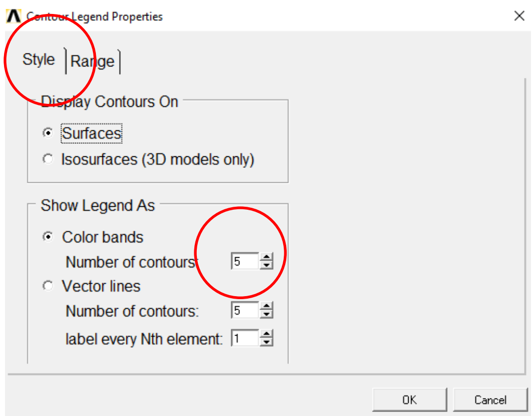
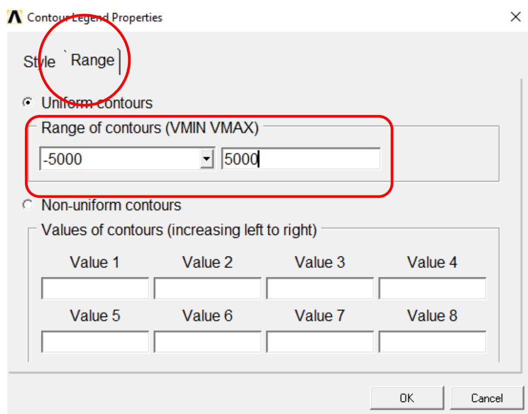
The following pages show the x-direction stress contour plots for “small”, “medium” and “large” elements for all 4 element types in HW7. Bending stress is in the x-direction. Remember, the BEAM elements **do** use the bending stress equation (My/I) to calculate bending stresses, but the 2D and 3D elements **do not.**

To adjust the contour (the color bar) – place curser over the color bar, right click, select Contour properties, then do as shown below. You will likely have to Replot (right click in the screen and select Replot, or type /REPLOT in the command line).

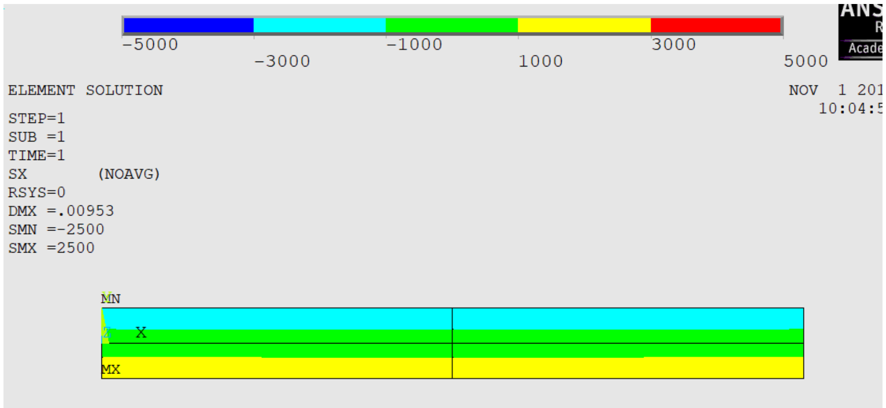




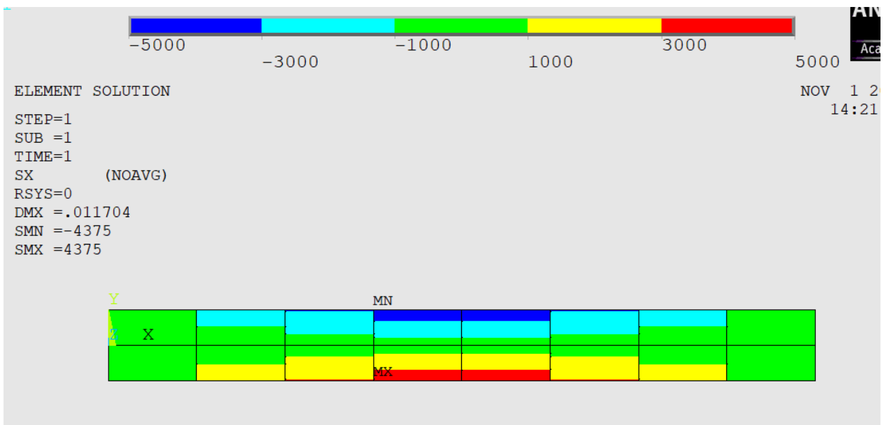
PRIMARY CONCLUSIONS:

- Very coarse mesh (very large elements) may produce poor results. But very small elements are not always better.
- Therefore, **a convergence study (with at least 2 different element sizes – and perhaps multiple element types) is always necessary to evaluate the validity of the model.**
- Beam elements work very well (better than other elements) for determining bending results. **Selecting appropriate elements is important.**
- And perhaps most importantly, **FEA modelers need to be keenly aware of Saint Venant’s Principle** (which is discussed below)

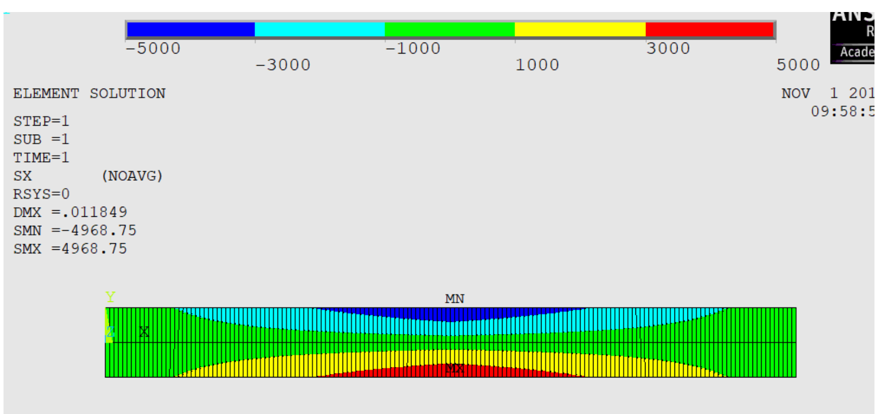
BEAM188 (linear line body)



BEAM188 (linear line body), 2 elements. Stress is half of theoretical bending stress.

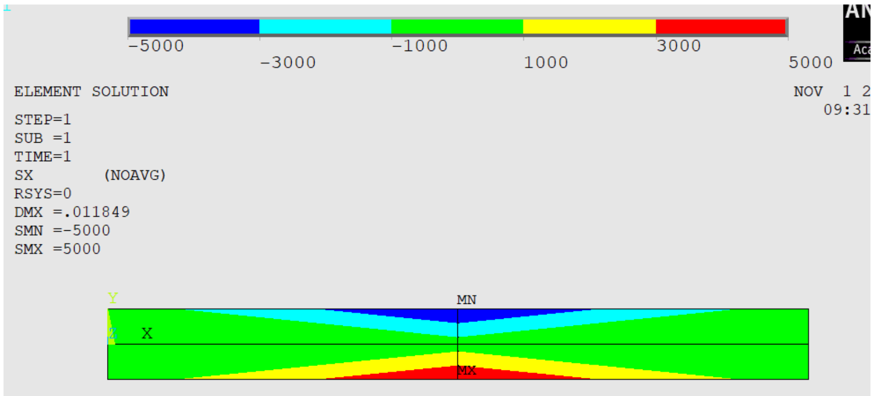


8 elements. Stresses nearly match theory.

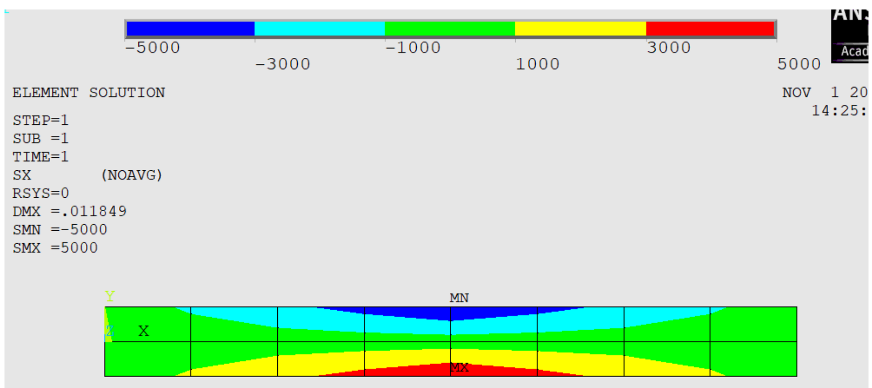


160 elements. Stress is within a few percent of theoretical bending stress.

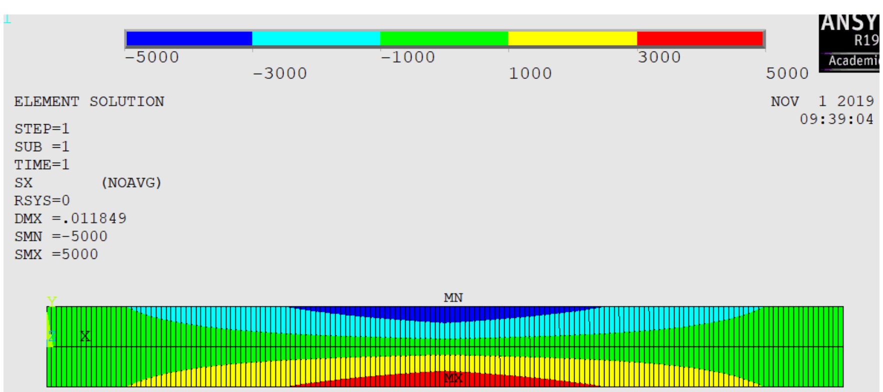
BEAM189 (quadratic line body)



2 elements. Maximum bending stresses match theory precisely although the contours do not. Comparing the results of 2 element models using BEAM188 (linear) and BEAM189 (quadratic) it is clear that the quadratic shape function (the stiffness matrix is derived from the shape functions) does a better job of determining nodal displacements and loads (including bending moments) than the linear shape function. However, both models demonstrate that they linearly interpolate the results between the nodes.

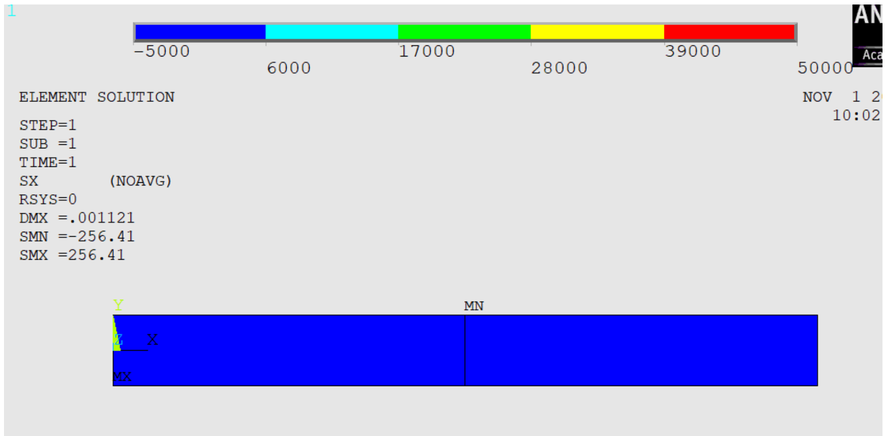


8 elements. Bending stresses match theory precisely.

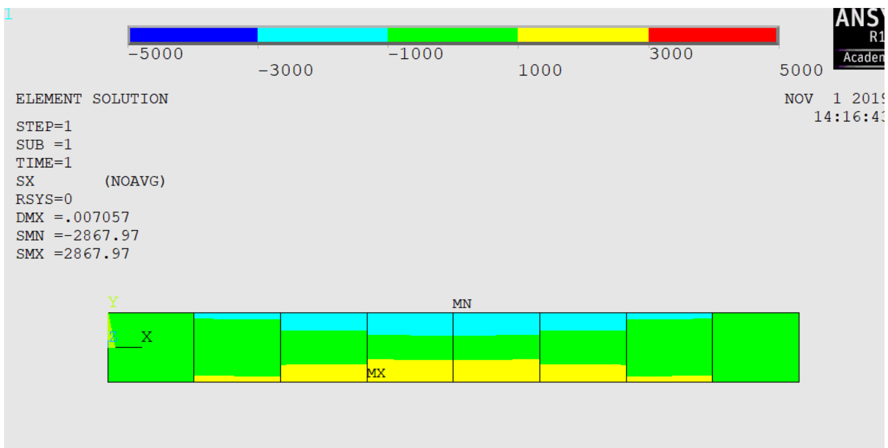


160 elements. Bending stresses match theory precisely.

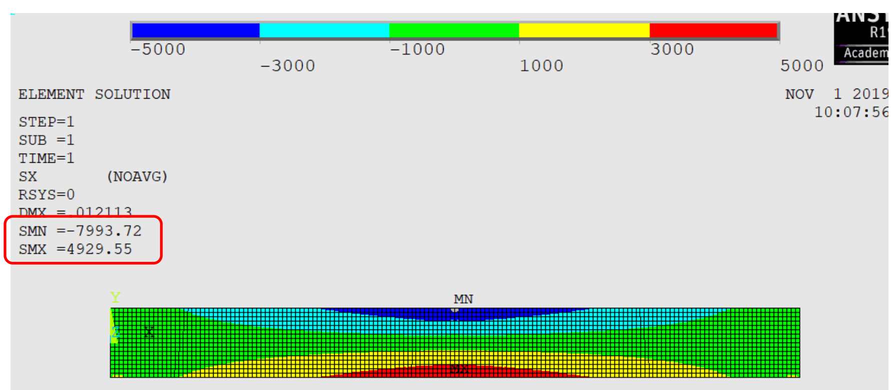
PLANE182 (linear 2D)



2 elements. Results are highly erroneous.

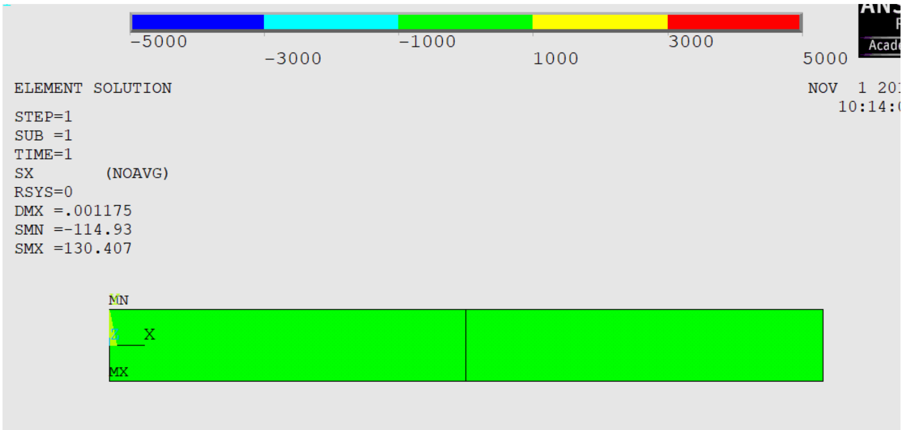


8 elements. Results are highly erroneous.

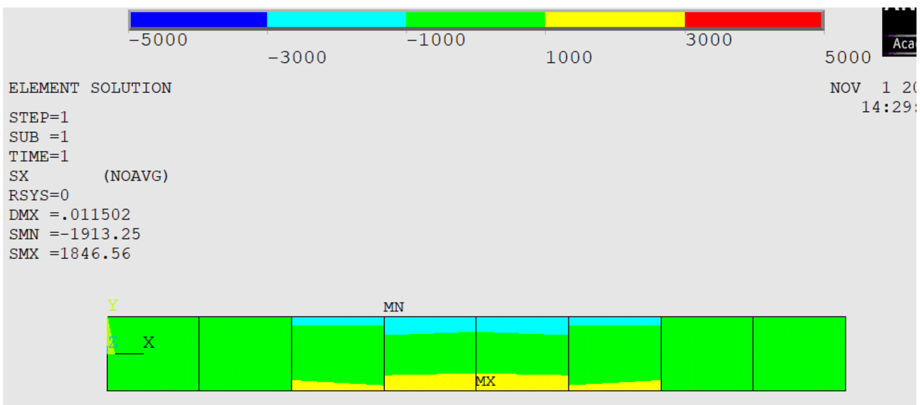


2560 elements. The stress contour compares well with theory. However, the maximum and minimum stresses were significantly different. Why?

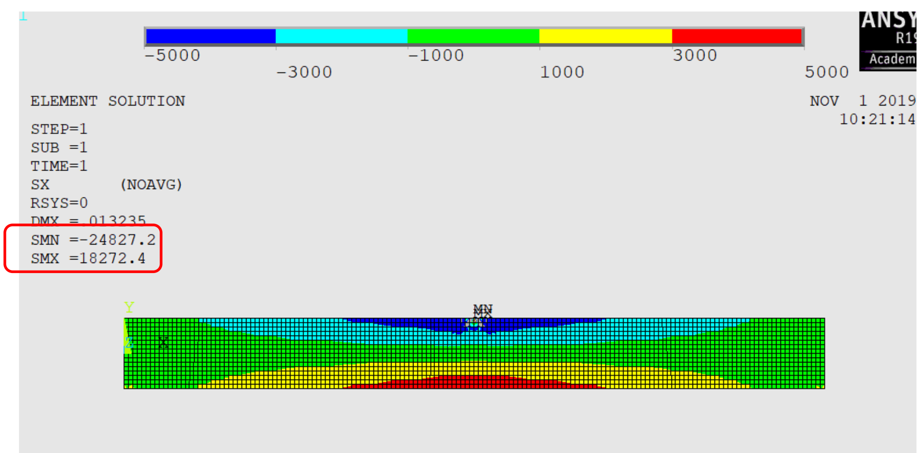
SOLID185 (linear 3D brick elements)



2 elements. Results are highly erroneous.



8 elements. Results are highly erroneous.



30,720 elements. The stress contour compares well with theory. However, the maximum and minimum stresses were significantly different. Why?

You may have noticed that for the 2D and 3D results, the maximum tension and maximum compressive stresses **did not match** beam bending theory; even with fine mesh (small elements). However, you may also have noticed that the contour plots with small elements, **did match** beam bending theory quite well. Conclusion? The maximum and minimum stresses were not associated with bending! If you look closely at your results, you may have noticed that the extreme stresses occurred at the load application point. That is because the entire force was applied to a single node (for the 3D model, the load was applied to 2 nodes). Conclusion: **FEA does not handle point loads well.** Why did the BEAM elements not exhibit this behavior?

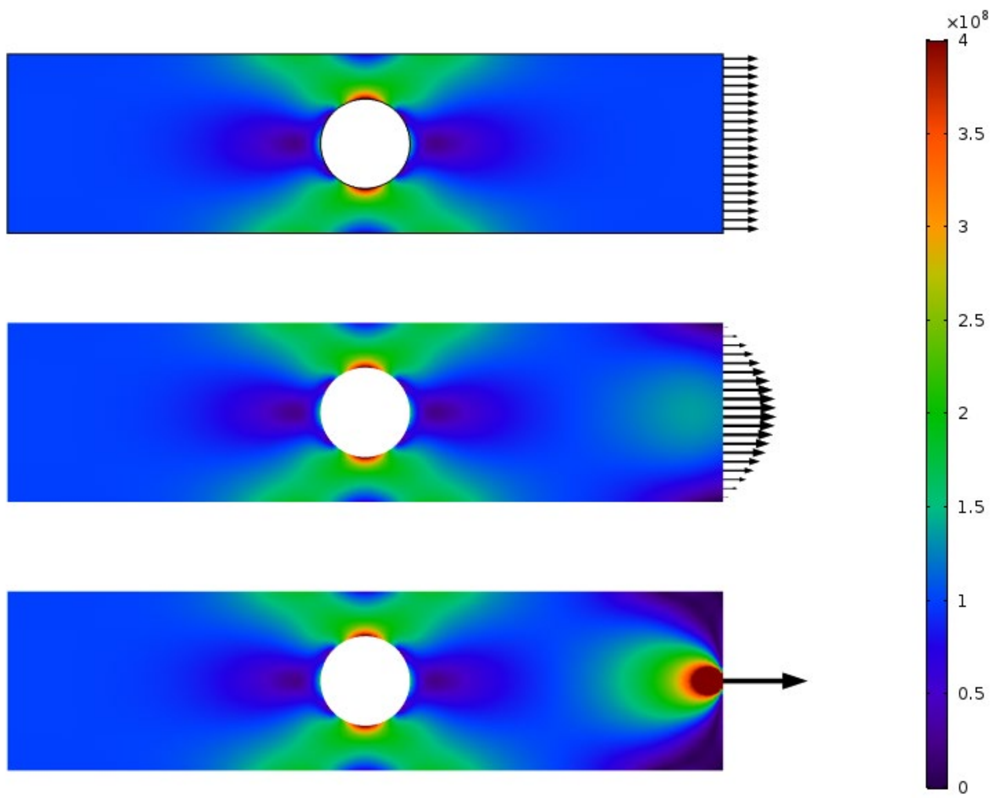
In the 19th century (long before FEA), Adhémar Jean Claude Barré de Saint-Venant, a French elasticity theorist, expressed as follows what is now referred to as the Saint-Venant Principle:

... the difference between the effects of two different but statically equivalent loads becomes very small at sufficiently large distances from load.

[Wikipedia]

In other words, if you are not worried about local effects, ignore them. If you are, then you need to be very careful in modeling them appropriately, which may be very difficult or impossible.

Saint-Venant's Principle is clearly demonstrated in the 3 different loading conditions below. The stresses near the load application vary substantially, but far from the loading the stresses are the



same:

https://www.comsol.com/blogs/applying-and-interpreting-saint-venants-principle/