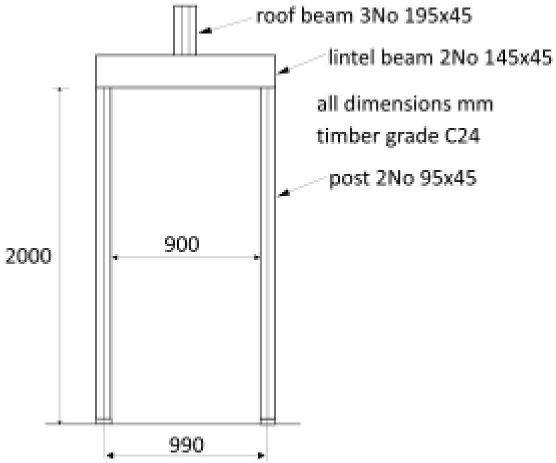
Axial force, stress and deformation of a door post

(a) Door frame



(b) Engineering model of the door frame

Figure 1 The door frame

For the door frame, the lintel beam is supported on ‘posts’ on either side of the door opening. These can also be described as ‘columns’. i.e. vertical members in compression.

Analysis model

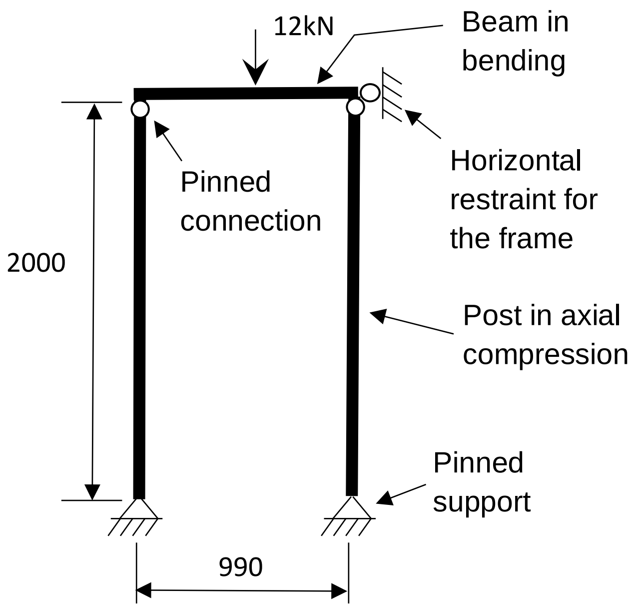


Figure 2 Analysis model of the door frame

The horizontal restraint indicates that the frame is prevented from moving sideways (by the stud frame that surrounds it).
The pinned supports and connections indicate that there is no restraint or rotation

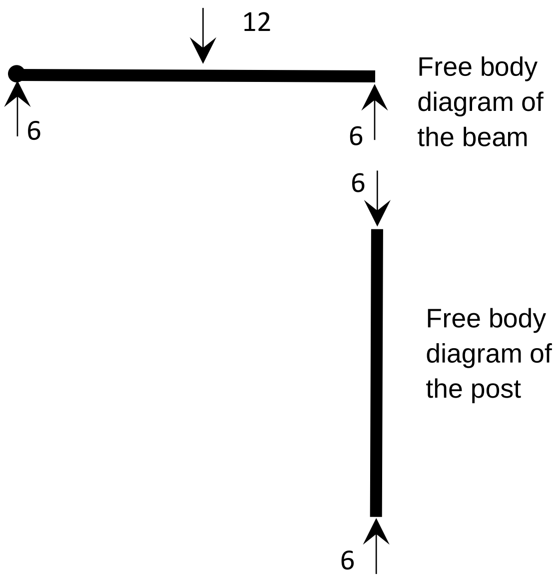


Figure 3 Free body diagrams for the beam and the post

Note that the reaction on the beam and the end force on the top of the post are equal and opposite.

Axial deformation Δ of a post of the door frame

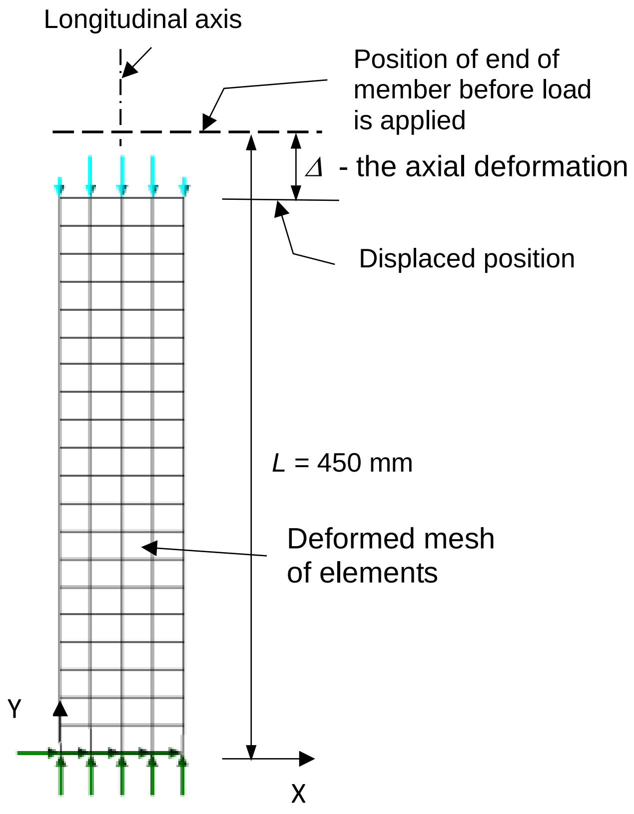


Figure 4 Deformation of part of the post

Figure 4 shows a plane stress model of a 450 mm length of the post. Unlike a model of a frame member that is defined along a line, this model is made up of elements that are defined in two dimensions. The bottom end of the model has pin supports and a uniform load of 6 kN is applied at the top. The mesh shown is the 'deformed mesh'. That each element in the mesh is deformed is not evident from the diagram, but the cumulative vertical deformation of the elements results in a top downward deflection Δ as shown. This deflection is not shown to scale.
Note that there is no deformation in the X direction. This is basic to the concept of axial deformation. It is only in the direction of the longitudinal axis.

Calculate the value of the axial deformation - Δ - for the post

Data

Length L = 2000 mm
Area A = 2*95*45 = 8550 mm^2
Young's Modulus = 11.0 kN/mm^2 = 11000 N/mm^2
Axial force in the member F = 6.0 kN = 6000 kN

Calculation

Axial stress in the member $\sigma = F/A$ = 6000/8550 = 0.701 N/mm^2
Stress-strain $\sigma = E*\varepsilon$ hence strain $\varepsilon = \sigma/E$ = 0.701/11000 = 6.4E-5 (non-dimensional)
Over the length of the member the strain $\varepsilon = \Delta/L$ hence $\Delta = \varepsilon*L$ = 6.4E-5*2000 = 0.13 mm

Formula for Δ

Start with $\sigma = E*\varepsilon$, substitute $\sigma = F/A$ and $\varepsilon = \Delta/L$ and change the subject of the equation to get:

$\Delta = F*L/(E*A)$

Axial stress in the post

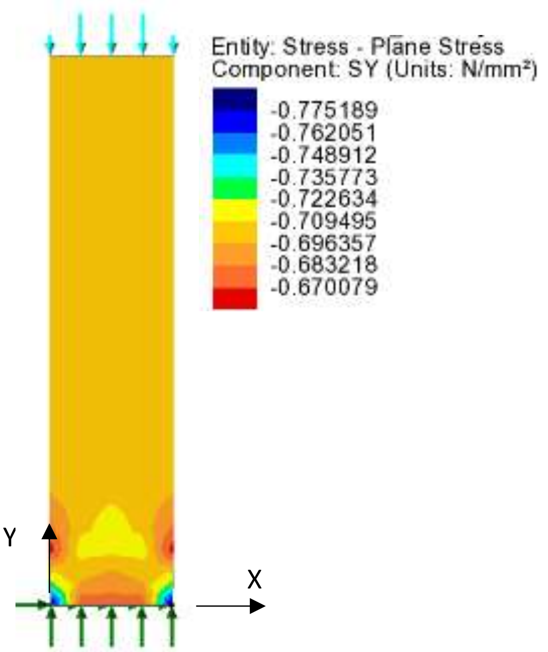


Figure 5 Stress in part of the post

This is a plot of axial stress (i.e. direct stress in the X direction) from the plane stress model of a door post. Except near the supported end it is constant vertically and horizontally. Only at the supported end is the axial stress different from the average of 0.701 N/mm^2. This is due to the model having point supports at the nodes. Elsewhere the stress is uniform. These non-uniform stresses near the support would not exist in the real member. They represent an example of *local stress* that needs to be considered in some situations.

Summary

Features of axial force

- Axial force is a direct force (i.e. it is in a direction at right angles to the cross-section on which it acts). It is in the direction of the longitudinal (x) axis of a member.
- Its resultant is at the centroid of area of the cross-section.

Axial stress

- Axial stress is the axial force per unit area.
- It is assumed to be constant over the area of the cross-section.
- It is constant along the length of the member if no axial loads are applied within the length

Features of axial deformation

- The deformation is along the length of the member - parallel to the longitudinal axis.
- Under axial load only, there is no deformation at right angles to the longitudinal axis - i.e. there is no bending in the member.

Metadata
Keywords: Axial force, strain, axial deformation
Author: I MacLeod
Last edited: 11.08.2020