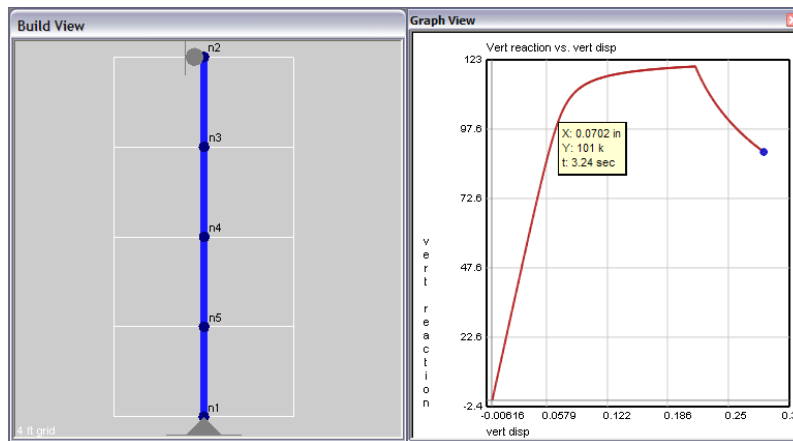


Inelastic vs. Elastic Buckling of Steel Columns

This exercise concerns the buckling behavior of columns. It compares the elastic and inelastic buckling of three AISC wide flange columns using the AISC formulas and using Arcade. The model has the following characteristics:

- Both ends are pinned, and braced against sidesway.
- The unsupported length for both strong and weak axis buckling is 16 feet.
- The material is grade 50 steel.
- The column is modeled as four Beam-2 elements, the nodes are positioned on a parabolic trajectory corresponding to an out-of-straightness of $L/1500$ (0.128 inches off the line connecting the ends of the column).
- The column is loaded by imposing a downward displacement at the top of the column
 - That way, the column does not suddenly collapse when the buckling load is exceeded.
- The vertical axis of the graph plots the reaction at the base of the column, the horizontal axis of the graph plots the vertical displacement at the top of the column.



The three column sections are as follows:

Sections	Area (in ²)	I _y (in ⁴)	Z _y (in ³)	r _y (in)
W14x808	237	5510	927	4.82
W18x65	19.1	54.8	22.5	1.69
W18x35	10.3	15.3	8.06	1.22

Part 1: Comparison of elastic buckling.

For each of the three columns, do the following:

- Calculate the theoretical Euler buckling load, using the Euler formula.
- Use Arcade to analyze each column for elastic buckling. The analysis requires the following steps:
 - Set section properties.
 - Click *Build > Elements > Beam-2*.
 - In the table in the upper window, type in the appropriate values of A, I_{xx}, Z_{xx} for each element. Use the weak axis values for the sections, since the column can buckle on weak axis.
 - Click *Simulation Start*.
 - After the graph shows that the column has buckled, click *Simulation > Stop*.

The analysis takes about almost a minute for the largest column. The displacement is applied slowly to reduce dynamic effects.

- On the graph, right click on the point where the graph first deviates from its initial linear trajectory, a pop-up window will appear, showing the load and displacement at that point (See the figure above).

This point is where the column begins to lose stiffness, and so marks the beginning of buckling. In most real columns, the transition to a buckled state is not crisply defined. Do your best to estimate this point from the graphs, realizing that answers may vary by a few percent. The graph of the largest column takes a different shape, where the buckling load is more obvious.

Make a table summarizing the results, including the following:

- The section name.
- The theoretical Euler load.
- The elastic buckling load predicted by Arcade.
- The percentage difference between the two the Euler buckling load and the buckling load predicted by Arcade, positive when the Euler load is larger.

Part 2: Comparison of inelastic buckling.

In inelastic buckling, parts of the section yield before buckling occurs. This partial yielding occurs because of residual compression stresses in the section

The AISC code accounts for the possibility of inelastic buckling with formulas E2-2 and E2-3. E2-3 applies to columns which are slender enough to avoid inelastic buckling, the stresses are never high enough to cause yielding. E2-3 gives results which are 0.877 times the Euler load.

The 0.877 is a safety factor to account for the fact that real columns typically buckle below the theoretical Euler load because of out-of-straightness and other imperfections.

In less slender columns, formula E2-2 applies. This formula makes a smooth transition from the Euler-proportional curve of E2-3 where the column slenderness parameter λ_c

equals 1.5, to the “squash load” of the column, defined as the yield stress times the cross section area, at the point where the slenderness parameter equals zero.

In the following analysis you’ll compare inelastic buckling as predicted by the AISC formulas and by Arcade.

For each column, do the following:

- Calculate P_n according to the AISC formulas E2-1, E2-2, and E2-3.
- Calculate the inelastic buckling load using Arcade. The analysis requires the following steps.
 - Set the program to account for inelastic buckling.
 - Click *Settings > Advanced*.
 - Check the box labeled *Reduce I_{xx} with axial load*.
 - Set section properties.
 - Click *Build > Elements > Beam-2*.
 - In the table in the upper window, type in the appropriate values of A , I_{xx} , Z_{xx} for each element.
 - Reset Graph Y Axis.
 - Click *Graphing > Edit Graph*.
 - In the upper window, in the *Y Axis* area, click the *Reset* button.
This will automatically rescale the graph axis according to the current data.
 - Click *Simulation > Start*.
 - After the graph shows that the column has buckled, click *Simulation > Stop*.
 - Determine the buckling load as in Part 1.

Summarize your results in a table including the following for each column:

- The section name.
- The column slenderness parameter λ_c .
- The nominal strength P_n per AISC formulas E2-1, E2-2, and E-3.
- The inelastic buckling load predicted by Arcade.
- The percentage difference between P_n and the inelastic buckling load predicted by Arcade, positive when P_n is larger.
- The elastic buckling load predicted by Arcade.
- The percentage difference between the elastic buckling load and the inelastic buckling load predicted by Arcade, positive when the elastic buckling load is larger.

Note that the difference between the elastic and inelastic buckling loads decreases significantly as the column becomes more slender.