WORKSHEET 1
LINE MODELLING OF REAL STRUCTURES

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PRODUCED WITH FUNDING FROM THE ROYAL ACADEMY OF ENGINEERING'S
NATIONAL HE STEM PROGRAMME.

INTRODUCTION

Structural analysis requires the simplification of the real structure to a mathematical (line) model, by making realistic assumptions for member connections and supports. Understanding the limits of the mathematical model is very important for a structural engineer since the design of the real structure will be based on the analysis of the model. If the mathematical model does not follow the real structure closely, then there is always the danger of the structure behaving in a different way.

The objective of this tutorial is to help students draw the connections between real structures and mathematical models used for structural analysis.

SIMPLE SUPPORT

Fig. 1. Render of a simple support in a Push Me Pull Me Model.

Cleat angles connecting the beam on the wall prevent it from moving horizontally or vertically, but they are not able to stop the beam end from rotating under bending action.

If we want to quantify the stress resultants, we need to translate the structure into a mathematical line model.

Kinematics - Allowed Displacements: ROTATIONAL
Statics - Reactiions: HORIZONTAL + VERTICAL

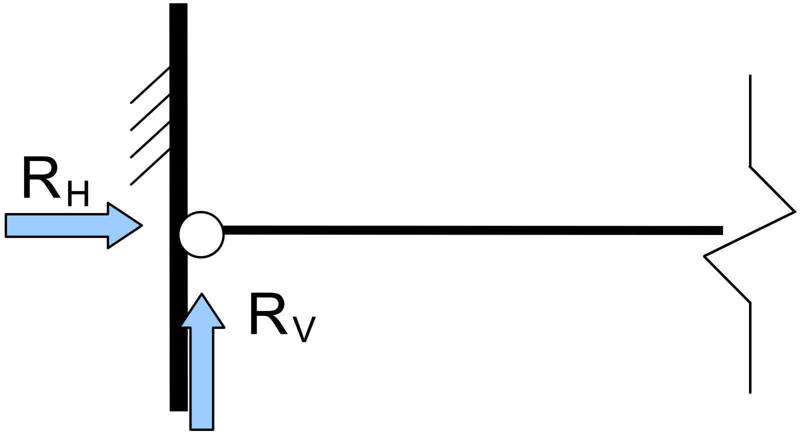

Fig. 2. A simply supported beam modelled with a pin support.

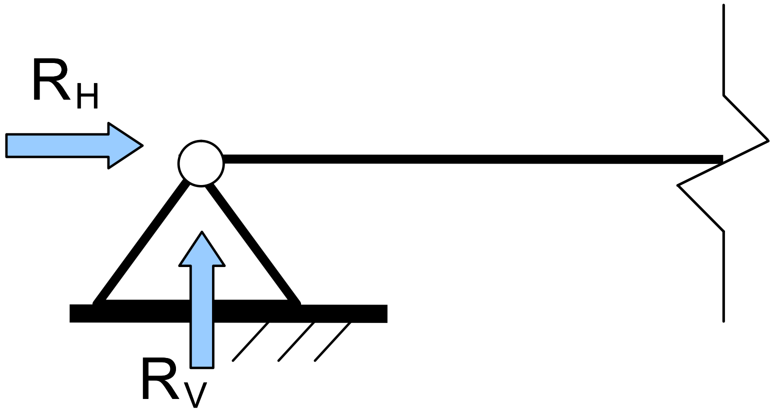

Fig. 3. A simply supported beam modelled with a simple support. Note both Fig. 2 and Fig. 3 represent the same support condition.

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SIMPLE SUPPORT ON ROLLERS

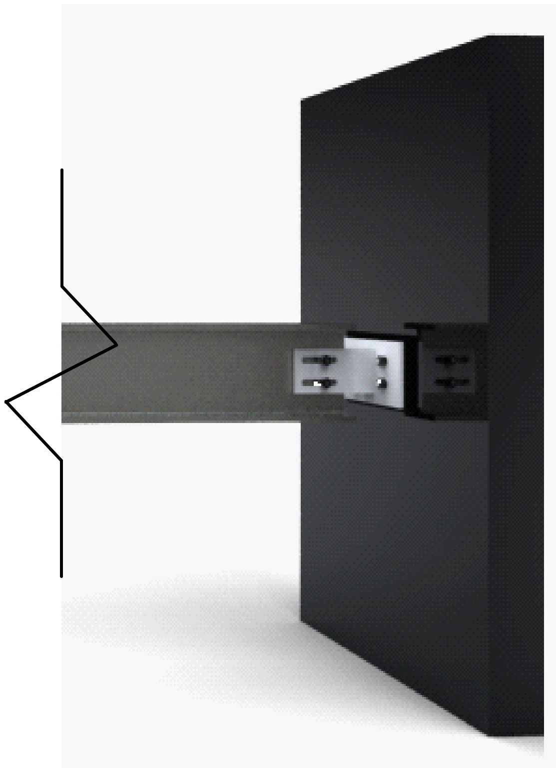

Fig. 4. Render of a roller support in a Push Me Pull Me model.

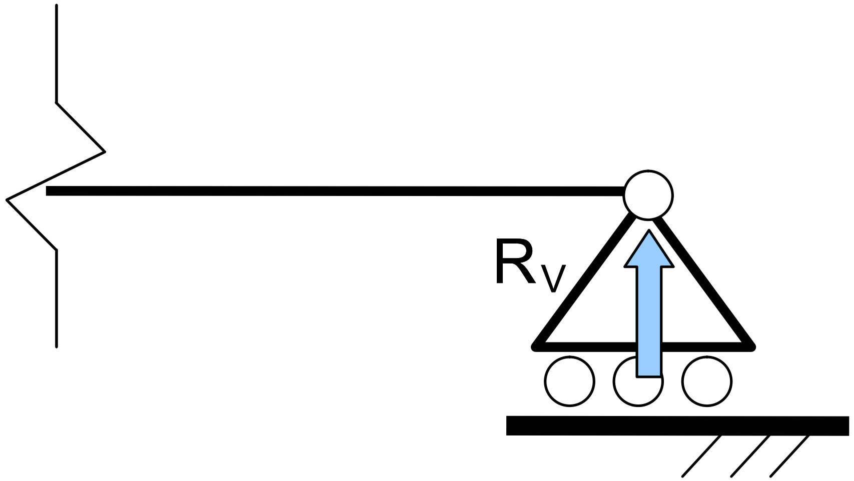

Fig. 5. The same support shown as a line diagram.

Kinematics - Allowed Displacements: HORIZONTAL + ROTATIONAL
Statics - Reactiions: VERTICAL

Cleat angles with longitudinal slots allow some tolerance to the beam end horizontally and also rotationally, but the beam end is prevented from displacing vertically.

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FIXED SUPPORTS

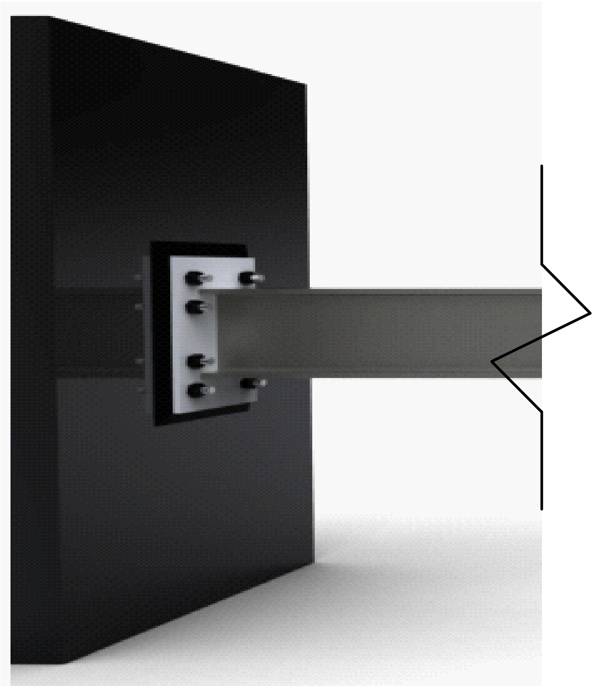

Fig. 6. A fixed beam support in Push Me Pull Me

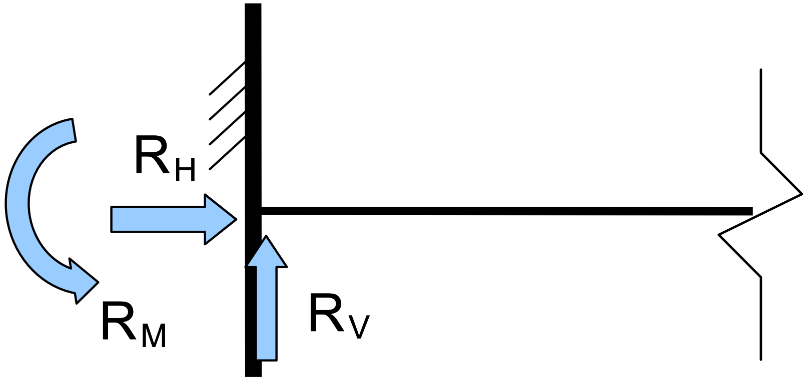

Fig. 7. The beam as a line diagram.

Kinematics - Allowed Displacements: NONE
Statics - Reactions: VERTICAL + HORIZONTAL + ROTATIONAL

TRIVIA: Note that when a displacement is suppressed, a reaction force arises.

Plate connections with bolts further away from the neutral axis of the beam not only prevent the beam end from moving horizontally or vertically, but also restrict it from rotating.

This can be further reinforced through the use of haunches (see p.6)

MOMENT CONNECTIONS

Plate connections with bolts located some distance from the neutral axis of the beam result in a rigid connection between the beam and the top of the column. The rigidity of the connection forces the column and beam ends to translate and rotate in unison. The rigidity of the joint can sometimes be reinforced through the use of haunches (see Fig. 8).

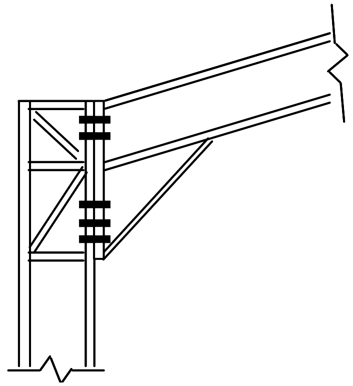

Fig. 8. Haunched joint.

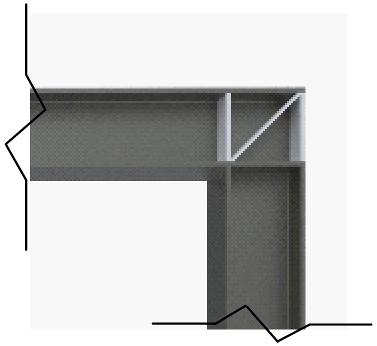

Fig. 9. A fixed corner joint on Push Me Pull Me.

Crucial Point: When isolating a moment connection, the stress resultants (MOMENT, SHEAR, AXIAL), must be in a equilibrium. So:

$$M_1 = M_2$$
$$A_2 = V_1$$
$$V_2 = A_1$$

For a non-orthogonal angle fixed joint, the axial and shear forces on either end must be balanced in two orthogonal directions.

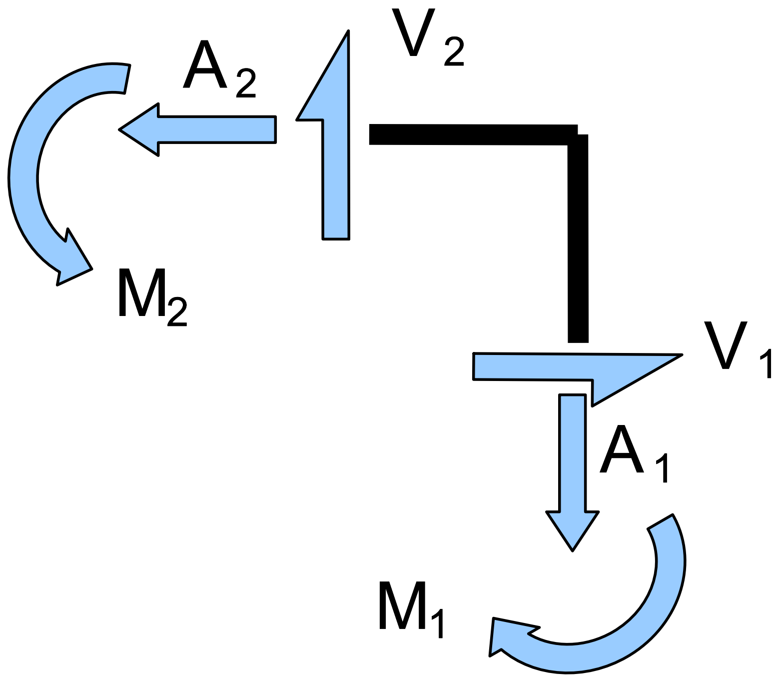

Fig. 10. The joint as a line diagram, showing forces in equilibrium.

PINNED JOINT

A simple or pinned joint, is a connection that can transfer only shear and axial forces, by almost free rotation of the adjoining steel members. This is done by joining the two steel members with narrow plates on either side of the web, or cleat angles for corner joints.

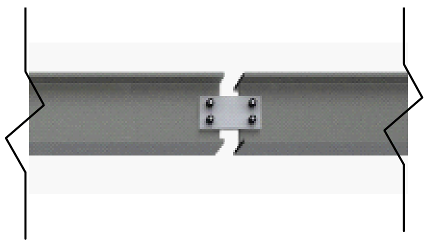

Fig. 9. A pinned joint in Push Me Pull Me.

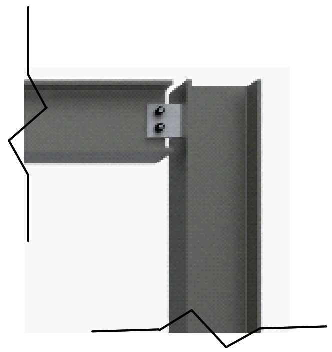

Fig. 10. A pinned corner joint in Push Me Pull Me.

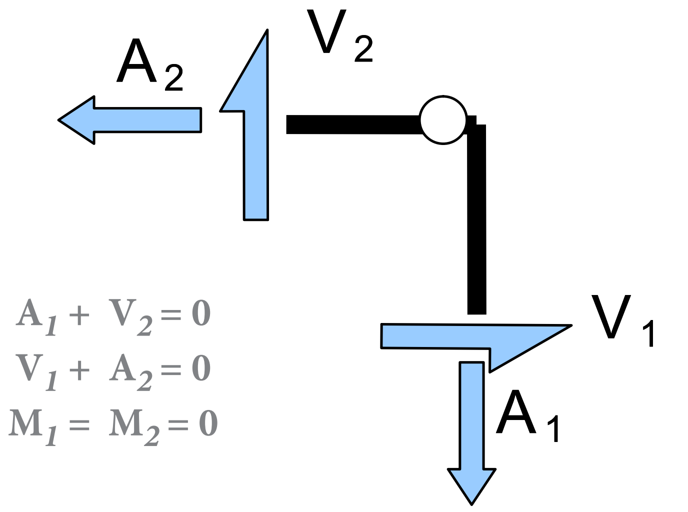

Fig. 11. Figure 10 as a line diagram, showing forces in equilibrium.

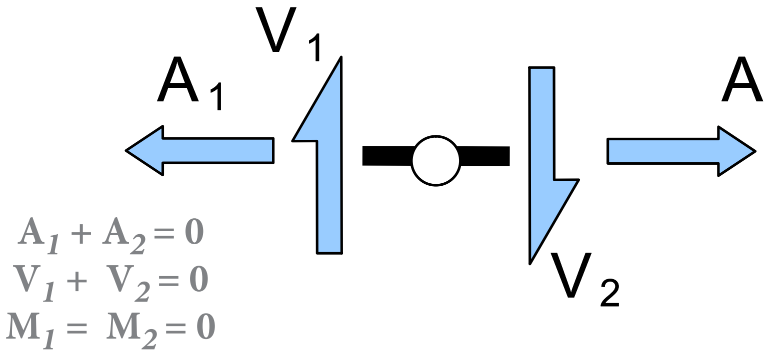

Fig. 12. Figure 9 as a line diagram, showing forces in equilibrium.

Crucial Point:
Once again the joint must be in equilibrium, and it is safe to assume that the joint will not be transferring any bending moment for analysis. In reality pinned joints might provide some bending resistance but neglecting this is a conservative approach. Why?

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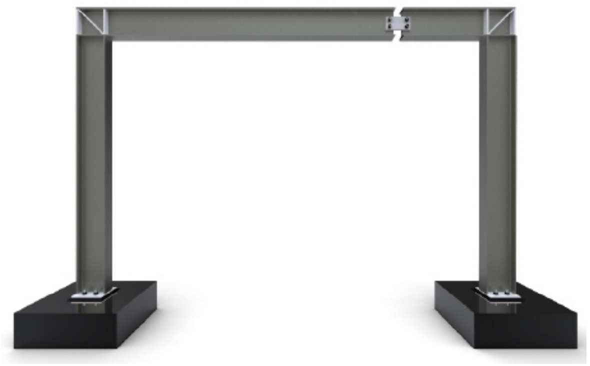
QUESTION TIME

Draw mathematical models of the structures that follow. Use Push Me Pull Me to verify your results.

a.



b.

c.

d.

e.

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QUESTION TIME

f.

g.