Verification Example

Program: RFEM 5, RSTAB 8

Category: Post-Critical Analysis, Isotropic Linear Elasticity, Member

Verification Example: 0200 – Four-Member Truss Snap-Through

0200 – Four-Member Truss Snap-Through

Description

A structure is made of four truss members, which are embedded into hinge supports according to **Figure 1**, [1]. The structure is loaded by a concentrated force F and alternatively by imposed nodal deformation u_z over the critical limit point, when snap-through occurs. Imposed nodal deformation is used in RFEM 5 and RSTAB 8 to obtain full equilibrium path of the snap-through. The self-weight is neglected in this example. Determine the relationship between the actual loading force F_a and the deflection u_z considering large deformation analysis. Evaluate the load factor f at given deflections u_z. The problem is described by the following set of parameters.

Material		Modulus of Elasticity	E	$1 \cdot 10^7$	psi
		Poisson's Ratio	ν	0.300	–
Geometry	Structure	Half Length	b	100.000	in
		Height	h	20.000	in
		Half Width	w	20.000	in
	Cross-Section	Area	A	1.000	in^2
Load		Force	F	98100.000	lbf
		Imposed Nodal Deformation	u_z	44.000	in

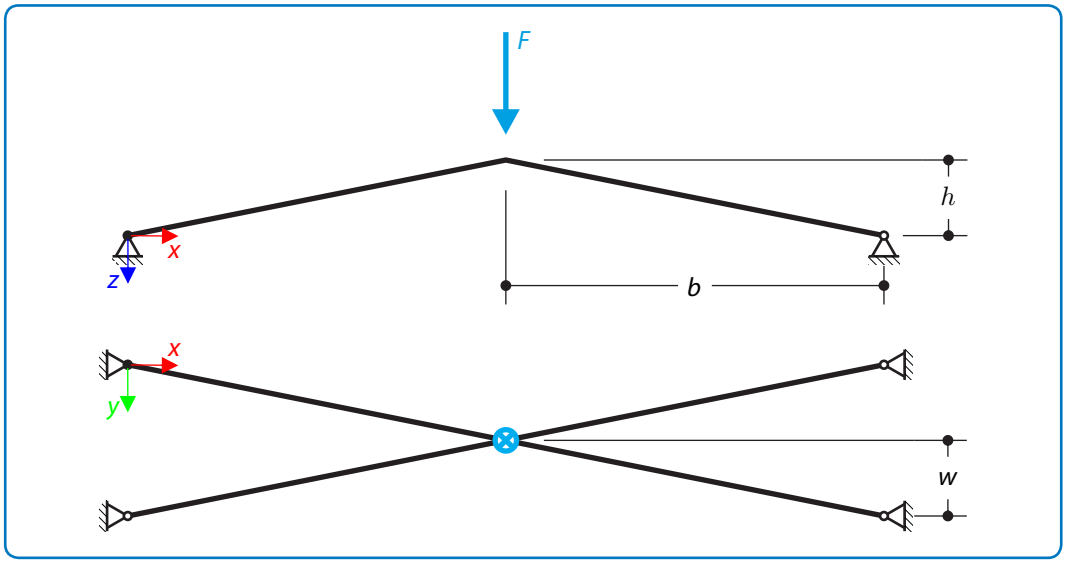

Figure 1: Problem sketch

Analytical Solution

Analytical solution is based on Verification Example 0045, where two-truss structure is solved , for more details see [2]. Considering large deformations, the axial force N in each of four trusses can be determined from the force equilibrium

$$N = F\frac{\sqrt{(h-u_z)^2+b^2}}{4(h-u_z)}. \qquad (200-1)$$

Considering large deformation analysis, the logarithmic form of the axial strain ε should be used

$$\varepsilon = \ln\left(1-\frac{\Delta L}{L_0}\right). \qquad (200-2)$$

The general relationship between the actual loading force F_a and the deflection u_z then results

$$F_a = \frac{4EA(h-u_z)\ln\left(1-\frac{\sqrt{(h-u_z)^2+b^2}-L_0}{L_0}\right)}{\sqrt{(h-u_z)^2+b^2}}, \qquad (200-3)$$

where L_0 is the initial lenght of the truss $L_0 = \sqrt{b^2+h^2}$. For further results evaluation the load factor f is used. It is defined as a ratio of the maximum loading force F and actual loading force F_a

$$f = \frac{F}{F_a}. \qquad (200-4)$$

RFEM 5 and RSTAB 8 Settings

- Modeled in RFEM 5.16.01 / RSTAB 8.16.01
- The number of elements is 4
- The number of increments is 100
- The structure is modeled using members (Truss - only N)
- Isotropic linear elastic material model is used
- Postcritical analysis and modified Newton-Raphson method is used

Results

Structure Files	Program	Loading
0200.01	RFEM 5	Concentrated Force
0200.02	RFEM 5	Imposed Nodal Deformation
0200.03	RSTAB 8	Concentrated Force
0200.04	RSTAB 8	Imposed Nodal Deformation

The load factor is calculated according the deflections given in [1]. The corresponding results are listed in the table bellow and the overall course can be seen in **Figure 3**.

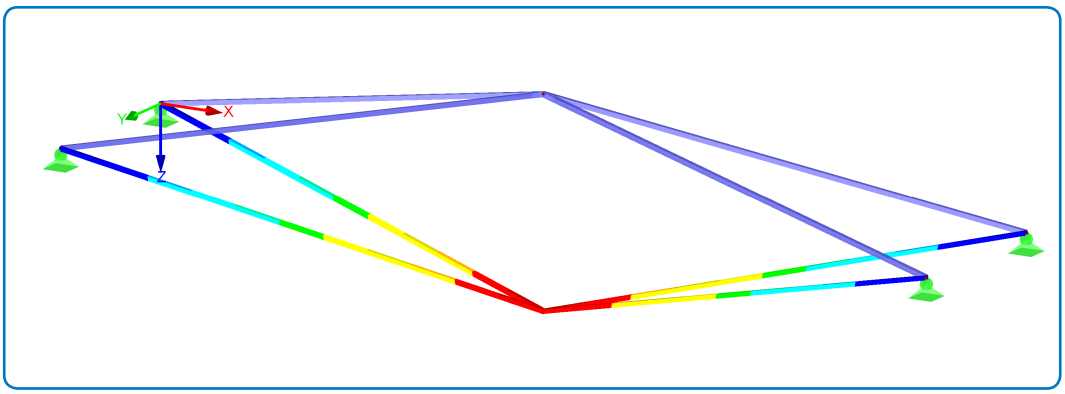

Figure 2: Result shape after snap-through in RFEM 5 / RSTAB 8

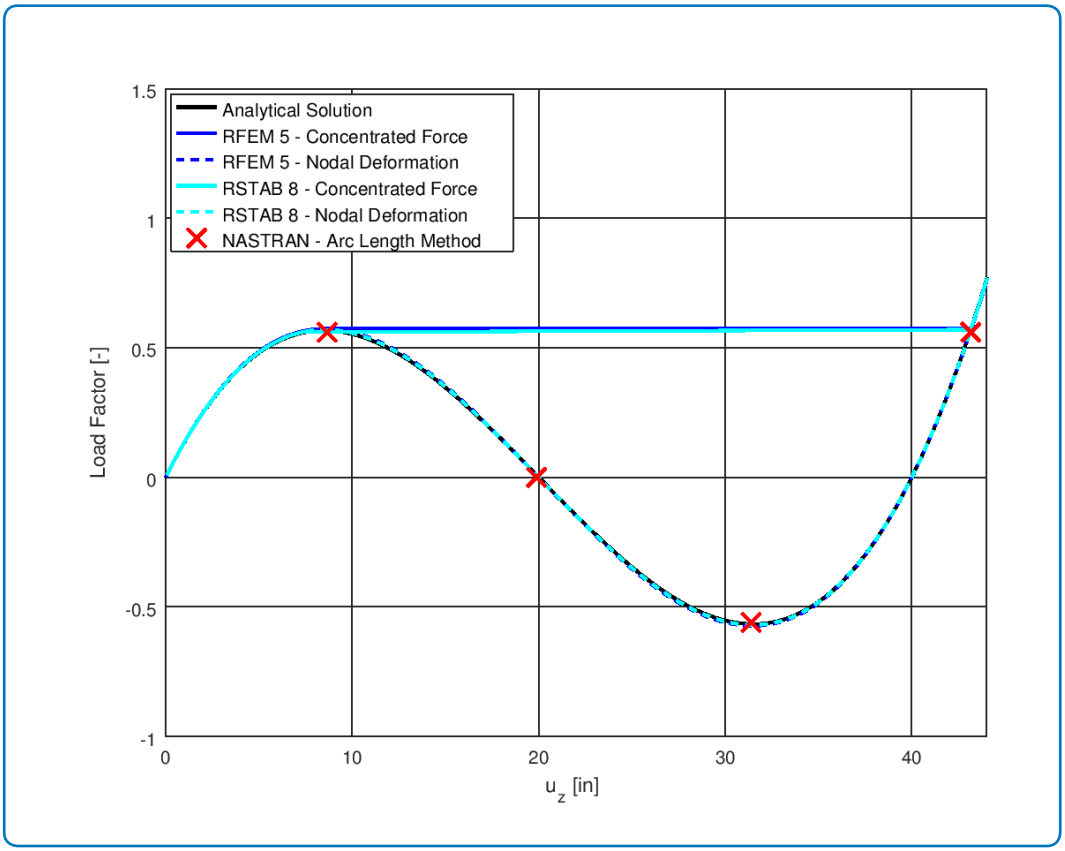

Figure 3: Results comparison – analytical solution, RFEM 5, RSTAB 8 and NASTRAN

Results evaluation in case of imposed nodal deformation loading:

Load Factor [-]	Deflection u_z [in]	Analytical solution	NASTRAN - Arc Length Method	RFEM 5	Ratio [-]	RSTAB 8	Ratio [-]
$f(u_z)$	8.660	0.566	0.560	0.574	1.014	0.570	1.007
	19.89	0.008	0.000	0.008	1.000	0.008	1.000
	31.39	-0.566	-0.560	-0.573	1.012	-0.570	1.007
	43.170	0.572	0.560	0.569	0.995	0.571	0.998

Results evaluation in case of concentrated force loading:

Load Factor [-]	Deflection u_z [in]	Analytical solution	NASTRAN - Arc Length Method	RFEM 5	Ratio [-]	RSTAB 8	Ratio [-]
$f(u_z)$	8.660	0.566	0.560	0.574	1.014	0.560	0.989
	43.170	0.572	0.560	0.574	1.014	0.571	0.998

Remark: RFEM 5 and RSTAB 8 results are compared with the analytical solution.

References

[1] HINDRA, G. A.. Snap-through instability patterns in truss structures. *American Institute of Aeronautics and Astronautics*, 2010.

[2] DLUBAL SOFTWARE GMBH, *Verification Example 0045 – Snap-Through*. 2015b.