Analysis of Boundary Conditions in ANSYS APDL

Computer Homework 4

MEMS1047, Finite Element Analysis

Dr. Patrick Smolinski

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Seth Strayer

Introduction:

The aim of this homework was to examine the effect of boundary conditions by doing a plane stress finite element analysis of the problems shown in Figures 1 and 2, below.

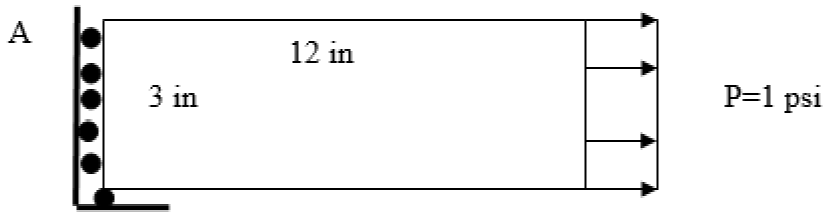

Figure 1 – Problem A

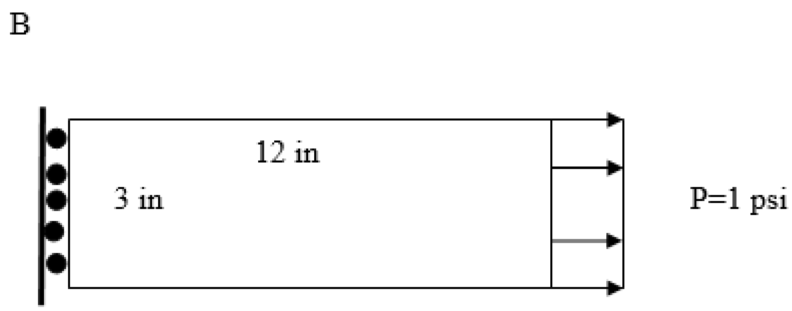

Figure 2 – Problem B

We note that in both problems, the beam is constrained by roller supports. I.e., the displacement in the x-direction, u_x, is equal to zero at every point. For Problem A, the bottom left node is constrained in both the horizontal and vertical (x and y, respectively) directions. I.e., at this node, $u_x = 0$, $u_y = 0$. We will use unit thickness, E = 29e06 psi and Poisson's Ratio, υ, of 0.25. We will analyze each of the above problems and, considering axial stress, σ_{xx}, comment on the differences in results.

Problem Statement:

As stated above, we would like the examine the effect of different boundary conditions and comment on how σ_{xx} changes in each case. For Problem A, the model is constrained in the x-direction at every point and constrained in both the x and y directions at the bottom node. For

Problem B, the model is only constrained in the x-direction. Before proceeding, we note that due to the lack of boundary conditions in the y-direction, APDL may have issues when running the solution. I.e., we suspect that there are insufficient boundary conditions for Problem B. It is not requested, but we will also analyze a third case, say Problem C, where there is a fixed support at the left edge of the beam. I.e., at every point, $u_x = 0$, $u_y = 0$. See Figure 3 below for a illustration of this problem.

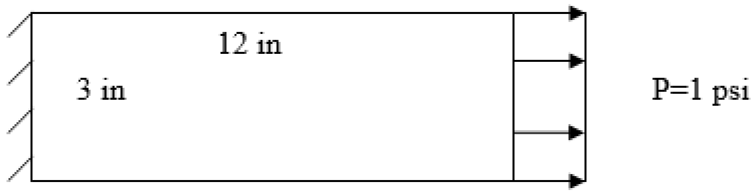

Figure 3 – Problem C – Fixed Support

Note that in each case, we expect different results for σ_{xx}.

<u>Results:</u>

Let us first consider the loading scenario for Problem A as shown in Figure 4, shown below.

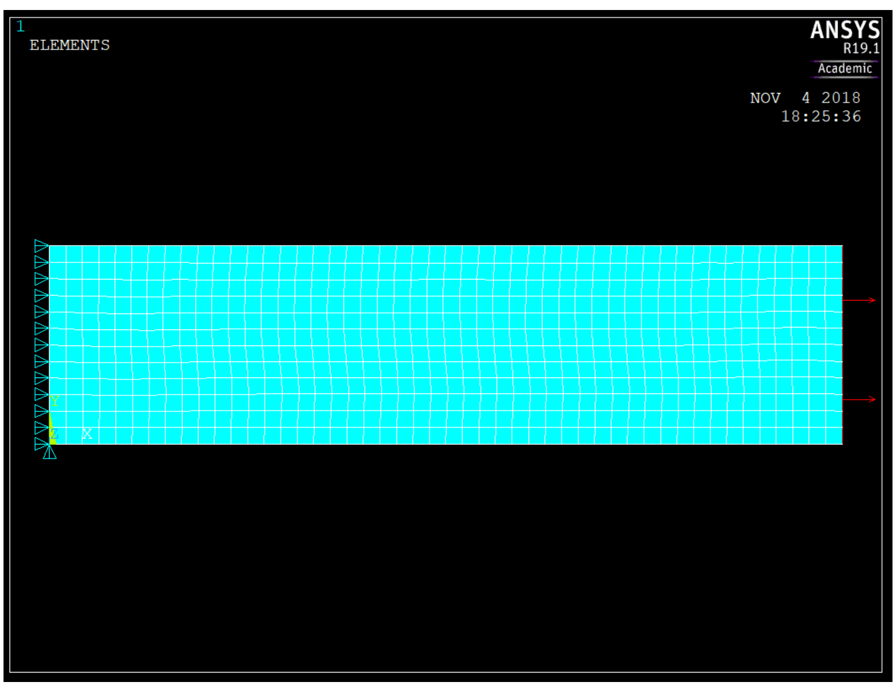

Figure 4 – Loading Scenario for Problem A

We see that the model is constrained in the x-direction at every point, i.e., $u_x = 0$, and at the bottom left node, it is constrained in both the x and y directions, i.e., at this node, $u_x = 0$, $u_y = 0$. We have applied a pressure load of $P = 1$ [psi] at the free edge. A contour plot displaying the distribution of σ_{xx} for this problem is shown in Figure 5.

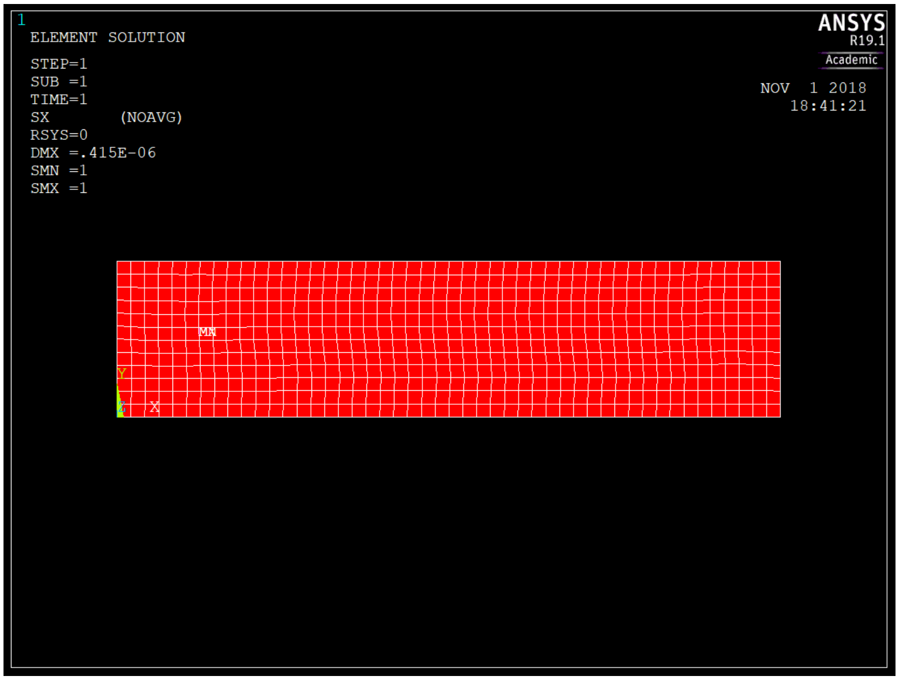

Figure 5 – Axial Stress Distribution for Problem A

We note that, in this case, σ_{xx} is constant, namely,

$$\sigma_{xx} = 1\, psi \tag{1}$$

This is the value we expect given the specified loading conditions. There are no stress concentrations due to the boundary conditions in this case. Now let us consider the loading scenario for Problem B as shown in Figure 6 on the following page.

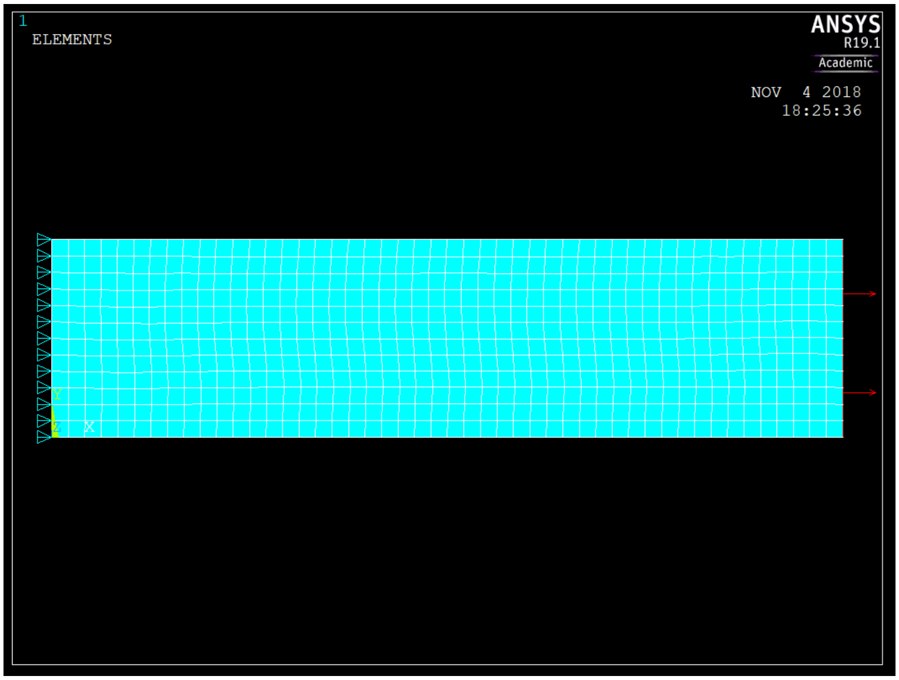

Figure 6 – Loading Scenario for Problem B

We see that the model is constrained in the x-direction at every point, $u_x = 0$. There is no boundary condition for the y-direction in this case. When we attempt to solve this problem, we receive the following error message from the APDL Output Window:

```
*** ERROR ***                               CP =        5.188    TIME= 18:26:08
There is at least 1 small equation solver pivot term (e.g., at the UY
degree of freedom of node 204).  Please check for an insufficiently
constrained model.
```

Figure 7 – Error Message for Problem B

This error message is telling us that our model is insufficiently constrained. This is because we have no boundary condition for the y-direction. For this problem, the model could essentially “fly off into space”. Thus, we conclude that in order to solve the model, we would need to add a boundary condition for the y-direction. Now let us consider the loading scenario for Problem C as shown in Figure 8 on the following page.

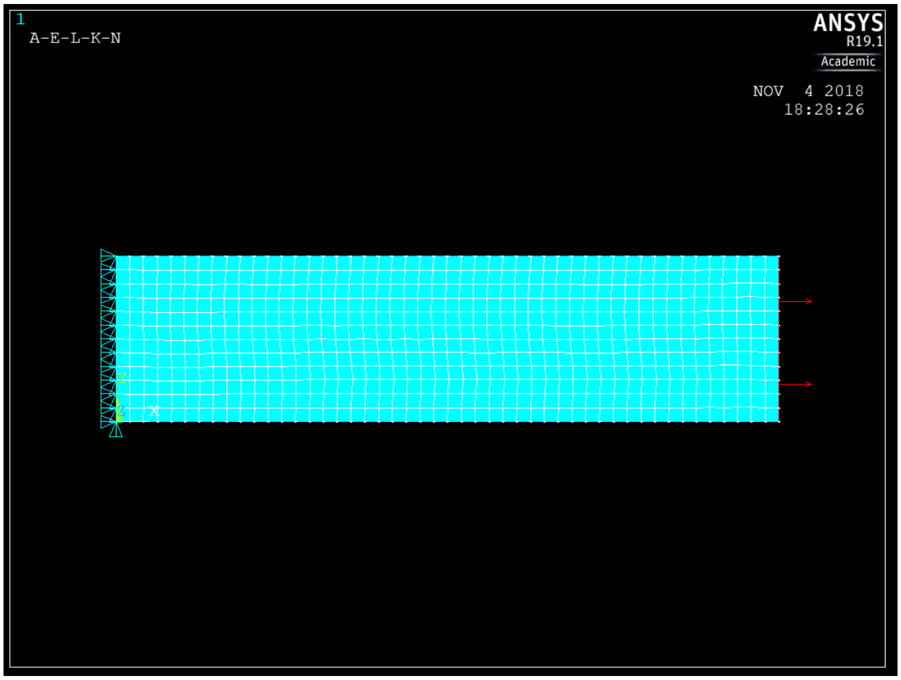

Figure 8 – Loading Scenario for Problem C

This problem models a fixed support, i.e., u_x = 0, u_y = 0 at every point. A contour plot displaying the distribution of σ_{xx} for this problem is shown in Figure 9, below.

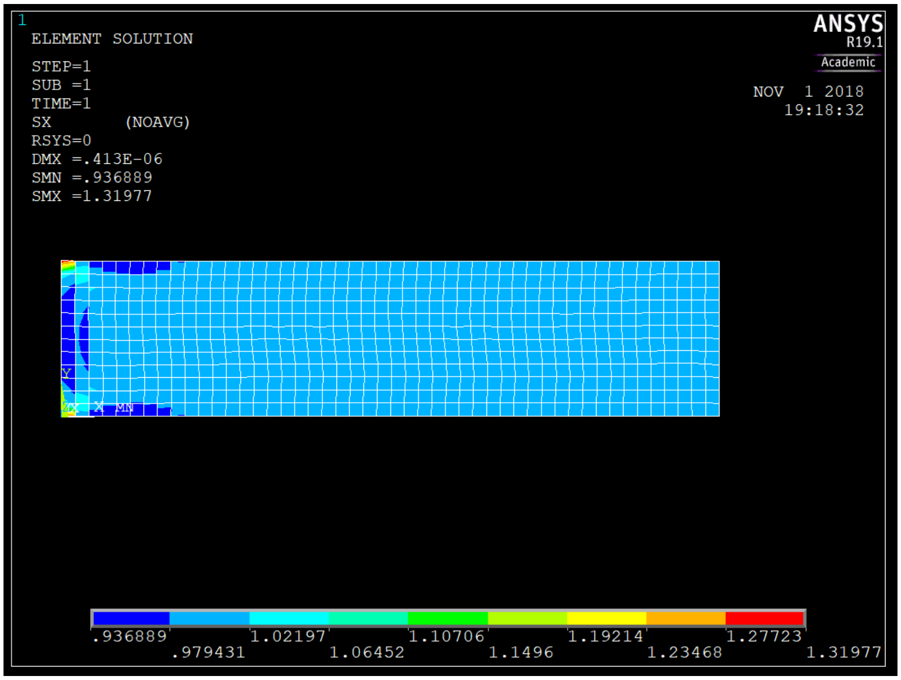

Figure 9 – Axial Stress Distribution for Problem C

We see that in this case, we receive an uneven stress distribution (i.e., stress concentrations) caused by our boundary conditions. There is a maximum stress of

$$\sigma_{xx,max} = -1.31977 \, psi \tag{2}$$

which is greater than the average, theoretical stress of σ_{xx} = 1 [psi], a result given by equation 1. Perhaps, in this case, the model is over-constrained.

Discussion:

We note that, as expected, σ_{xx}, differs in each case and is dependent on the boundary conditions. Problem A gives us the expected theoretical axial stress, Problem B is under constrained and thus not solvable, and Problem C gives us singularities due to the boundary conditions. Looking at our results, we conclude that Problem A gives us the most accurate results for the given loading scenario.