Project #1 – K'NEX Truss

- An important part of your K'NEX truss design is the utilization of tension and compression failure models.
- After you have modeled you structure in SAP2000 and determined the force in each member, failure model can help you predict the ultimate capacity of you structure.
- Therefore, we should discuss failure model for both tension and compression.

Project #1 – K'NEX Truss

- One simple mathematical model for predicting ***compression failure*** is the ***Euler buckling model***.

$$P_{cr} = \frac{\pi^2 EI}{\left(KL^2\right)}$$

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

Project #1 – K'NEX Truss

- If the end supports are considered pin connections, then ***K*** = 1.

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

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

I = 8.8 x 10^{-5} in^4
E = 377 *ksi*

Project #1 – K'NEX Truss

- 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 in (includes the length of the rod and the spacing of the connectors).

$$P_{cr} = \frac{\pi^2\left(377{,}000psi\right)\left(8.8\times10^{-5}in^4\right)}{\left(6in\right)^2} = 9.1\,lb$$

Project #1 – K'NEX Truss

- Example: Estimated the critical force in a yellow K'NEX rod. Assume *L* = 4.25 *in* (includes the length of the rod and the spacing of the connectors).

$$P_{cr} = \frac{\pi^2\left(377{,}000psi\right)\left(8.8\times10^{-5}in^4\right)}{\left(4.25in\right)^2} = 18.1\,lb$$

- Why does the yellow K'NEX rod have a larger critical force then the **red** K'NEX rod?
  - Decrease ***L*** increase $\boldsymbol{P_{cr}}$
  - Increase ***L*** decrease $\boldsymbol{P_{cr}}$

Project #1 – K'NEX Truss

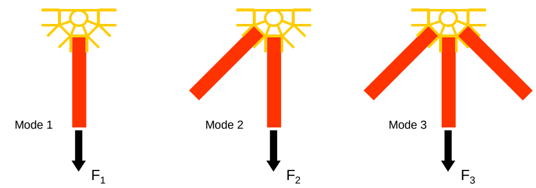
- Unlike the compression failure, a ***tension failure*** will probably not occur in the K'NEX material.
- It is more probable, that the K'NEX rod to pull out of the K'NEX connector up tension force.
- To develop an understanding of ***tension failure*** in K'NEX rods and connector an experimental failure 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.

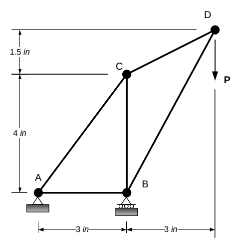
Project #1 – K'NEX Truss

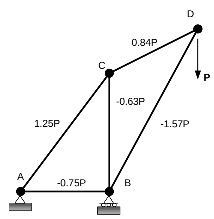
- One difference from the compression model is that the tension model is based on experimental data not a mathematical model.
- Therefore, you should probably perform numerous tests and take an average valve for your tension failure limit.



Project #1 – K'NEX Truss

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





Project #1 – K'NEX Truss

Member	L (in)	F_{SAP}	P_{cr} (lb)	Mode	P (lb)
AB	3.00	-0.75	-36.38	1	48.5
AC	5.00	1.25	12.00	2	9.6
BC	4.00	-0.63	-20.46	2	32.5
BD	6.26	-1.57	-8.34	2	5.3
CD	3.52	0.84	10.00	1	11.9

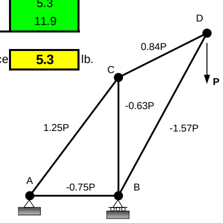
Mode	T_f (lb)
1	10
2	12
3	18

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

Utilmate Force **5.3** lb.

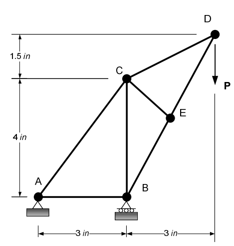
If $F_{SAP} < 0$, then $P = \frac{P_{cr}}{F_{SAP}}$

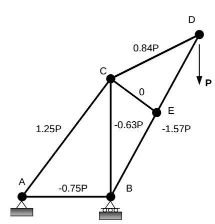
If $F_{SAP} > 0$, then $P = \frac{T_f}{F_{SAP}}$



Project #1 – K'NEX Truss

Does the ultimate load predict change if we added an additional member CE that bisects the original member BD?





Project #1 – K'NEX Truss

Member	L (in)	F_{SAP}	P_{cr} (lb)	Mode	P (lb)
AB	3.00	-0.75	-36.38	1	48.5
AC	5.00	1.25	12.00	2	9.6
BC	4.00	-0.63	-20.46	2	32.5
BE	3.13	-1.57	-33.37	1	21.3
CD	3.35	0.84	10.00	1	11.9
DE	3.13	-1.57	-33.37	1	21.3
CE	1.95	0.00		1	

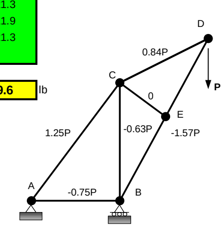
Mode	T_f (lb)
1	10
2	12
3	18

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

Utilmate Force **9.6** lb

If $F_{SAP} < 0$, then $P = \frac{P_{cr}}{F_{SAP}}$

If $F_{SAP} > 0$, then $P = \frac{T_f}{F_{SAP}}$



Project #1 – K’NEX Truss

Design Strategy

- Develop several conceptual designs
- Model each design in SAP2000 and determine the members 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 decision 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 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 is 4.25 in. Also, let E = 377,000 psi and $I = 8.8 \times 10^{-5}$ in^4.

Project #1 – K’NEX Truss

Apply Design Strategy to K’NEX Truss

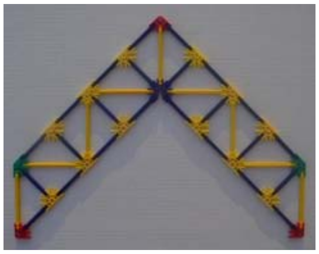
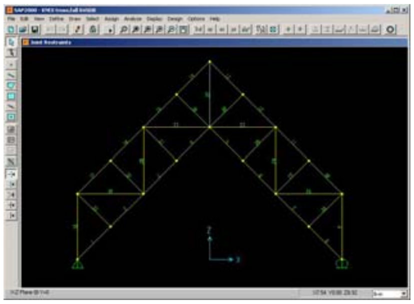


Figure 1. One of the coplanar structures comprising the 3-D structure

Project #1 – K’NEX Truss

Apply Design Strategy to K’NEX Truss



Project #1 – K’NEX Truss

Apply Design Strategy to K’NEX Truss

Member	L (in)	F_{SAP}	P_{cr} (lb)	Mode	P (lb)
1	3.01	0.00		1	
2	3.01	0.00		1	
3	3.01	0.35	15.00	1	42.4
4	3.01	0.35	15.00	1	42.4
5	3.01	0.35	15.00	1	42.4
6	3.01	0.35	15.00	1	42.4
7	3.01	0.00		1	
8	3.01	0.00		1	
9	4.25	-0.25	-18.13	2	72.5
10	3.01	-0.35	-36.26	1	102.5
11	3.01	-0.35	-36.26	1	102.5
12	3.01	-0.71	-36.26	1	51.3
13	3.01	-0.71	-36.26	1	51.3
14	3.01	-0.71	-36.26	1	51.3
15	3.01	-0.71	-36.26	1	51.3

Mode	T_f (lb)
1	15
2	20
3	25

Project #1 – K’NEX Truss

Apply Design Strategy to K’NEX Truss

Member	L (in)	F_{SAP}	P_{cr} (lb)	Mode	P (lb)
17	3.01	-0.35	-36.26	1	102.5
18	4.25	-0.25	-18.13	2	72.5
19	4.25	0.25	25.00	3	100.0
20	4.25	-0.25	-18.13	3	72.5
21	4.25	0.25	25.00	3	100.0
22	4.25	0.50	25.00	3	50.0
23	4.25	0.25	25.00	3	100.0
24	4.25	-0.25	-18.13	3	72.5
25	4.25	0.25	25.00	3	100.0
26	3.01	0.00		1	
27	3.01	0.00		1	
28	3.01	0.00		1	
29	3.01	0.00		1	
30	3.01	0.00		1	
31	3.01	0.00		1	
32	3.01	0.00		1	

Mode	T_f (lb)
1	15
2	20
3	25

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?