SIGN CONVENTION OF STRESS RESULTANTS

A quick guide to understanding
the sign conventions used in the
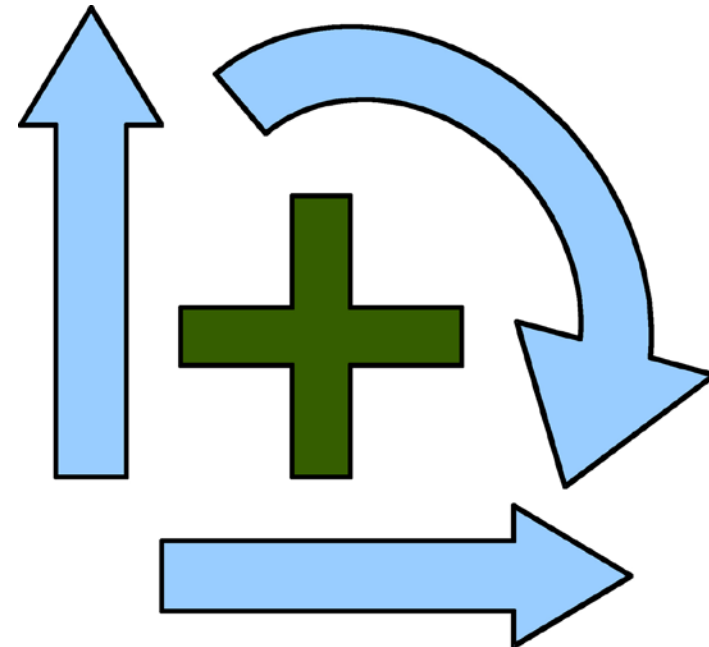Push Me Pull Me models

INTRODUCTION

Representing stress resultants graphically on line models is one of the most widely used features of communicating information in structural analysis.

Experienced structural engineers and analysts who have a deep qualitative appreciation of the influence of the applied loads on the line model can readily 'read through' and understand the information represented on the stress resultant diagram.

In general though, graphical representations of stress resultants without the use of a consistent sign convention can lead to misleading understanding which can have serious implications in the design and construction processes.

Since one of the objectives of Push Me Pull Me is to help students develop an intuitive understanding of structural behaviour, it is fundamental that Push Me Pull Me users become familiar with the sign convention used by the tool to represent each stress resultant, specifically bending moment, shear force and axial force.

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SHEAR FORCE DIAGRAMS

A shear force diagram (SFD) represents the magnitude and direction of the total shear force acting across any section of a beam. This shear force is the resultant of a set of applied forces on the beam in question and SFD shows how the beam responds to the applied load and how the latter is transferred to the foundations.

Consider a simply supported beam as shown opposite.

A vertical point force is applied somewhere along its span.

Isolate a part of the beam on either side of the applied force.

For this free body to be in vertical equilibrium, the load P is equalized by the two shear forces on either side of the free body.

This free body can be as big as the physical length of the whole beam.

Looking at the other side of the cut an equal and opposite shear force is present to maintain vertical equilibrium.

Finally to maintain vertical equilibrium, the Reaction force is equal and opposite to the corresponding shear force on the free body.

$$V_1 = R_1 \longrightarrow \boxed{P = R_1 + R_2} \longleftarrow V_2 = R_2$$
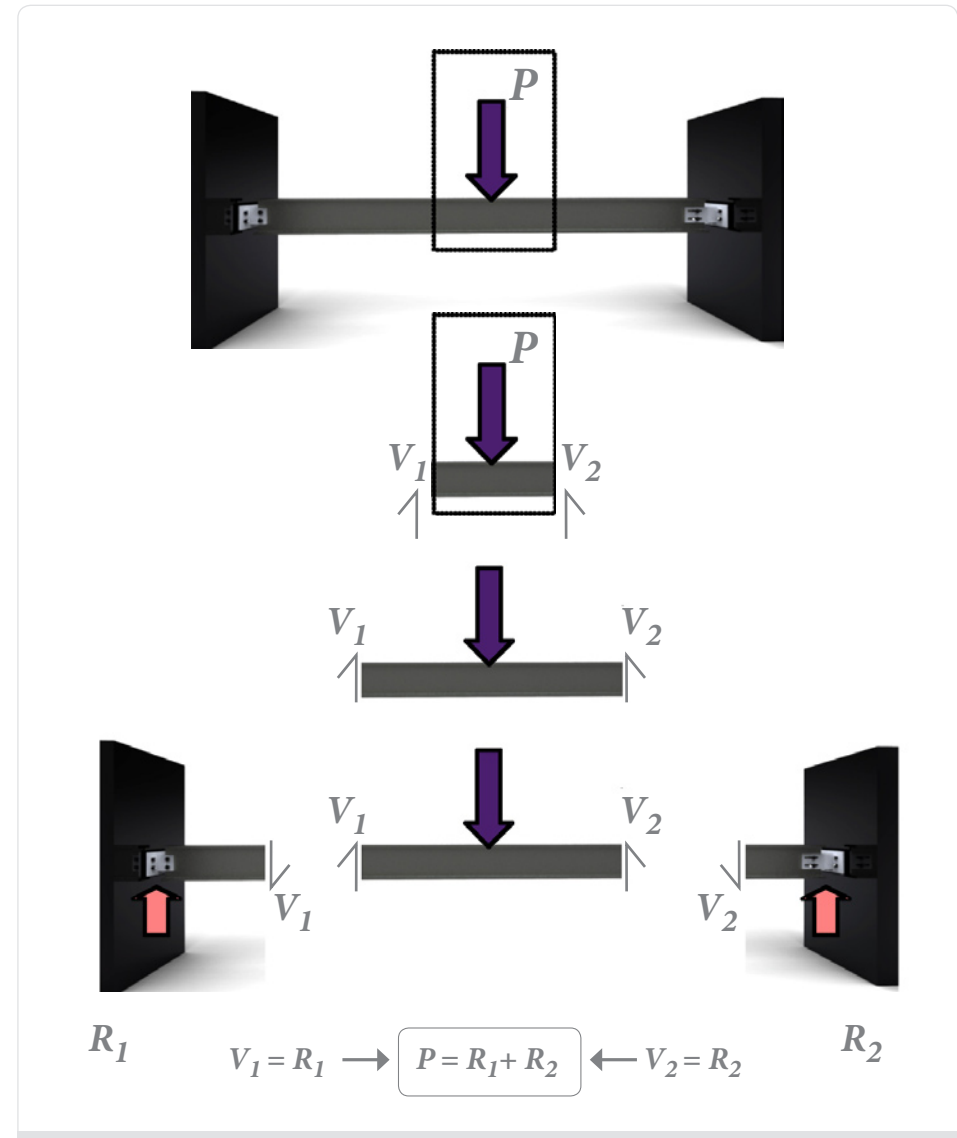
SHEAR FORCE DIAGRAMS: BEAMS

Shear force diagrams are plotted on the positive shear force side.

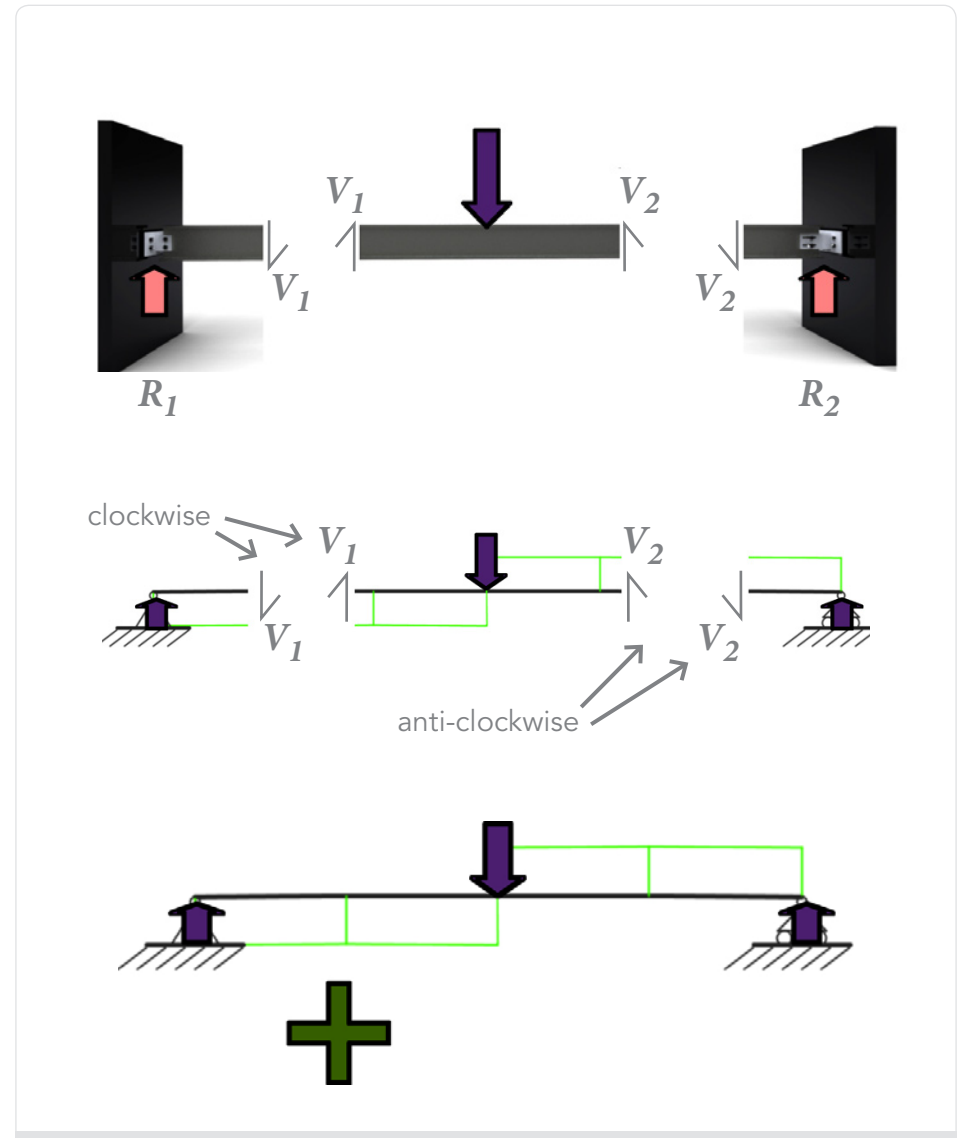This is defined by the sense of the shear force direction:

a) A clockwise shear force is taken as positive and an anti-clockwise shear force as negative.

b) A positive shear force is plotted on the underside of the line model.

NOTE:
Whether you plot the positive (clockwise) shear force on the below or above the beam is not a problem as long as you state this in the beginning.

Convention:

CLOCKWISE
POSITIVE

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SHEAR FORCE DIAGRAMS: FRAMES

The same convention rules apply for planar frames.

A clockwise shear force at any point along the structure is assumed positive.

For the examples in Push Me Pull Me, positive (clockwise) shear forces are plotted on the inside of the frame:

a) Beams: Positive plotted on the underside

b) Column on the left: Positive plotted on the right side.

c) Subsequent column(s) on the right: Positive on the left side.
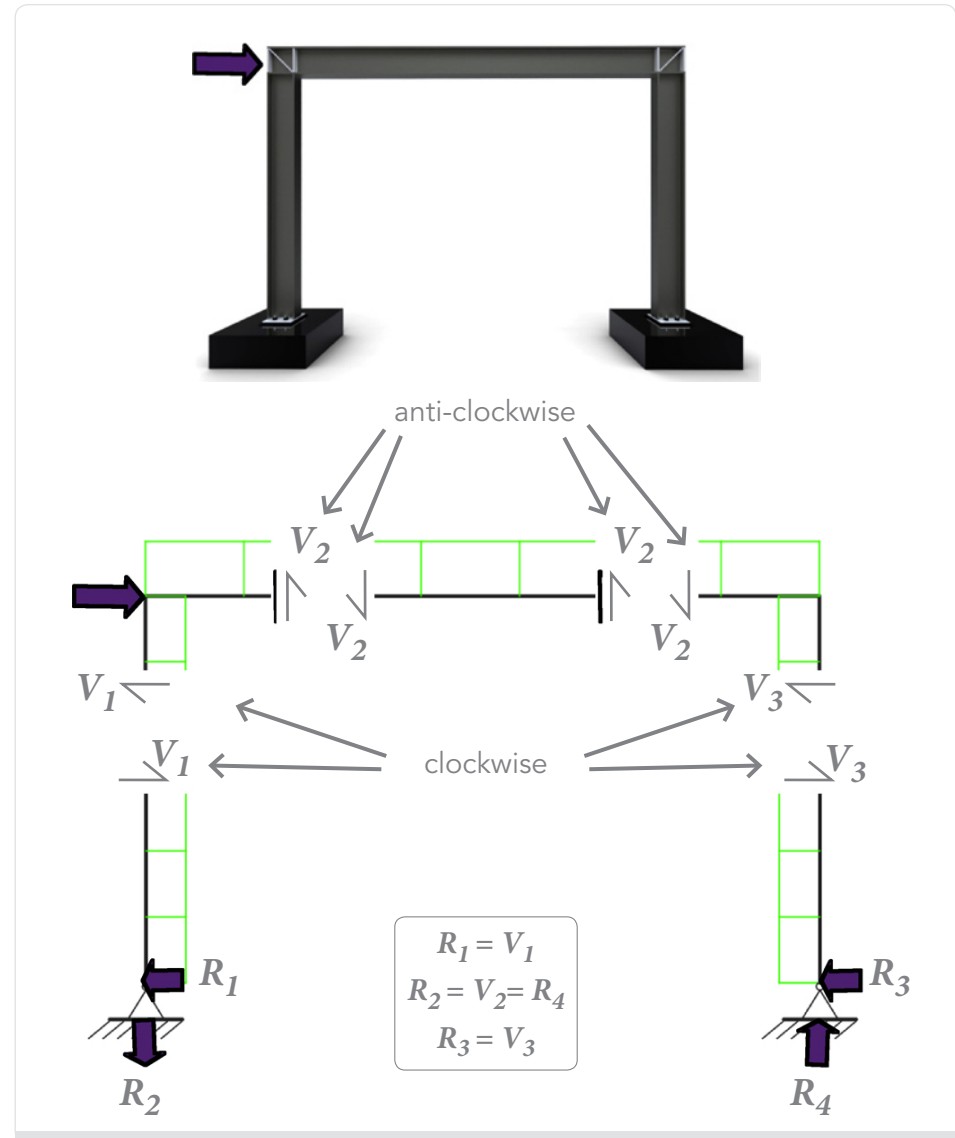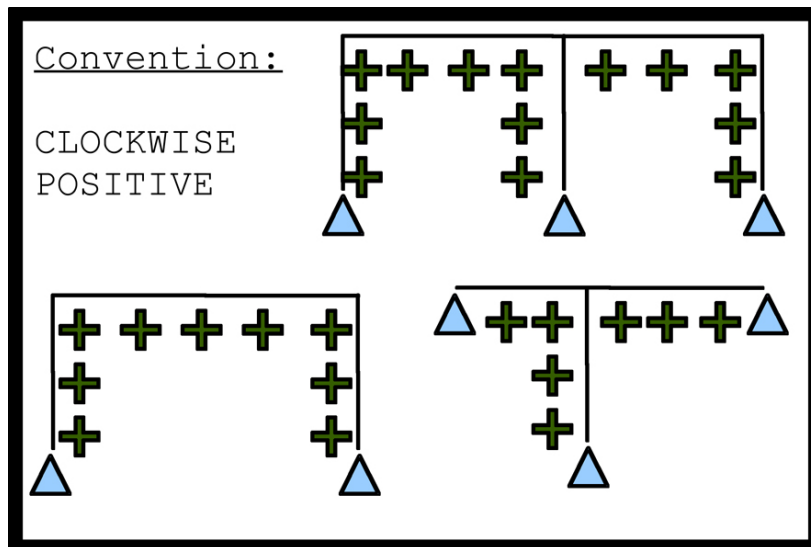
AXIAL FORCE DIAGRAMS

The axial force diagram represents the magnitude and type (compressive/tensile) force anywhere along the structure.
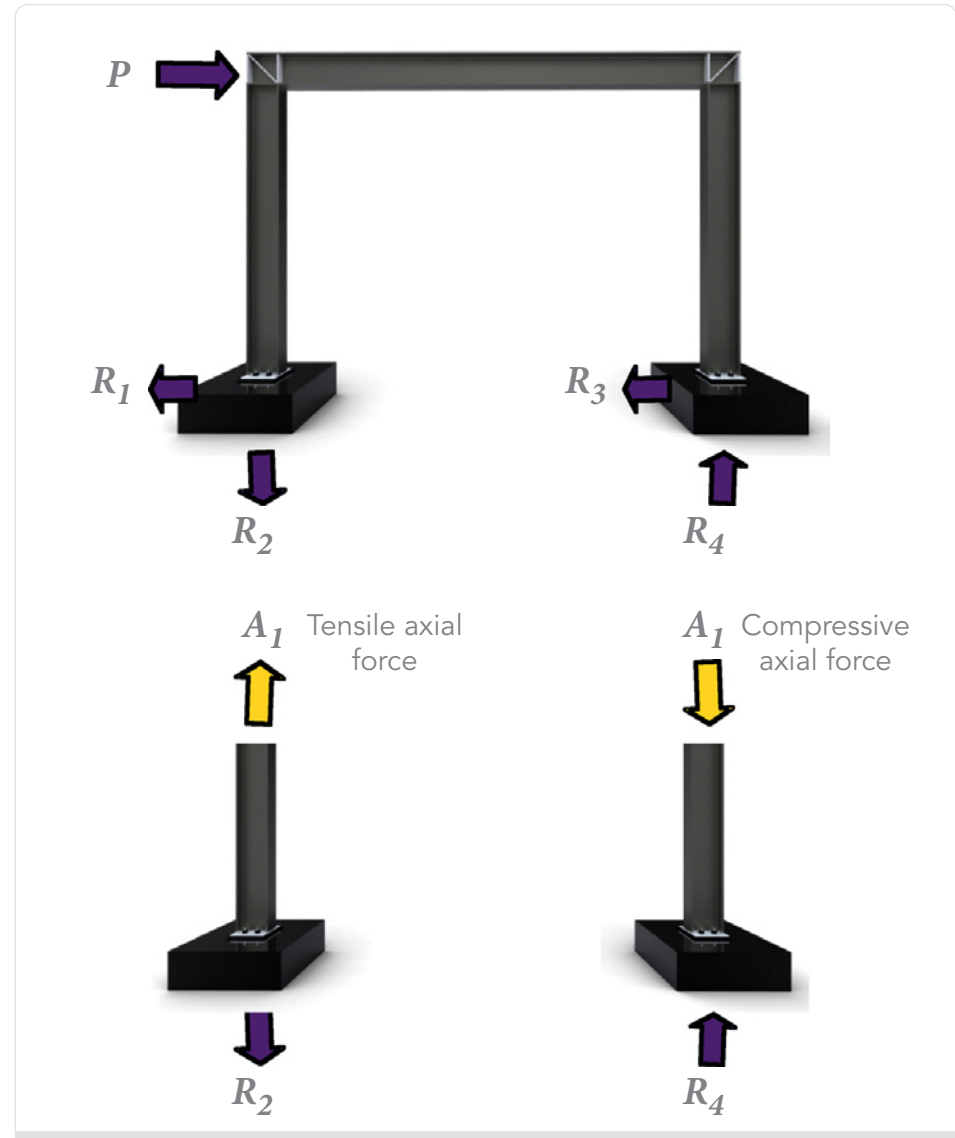
An axial force in a structural component is the resultant of applied loading as this is expressed as the summation of normal stresses along the axis of the component.

Consider the frame on the right with the lateral applied load. This loading as seen before causes downward reaction force on the left hand side support and an upward reaction on right hand support.

If the column on the left hand side is isolated at any height, a TENSILE (stretching) axial force will be present in order to keep the column in equilibrium. This is represented by an arrow pointing away from the member as shown opposite.

The magnitude of the resultant (axial) force is the equal to the downward reaction and opposite in direction.

Equally, looking at the column on the right, since the reaction force is upwards, the resultant in the column is COMPRESSIVE.

P

R_1 R_3

R_2 R_4

A_1 Tensile axial force A_1 Compressive axial force

R_2 R_4

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AXIAL FORCE DIAGRAMS

In all PmPm examples the convention for plotting the axial force diagram (AFD) is the similar to the convention of the shear force diagram

A compressive axial (resultant) force is taken as positive and it is plotted on the inside of a frame such that:

a) Beams: Positive plotted on the underside

b) Column on the left: Positive plotted on the right side.

c) Subsequent column(s) on the right): Positive on the left side.

$$R_1 + R_3 - P = 0$$
$$R_2 - A_1 = 0$$
$$R_4 - A_3 = 0$$
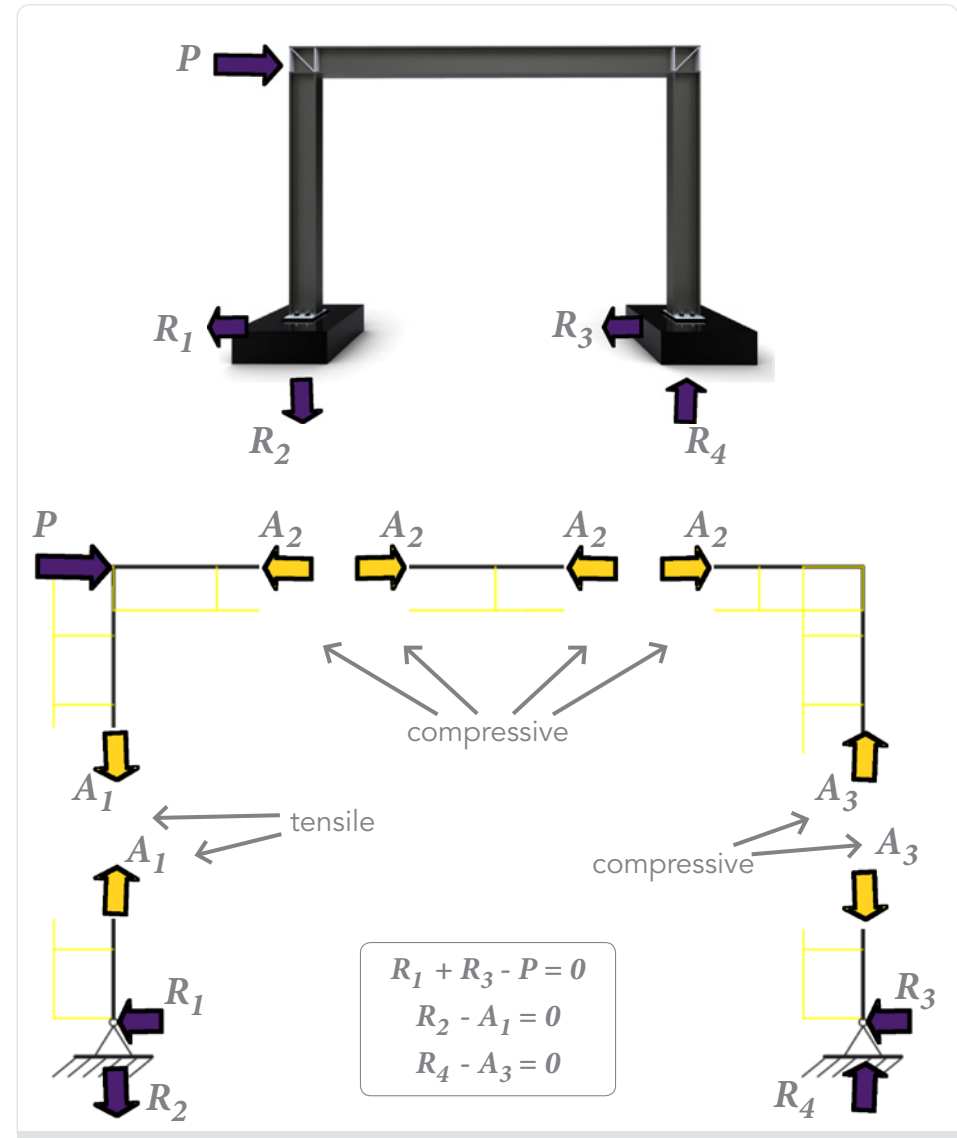
BENDING MOMENT DIAGRAMS

A bending moment diagram represents the magnitude and sense of bending in a structural component along a particular structure.

The bending moment is the resultant of an applied load case which causes a particular section of the structure to stretch on one side and contract on the other. This is caused by the development of corresponding tensile and compressive stresses in the section which are maximum at the respective edges and reduce linearly to zero at the neutral axis.

The bending moment is the couple represented by the resultants of the tensile and compressive forces multiplied by the perpendicular distance between them.

Considering the frame on the right and then isolating the left column from the support up to a point before to the top connection, a clockwise shear force is necessary for horizontal equilibrium. A tensile axial force vertically and an anticlockwise bending moment are necessary in order to balance the couple of the shear force and the horizontal reaction.

$$V_1 - R_1 = 0$$
$$A_1 - R_2 = 0$$
$$M_1 - V_1 x = 0$$
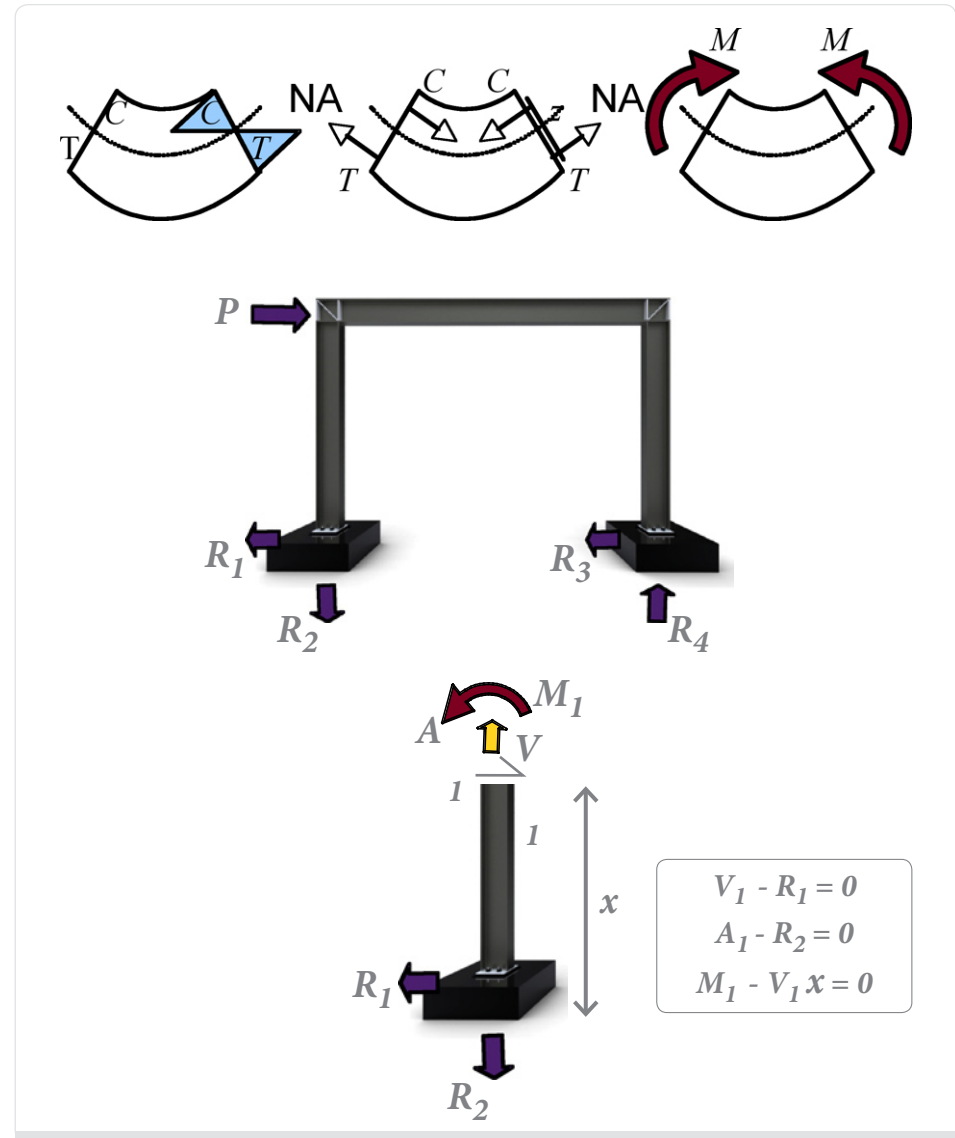
BENDING MOMENT DIAGRAMS

The bending moment diagram (BMD) is plotted on the tension side of the structural member.

The convention taken here is that tension inside is taken as positive as indicated opposite.

The structure opposite is seen below as 5 free bodies with the applied loads and the necessary resultants for balancing equilibrium (axial forces are not shown here for clarity).

Each free body must be in horizontal, vertical and rotational equilibrium, which dictates the sense of the bending moments at the cuts.