Application Sheet

Glasgow Central Station Truss

Context: Roof truss in the main concourse of the Glasgow Central Station
Objective: Estimating the size of members in an existing truss based on bending

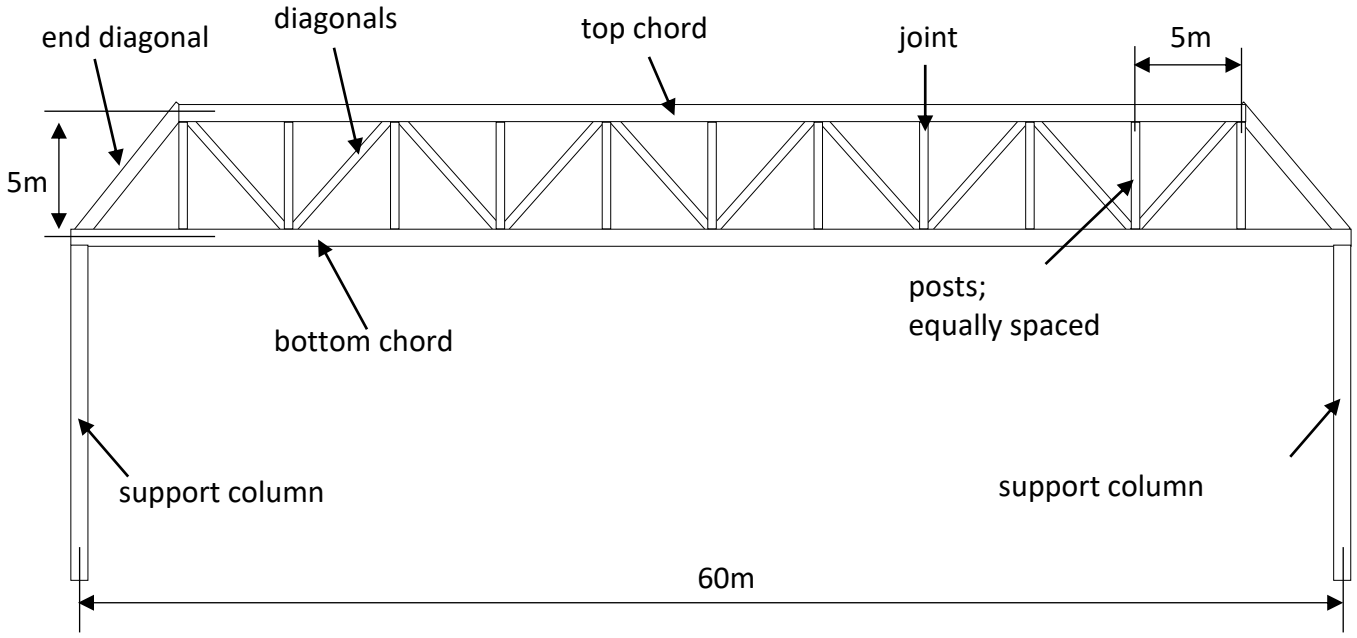
Concepts used in this application sheet

- Force: applied load, point load, internal force, resolution into components
- Equilibrium: equilibrium equation, force equilibrium
- Free Body Diagram

Main concourse truss ("Glasgow Central railway station" by Ed Webster, licenced under CC BY 2.0)

Truss details ("2014_276" by Chilanga Cement, licenced under CC BY 2.0)

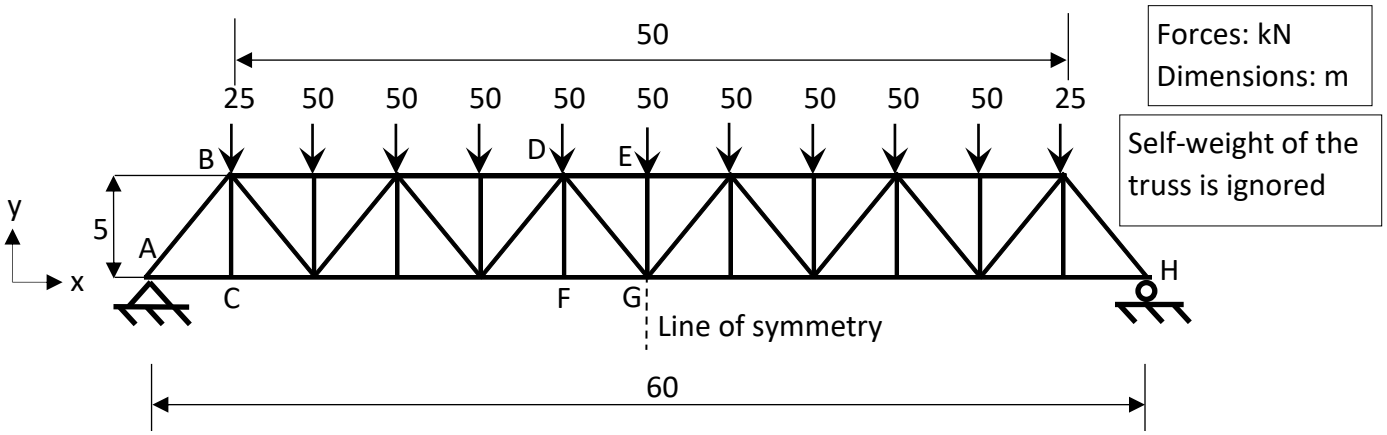
Engineering model



All sections: steel square hollow sections 200x200x5.0 with area, A_s = 3870 mm^2

Structural analysis

Analysis model

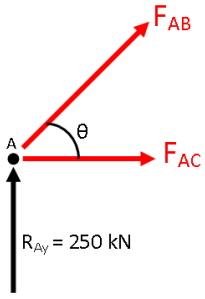


For this calculation only axial forces in the members are taken into account i.e. moment continuity is neglected.

Calculations

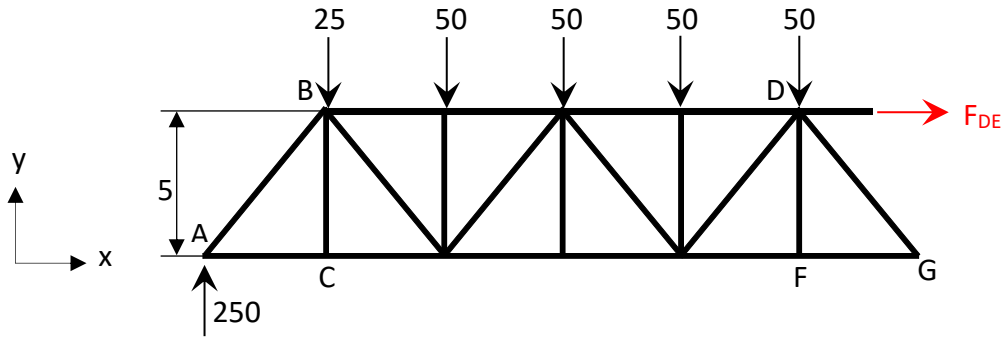
Two of the heavily loaded members are the end diagonal AB and the top chord DE at the centre of the beam.

Calculate the force in the end diagonal AB:
Calculate the support reaction at A and H:
Total load on the truss: 500 kN
Vertical support reaction = 500/2 = 250 kN (because truss and loading are symmetric)



Use the free-body diagram at the end support:
$\theta = \tan^{-1}(BC/AC) = \tan^{-1}(5/5) = \tan^{-1}(1) = 45°$
$\sum F_y = 250 + F_{AB}*\sin(\theta) = 0$
$F_{AB} = -250/\sin(\theta) = -250/\sin(45) = -356kN$
F_{AB} is negative. i.e. force in AB is compressive

Calculate the force in the chords at the centre of the truss
Use a cut just to the left of the central post:



Take moment equilibrium about joint G:
$-F_{DE}*5 - 250*30 + 25*25 + 50*(20+15+10+5) = 0$
$F_{DE} = -875kN$ (i.e. compressive)

Assessment

Factor of Safety = σ_u / σ_w

- σ_u is the ultimate compressive stress
- σ_w is the working stress

Data input

Minimum required FOS: 2.0 (given)

Ultimate compressive stress σ_u = 240 N/mm^2 (240 N/mm^2 is an older steel classification that is no longer used. However, it is used here because the truss was built in the late 1800s.)

Area of section, A_s = 3870mm^2

End diagonal AB assessment

AB specific data input

Axial force F_{AB} = 356 kN = 356000N (from analysis)

Calculations

σ_w =F/A = 356000/3870 = 92.0 N/mm^2

Calculate the FOS

FOS = 240/92 = 2.6

Decision

The chosen steel section is suitable for the compressive forces it has to withstand and meets the minimum FOS criterion.

Top chord DE assessment

DE specific data input

Axial force F_{DE} = 875 kN = 875000N (from analysis)

Calculations

σ_W =F/A = 875000/3870= 226.1 N/mm^2

Calculate the FOS

FOS = 240/226.1 = 1.06

Decision

The FOS is less than 2 and hence a bigger section should be chosen to ensure that the structure is safe.

The next steps can either be:

- Choosing an arbitrary section and performing the same calculations as above or
- In this case it is possible to rearrange the equations to solve for the minimum required section area

Adjustment calculations

Substitute the equations for working and ultimate stress into the factor of safety equation and setting the required FOS to 2:

FOS = σ_u / σ_w = *240/(F/As)* = 240/(875000/As) = 2

Solve for As

875000/As = 240/2

As = 875000/120 = 7292mm^2

Therefore, any section with an area greater than 7292mm^2 will be ok

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