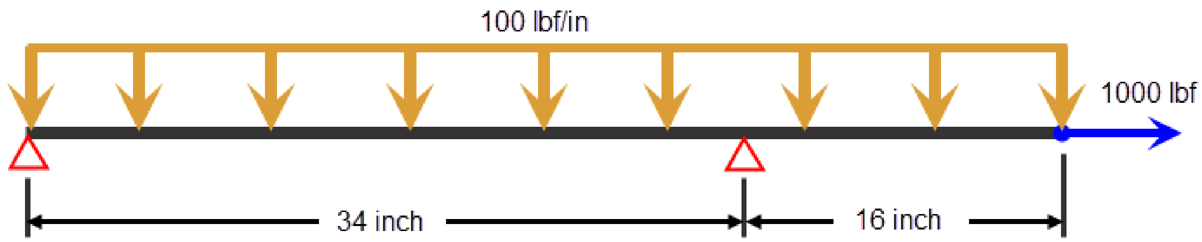
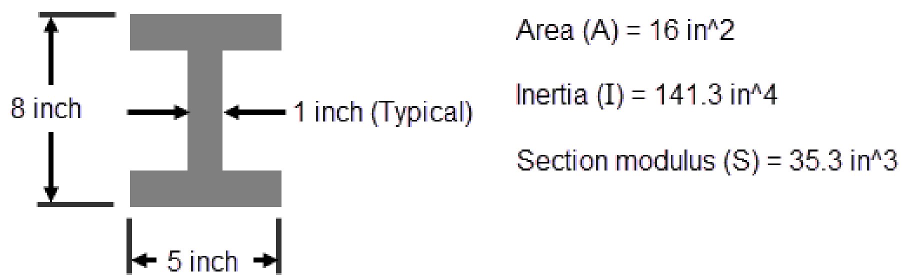
Extracting Forces and Moments from a Brick Model

Given: The following beam problem.

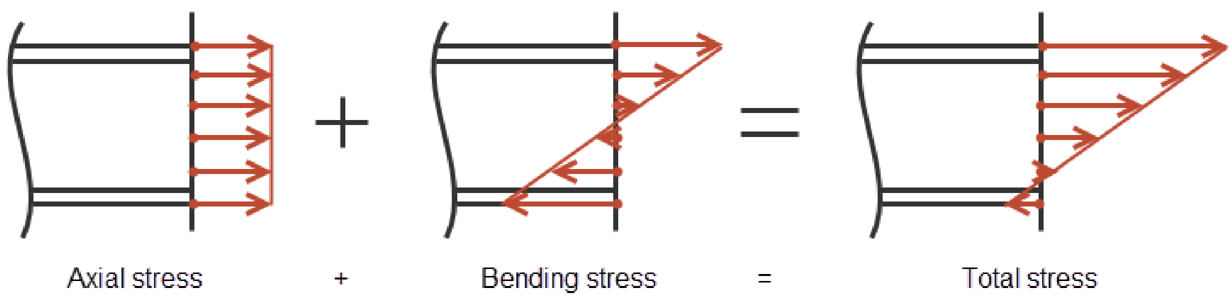




Find: The bending moment and axial force within the beam using a 3-D brick model.

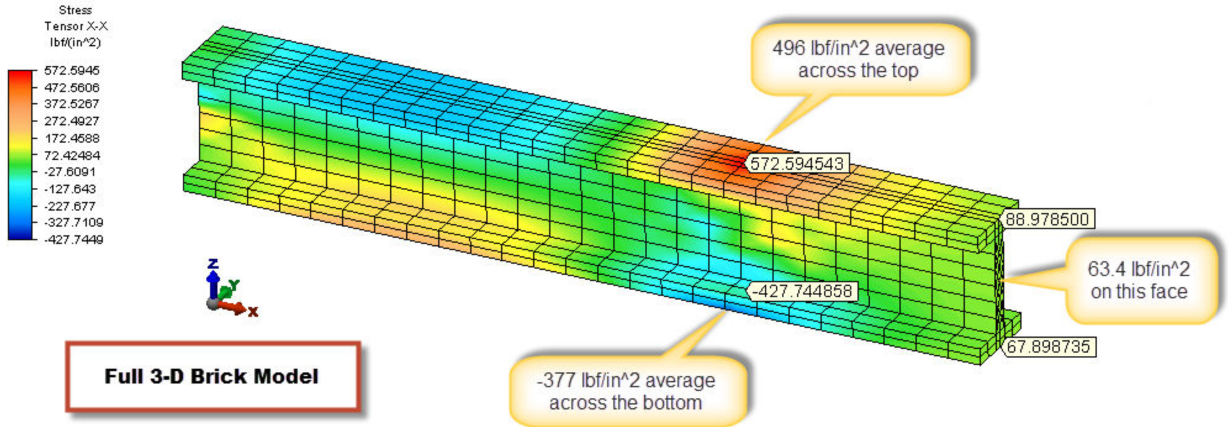
Solution: Because brick elements in Autodesk Simulation Mechanical do not provide results in terms of bending moments and axial forces[1], these can be approximated by using the tensor stresses[2]. From basic engineering statics, the following equations give the stress on the top and bottom fibers of the beam:

Axial stress + Bending stress = stress on top fibers
Axial stress – Bending stress = stress on bottom fibers



It can be seen from the image below[3] that the 3-D brick model includes many effects that are not possible to obtain with the traditional hand calculations[4]. For example:

3-D Brick Model	Hand Calculations
There is a small bending stress at the end of the beam; otherwise, the stress at the top and bottom would be equal.	The bending stress at the 1000 lbf end is zero.
The axial stress between the supports is non-zero. Since the beam is supported only on the neutral axis (to match the theoretical case), some of the axial force can "leak" into the span between the supports.	The axial stress between the supports is zero.
The stress across the width of the beam is not constant.	The stress across the width is considered to be constant.



The differences between the real world and the simplified hand calculations are trade-offs that engineers have been dealing with for a long time. For this exercise, let's use the average stresses across the width. Using the two equations above and entering the values gives[5]:

Axial stress + Bending stress = 496 psi

Axial stress – Bending stress = –377 psi

Adding the two equations gives:

2×Axial stress = 119 psi

which gives:

Axial stress = 60 psi

Bending stress = 436 psi

The axial force can be calculated from

$$\frac{\text{Axial force}}{\text{Area}} = \text{Axial stress}$$

which gives Axial force = 960 lbf (compared to the theoretical value[6] of 1000 lbf, a difference[7] of -4%). The bending moment can be calculated from

$$\frac{\text{Bending moment}}{\text{Section modulus}} = \text{Bending stress}$$

which gives Bending moment = 15390 inch·lbf (compared to the theoretical value[6] of 12800 inch·lbf, a difference[7] of 20%).

The archive of the model is contained in the file “I beam bending.zip”.

Notes:

1. Beam elements do provide bending moment and axial force results.
2. Tensor stresses – as used in the software – are stress components in a given direction. Because the axis of the beam is in the X direction, and both axial force and bending moments cause axial stress in the X direction, the XX stress tensor can be compared to hand calculations.
3. See the image “Brick tensor stress results.png” for the full resolution results.
4. Some of the differences can be seen visually from the image. Other results are “seen” only by using the equations to calculate the axial and bending stresses.
5. A simple arithmetic average was used to get the total stresses. Because the mesh size is not uniform, a more elaborate weighted average may produce better results.
6. See the results from the beam element model, “Beam axial results.png” and “Beam bending results.png”, for the theoretical results.
7. The difference between the calculated and the theoretical values was computed using (calculated – theoretical)/theoretical×100.

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