## Free Body Diagrams

A free body diagram (FBD) is a technique for identifying all the forces that act on a structure or on part of a structure. An imaginary 'cut' is made in the analysis model of the structure and the forces on the structure including those at the cut are identified. The principle of equilibrium can then be applied to the forces on the FBD. For example, Figure 1 shows an engineering model of a door frame and Figure 2(a) shows an analysis model of the lintel beam of the frame. This lintel model is the 'structure' to which the FBD concept is applied in Figure 2.

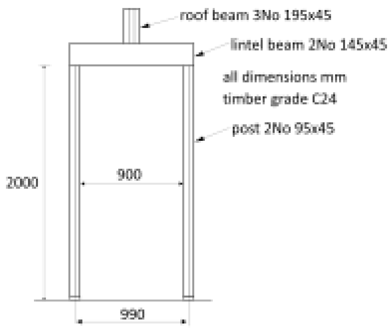


Figure 1 Door frame

**FBD for the whole structure**

Equilibrium analysis normally needs to start with a FBD of the whole structure separated from its supports.

***Simply supported lintel beam***

Figure 2(a) shows an analysis model of a lintel beam and Figure 2(b) shows the corresponding FBD for the beam separated from its supports.

For this type of free body diagram, one replaces each restraint with a corresponding force. The analysis model shows that there is a pin connection at the left-hand end. This means that the support is restrained vertically and horizontally. Therefore, it is possible to have a horizontal and a vertical force at this support as shown in the free body diagram. At the right end of the beam, the roller support is restrained vertically but not horizontally, therefore there can be a vertical force but no horizontal force - as shown.

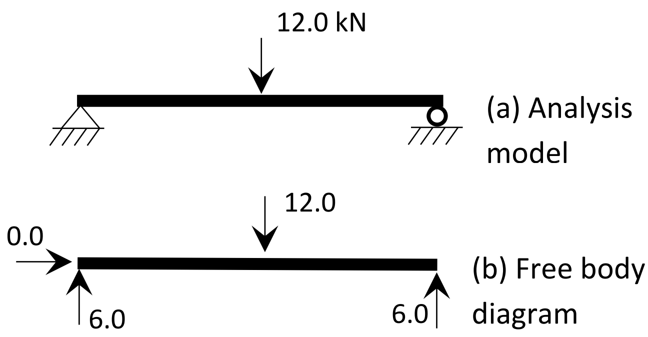


Figure 2 Lintel beam

***2 span continuous beam***

Figure 3(a) shows a 2-span continuous beam. The free body diagram, 3(b), has another vertical reaction force but in this case the values of the reactions are not so easy to calculate because the system is statically indeterminate.

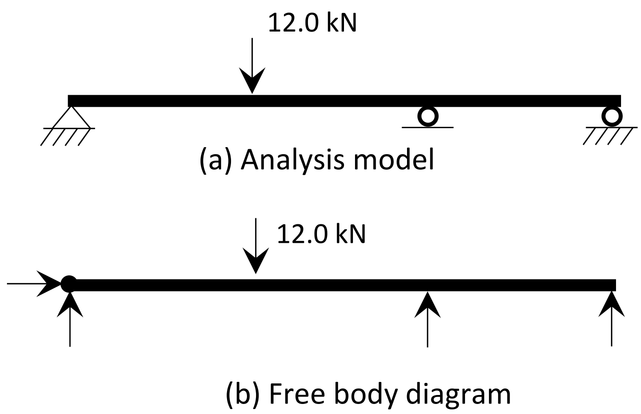


Figure 3 Continuous beam

**FBD at a joint with axial force members**

This is another common type of free body diagram used in nodal analysis of frames. Figure 4 shows Joint A for the truss used in the nodal analysis example. The joint is 'cut' out of the frame and the reaction force and the axial forces in the members are considered to act on the joint

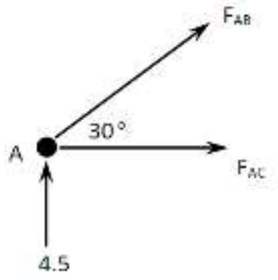


Figure 4 Joint A

**FBD with moment restraints**

Figure 5 shows an analysis model of a cantilever beam. The 'fully fixed' symbol for the cantilever support implies vertical, horizontal and rotational restraints. The free body diagram shows the reaction forces in this case. Corresponding to the rotational constraint is a support moment of 10.0 kNm.

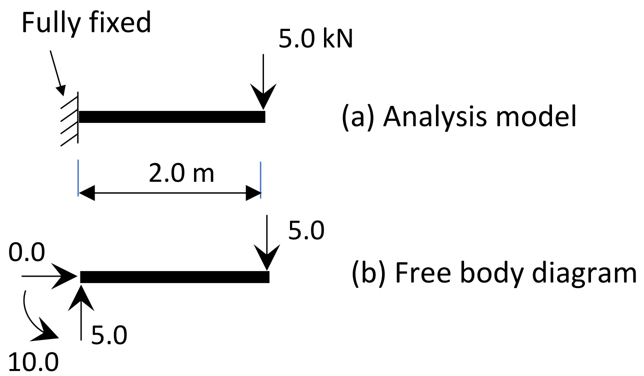


Figure 5 Cantilever beam

**FBD for part of a structure**

Figure 6 shows a FBD for part of a truss analysis from the Station Truss Application
Use of this FBD allows the axial force in the top chord to be easily calculated.

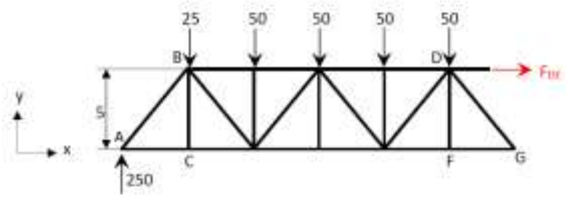


Figure 6 FBD for part of a truss

**FBD for a member with axial force and bending**

If a member of a frame is also in bending, then the moments and shears at the member ends need to be shown in a FBD for the members.
Figure 7 shows the forces at a cut in such a member at a joint.

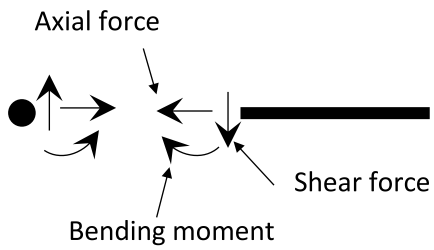


Figure 7 FBD for the forces at a joint including member bending

**Note**

Use of free body diagrams is a key strategy in the application of the principle of equilibrium. It is a 'thought experiment'. A real cut in a structure would mean that forces could not be transmitted. When you use the principle of equilibrium, a standard question is 'What FBD should I draw?'