 kN), and the maximum value of bending moment M_{MAX} (which occurs at mid-span) is given by

$$M_{\text{MAX}} = \frac{w \times L^2}{8}$$

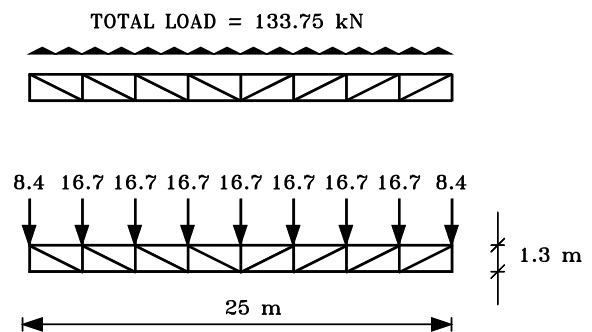


Figure 2

Thus
$$M_{MAX} = \frac{(5 + 0.35)\text{kN/m} \times (25\text{m})^2}{8} = 418.0 \text{ kNm}$$

The effective depth (d) will be assumed to be 1.25 m, taking note of the restriction in **overall depth**. The axial load in the top and bottom booms is

$$P = \frac{M_{MAX}}{d} = \frac{418.0 \text{ kNm}}{1.25 \text{ m}} = 334.4 \text{ kN}$$

If the maximum permissible stress for the steel is 205 MPa, the required cross-sectional area A of the truss to limit the stress to this value is

$$A \geq \frac{334.4 \times 10^3 \text{ N}}{205 \text{ MPa}} = 1631.2 \text{ mm}^2$$

If the maximum deflection of the truss under the action of the imposed load is restricted to span/350 (= 71.4 mm), then

$$\frac{L}{350} \geq \frac{5 w_L L^4}{384 E I} = \frac{5 \times w_L \times L^4}{384 \times E \times \frac{A \times d^2}{2}}$$

$$\Rightarrow A \geq \frac{3500 \times w_L \times L^3}{384 \times E \times d^2} = \frac{3500 \times 5\text{kN/m} \times (25\text{m})^3}{384 \times (200 \times 10^6) \times (1.25\text{m})^2}$$

$$A \geq 2.2786 \times 10^{-3} \text{ m}^2 = 2278.6 \text{ mm}^2$$

This value for A (2278.6 mm²) obtained by considering maximum stress is greater than the previous value for A (1631.2 mm²), and therefore the higher value must be taken as the required cross-sectional area for the truss members. Using the OneSteel Cold Formed Structural Hollow Sections and Profiles Catalogue:

- Square Hollow Section with the nearest cross-sectional area greater than 2278.6 mm² is 125 × 125 × 5 mm SHS with an area of 2310 mm², which has a mass of 18.2 kg/m.
- Rectangular Hollow Section with the nearest cross-sectional area greater than 2278.6 mm² is 200 × 100 × 4 mm RHS with an area of 2280 mm², which has a mass of 17.9 kg/m.
- Circular Hollow Section with the nearest cross-sectional area greater than 2278.6 mm² is 168.3 × 4.8 mm CHS with an area of 2470 mm², which has a mass of 19.4 kg/m.

The most economical section is the 200 × 100 × 4 mm RHS with a mass of 17.9 kg/m.

(NB Potential welding issues with 4mm wall thickness?)

The total length of steel section in one truss is approximately

$$2 \times 25 \text{ m} + 9 \times 1.25 \text{ m} + 8 \times \sqrt{\left(\frac{25\text{m}}{8}\right)^2 + 1.25^2} \text{ m} = 88.2 \text{ m}$$

Thus the total weight of steel in the truss is

$$88.2 \text{ m} \times 17.9 \text{ kg/m} = 1578.8 \text{ kg}$$

and if the cost of erected steelwork is A\$1880 per tonne, the total cost of the truss is approximately

$$1.5788 \text{ T} \times \text{A\$1880/T} = \text{A\$2968}$$