An important part of your K’NEX truss design is the utilization of tension and compression failure models.

After you have modeled your structure in SAP2000 and determined the force in each member, failure model can help you predict the ultimate capacity of your structure. Therefore, we should discuss failure model for both tension and compression.

One simple mathematical model for predicting compression failure is the Euler buckling model:

\[ P_{cr} = \frac{\pi^2 EI}{KL^2} \]

where \( P_{cr} \) is the critical load for the column, \( E \) is the modulus of elasticity, \( I \) is the moment of inertia, \( K \) is the effective length factor, and \( L \) is the length of the column.

If the end supports are considered pin connections, then \( K = 1 \).

For our K’NEX rods, we have estimated the cross-sectional area of a K’NEX rod and found that:

\[
I = 8.8 \times 10^{-5} \text{ in}^4 \\
E = 377 \text{ ksi}
\]

Therefore, the Euler buckling force for a K’NEX column can be estimated as:

\[ P_{cr} = \frac{\pi^2 EI}{L^2} \]

Example: Estimated the critical force in a red K’NEX rod. Assume that \( L = 6 \text{ in} \) (includes the length of the rod and the spacing of the connectors).

\[
P_{cr} = \frac{\pi^2 (377,000\text{ psi} \times 8.8 \times 10^{-5} \text{ in}^4)}{(6\text{ in})^2} = 9.1 \text{ lb}
\]

Example: Estimated the critical force in a yellow K’NEX rod. Assume that \( L = 4.25 \text{ in} \) (includes the length of the rod and the spacing of the connectors).

\[
P_{cr} = \frac{\pi^2 (377,000\text{ psi} \times 8.8 \times 10^{-5} \text{ in}^4)}{(4.25\text{ in})^2} = 18.1 \text{ lb}
\]

Why does the yellow K’NEX rod have a larger critical force than the red K’NEX rod?

- Decrease \( L \) increase \( P_{cr} \)
- Increase \( L \) decrease \( P_{cr} \)

Unlike the compression failure, a tension failure will probably not occur in the K’NEX material. It is more probable, that the K’NEX rod to pull out of the K’NEX connector up tension force.

To develop an understanding of tension failure in K’NEX rods and connector an experimental failure analysis should be performed.
Project #1 – K’NEX Truss

- Consider the following procedure for estimating tension failure in K’NEX.
- For a given connector, (in case a yellow connector), experimental measure the force required to pull a rod out of the connector.
- Fix the connector and attached a bucket of sand to the rod
- Determine the weight of sand required to pull-out the rod from the connector.

One difference from the compression model is that the tension model is based on experimental data not a mathematical model.
Therefore, you should probably perform numerous tests and take an average value for your tension failure limit.

To predict the ultimate load capacity of your truss take advantage of the fact that the structure is considered linear-elastic and use the principle of superposition.

Does the ultimate load predict change if we added an additional member CE that bisects the original member BD?
Project #1 – K’NEX Truss

Design Strategy
- Develop several conceptual designs
- Model each design in SAP2000 and determine the member forces due to a unit load
- Using the results of the SAP2000 analysis apply the failure models and predict ultimate load
- Compute the structural weight and cost
- Compute the SWR
- All design decisions should be based on increasing the SWR

Project #1 – K’NEX Truss

Apply Design Strategy to K’NEX Truss
- For the K’NEX truss structure shown in Figure 1, predict the strength-to-weight ratio (SWR) and estimate the cost in K’NEX dollars.
- Assume the structure is co-planar and linear-elastic and that the displacements are small such that the principle of superposition may be applied.
- Apply a load of ½ at the top of the structure (the red connector).
- Assume that there are two identical coplanar trusses that form the 3-D structure
- Assume pinned supports.
- Let the distance between joints for a yellow rod be 4.25 in. Also, let $E = 377,000$ psi and $I = 8.8 \times 10^{-3}$ in$^4$.

Project #1 – K’NEX Truss

Apply Design Strategy to K’NEX Truss

Figure 1. One of the coplanar structures comprising the 3-D structure

Member | $L$ (in) | $F_{applied}$ | $P_{cr}$ (lb) | $T_f$ (lb) | Mode | $P_{cr}$ (lb) | $T_f$ (lb)
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CIVL 3121
K’NEX Failure Models

3/4
Project #1 – K’NEX Truss

Apply Design Strategy to K’NEX Truss

- The maximum load is the minimum failure force or 42.41 lb. (19,241.4 g)
- An estimate of the weight and costs are computed as: 185 g and $4,720 K’NEX dollars
- Therefore the SWR is: 104

End of K’NEX Truss Project

Any questions?