Program: RFEM 5

Category: Geometrically Linear Analysis, Structural Nonlinearity

Verification Example: 0057 – Scaffolding Tube Connection - Hinge

0057 – Scaffolding Tube Connection - Hinge

Description

Consider a scaffolding tube connection subjected to an axial force of magnitude N and a moment $\boldsymbol{M}$. Self-weight is not considered. The material of the tube is idealised as perfectly rigid. All geometrical non-linearities are ignored. The problem is described in **Figure 1** and by the following set of input parameters.

Material	Rigid	Modulus of Elasticity	E	1000.000	TPa
Geometry	Scaffolding tube	Segment 1 Length	L	1.000	m
		Segment 2 Length	L	1.000	m
Loading	Compression	Moment	M_{1_X}	0.000	Nm
			M_{1_Y}	530.000	Nm
				1100.000	Nm
				1650.000	Nm
			M_{2_X}	374.767	Nm
				777.817	Nm
				1166.726	Nm
			M_{2_Y}	374.767	Nm
				777.817	Nm
				1166.726	Nm
		Force	N	50000.000	N
	Tension	Moment	M_{1_X}	0.000	Nm
			M_{1_Y}	1000.000	Nm
			M_{1_X}	707.107	Nm
			M_{1_Y}	707.107	Nm
		Force	N	−50000.000	N
Hinge Properties		Maximal Moment	M_{max}	545.750	Nm
		Maximal Force	N_{pl}	−90000.000	N

The task is to find the angle of deflection φ for four different moment magnitudes (three for compression, one for tension), two different forces (one for tension and one for compression), in two different geometrical settings.

Let M stand for the magnitude of the moment $\boldsymbol{M}$ a let it attain all values specified in the input table.

- Firstly, we a consider moment $\boldsymbol{M}_1 = [M_{1_x}, M_{1_y}, 0] = [0, M, 0]$ acting about the Y-axis.
- Secondly, we a consider moment $\boldsymbol{M}_2 = [M_{2_x}, M_{2_y}, 0] = [\frac{\sqrt{2}}{2}M, \frac{\sqrt{2}}{2}M, 0]$ acting about an X'—axis which we get by rotating the X-axis around the Z-axis by an $\alpha = 45°$.

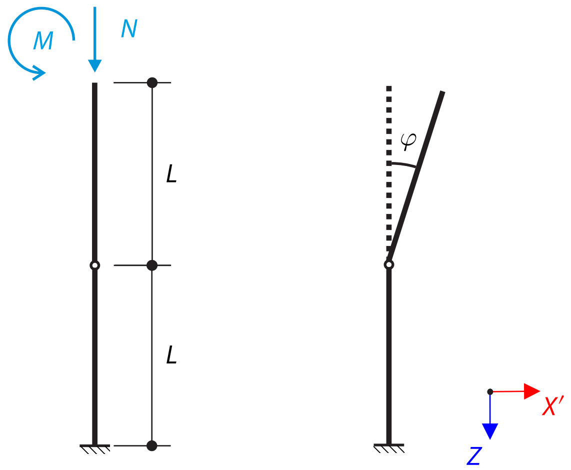

Figure 1: Problem Sketch and Solution in the loading plane $X'Z$.

Analytical Solution

The scaffolding tube connection is given by parallel combination of inter and outer tube. The behaviour of each tube is given quantitatively by a separate diagram. The Moment - Force diagram **Figure 2** is used for the outer tube and the Moment - Angle diagram **Figure 3** is used for the inner tube. For further inquiry see [1].

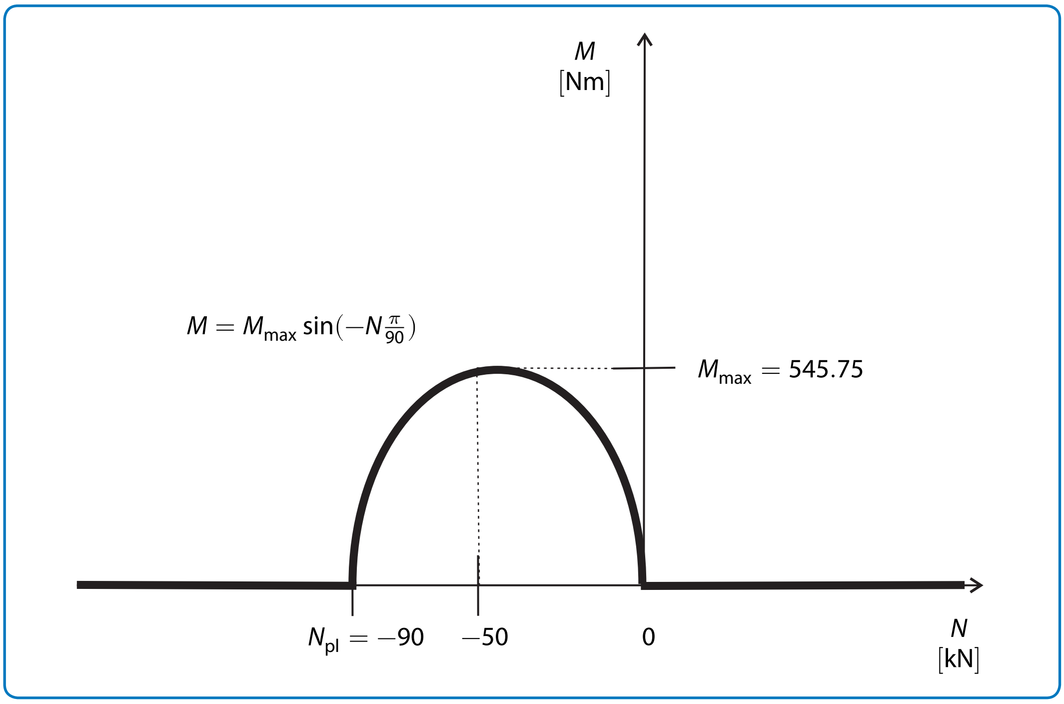

Figure 2: Scaffolding tube connection - outer tube, Moment - Force diagram

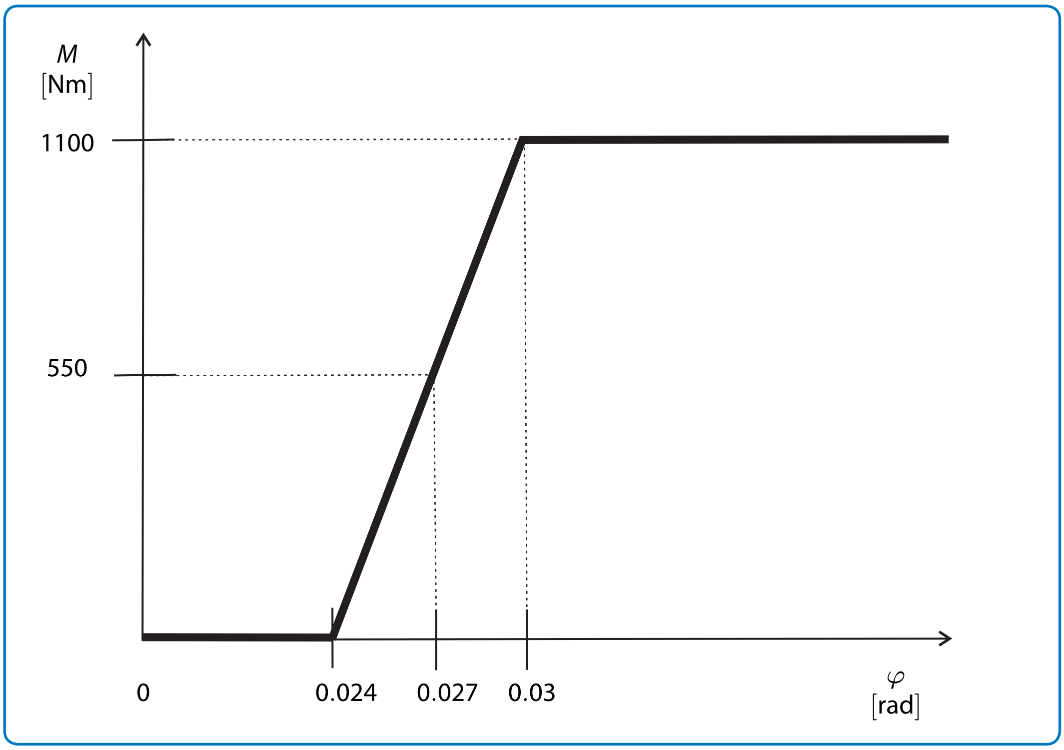

Figure 3: Scaffolding tube connection - inner tube, Moment - Angle diagram

The case of the lowest moment magnitude $M = 530$ Nm represent the most elementary scenario. The outer tube is strong enough to support the loading all alone. According to **Figure 2**, we have the following observation.

$$M_{1_y} - M(-50) = 530 - 537.46 < 0 \quad (57-1)$$

No moment is left to be caried by the inner tube. Therefore

$$\varphi = 0 \quad (57-2)$$

as given by **Figure 3**.

In case of moment magnitude $M = 1100$ Nm, we have that

$$M_{1_y} - M_{\text{max}} > 0 \quad (57-3)$$

This fact can be interpreted as a failure of outer tube. The rest of the loading $M_{1_y} - M_{\text{max}}$ must be carried by the inner tube. Reading the values from both **Figure 3** yields the result.

$$\varphi = 0.027 \text{ rad} \quad (57-4)$$

In case of moment magnitude $M = 1650$ Nm, the hinge structure can not support the loading. Both inner and outher tube have failed according to **Figure 2** and **Figure 3**.

RFEM Setting

- Geometrically linear analysis
- Hinge properties are given by diagrams in **Figure 2** and **Figure 3**

Results

Structure Files	Description
0057.01	Compression states only
0057.02	Tension states only

Loading Force	Loading Moment		Theory	RFEM 5	
N [N]	M_X [Nm]	M_Y [Nm]	φ [rad]	φ [rad]	Ratio [-]
50000	0.000	530	0.000 *	0.000 *	1.000
	0.000	1100	0.027 **	0.027 **	1.000
	0.000	1650	***	***	
−50000	0.000	1100	***	***	
50000	374.767	374.767	0.000 *	0.000 *	1.000
	777.817	777.817	0.027 **	0.027 **	1.000
	1166.726	1166.726	***	***	-
−50000	707.107	707.107	***	***	-

The angle of deflection φ is considered in the loading plane
*   Both inner and outer tube are ok
**   Inner tube is ok, outer tube has failed
*** Both inner and outer tube have failed

References

[1] 1065:1998, E. *Adjustable telescopic steel props - Product specifications, design and assessment by calculation and tests*. 1998.