Online information resource for structural mechanics

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

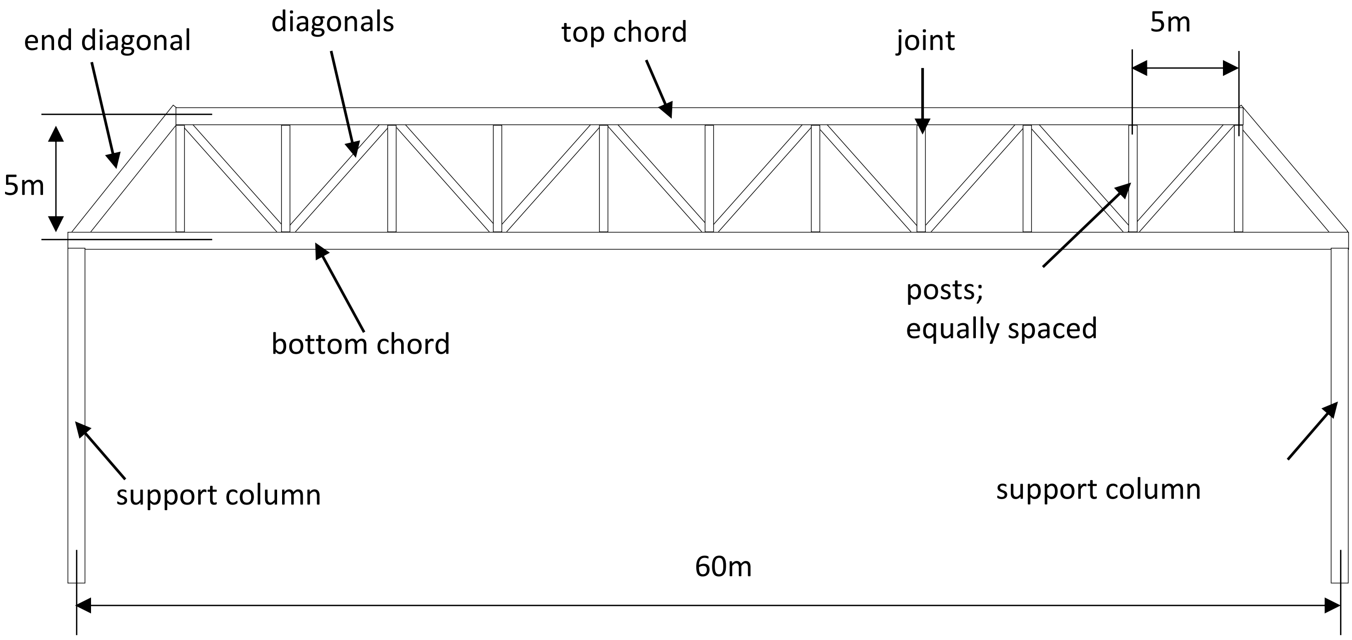
Concepts used in this application sheet

- 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)

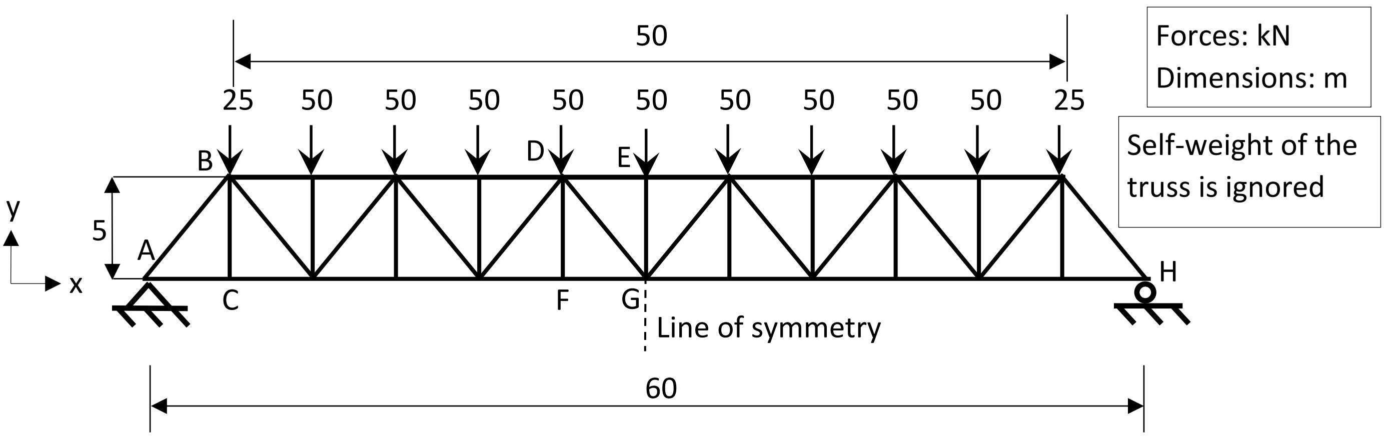
Engineering model



All sections: steel square hollow sections

Structural analysis

Analysis model

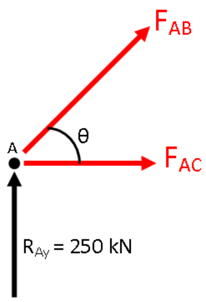


For this calculation only axial forces in the members are taken into account i.e. moment continuity is neglected.

Calculations

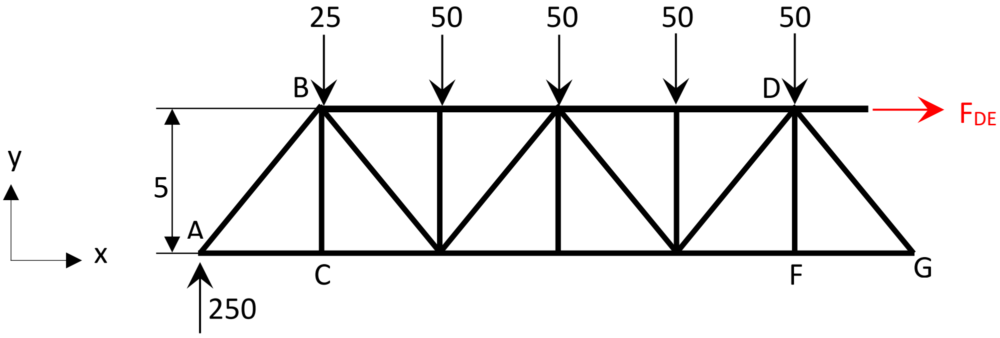
Two of the heavily loaded members are the end diagonal AB and the top chord DE at the centre of the beam.

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(θ) = 0
F_{AB} = -250/sin(θ) = -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

Using the allowable stress method

Strength criterion $\sigma_c/\sigma_a \leq 1.0$

- σ_c is the compressive stress due to loading
- σ_a is the design allowable compressive stress

Data input

Yield stress in steel σ_y = 240 N/mm^2 (from code of practice; 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.)

Factor of safety on stress *FoS* = 2.0 (assumed)

Selecting an arbitrary square hollow section (from steel tables) with dimensions 200x200x5.0

Area of section, As = 38.7cm^2 = 3870 mm^2 (from steel tables)

End diagonal AB assessment

AB specific data input

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

Calculations

Allowable stress in steel $\sigma_a = \sigma_y/FoS$ = 240/2.0 = 120 N/mm^2

Compressive stress in member σ_c =F/A = 356000/3870 = 92.0 N/mm^2

Apply the criterion

$\sigma_c/\sigma_a \leq 1.0$ = 92/120 = 0.77

Decision

The chosen steel section is suitable for the compressive forces it has to withstand. Also, the selection is not oversized as the unity factor is rather close to 1.0.

Top chord DE assessment

DE specific data input

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

Calculations

Allowable stress in steel $\sigma_a = \sigma_y/FoS$ = 240/2.0 = 120 N/mm^2

Compressive stress in member σ_c =F/A = 875000/3870= 226.1 N/mm^2

Apply the criterion

$\sigma_c/\sigma_a \leq 1.0$ = 226.1/120 = 1.88

Decision

The chosen section size is not suitable for the top chord. It needs to be bigger.

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 compressive and allowable stress into the unity factor equation:

$\sigma_c/\sigma_a = (F/As)/(\sigma_y/FOS)$ = (875000/As) / (120) = 1.0

Solve for As

875000/As = 120*1

As = 7292mm^2 = 72.9 cm^2

Choose a section from the steel tables with an area not less than As:

200x200x12.5 with A = 92.1cm^2

Validation
The calculation does not allow for buckling of the members. This needs to be checked. Neglect of continuity in the analysis model will be conservative.

A spreadsheet in which the above calculations can be checked can be found here

Last edited: 28.08.2020
Author: ACR
Keywords: truss, nodal analysis, allowable stress