Program: RFEM 5

Category: Geometrically Linear Analysis, Isotropic Linear Elasticity, Structural Nonlinearity, Member

Verification Example: 0056 – Scaffolding Nodal Support - Diagram with Gap

0056 – Scaffolding Nodal Support - Diagram with Gap

Description

A rigid scaffolding tube, fixed at the bottom using the Scaffolding Nodal Support and loaded by both a moment $\boldsymbol{M}$ and a force of magnitude P_z. Self-weight is not considered. The problem is described by the following set of input parameters.

Material	Steel	Modulus of Elasticity	E	210.000	GPa
Geometry	Scaffolding tube	Length	L	1.000	m
		Cross-Section		RO244.5x25	
Loading	Scaffolding tube	Moment	M_{1_x}	0.000	kNm
			M_{1_y}	1.000	kNm
			M_{2_x}	$\frac{\sqrt{2}}{2}$	kNm
			M_{1_y}	$\frac{\sqrt{2}}{2}$	kNm
		Force	P_z	25.000	kN
Support properties	Scaffolding Nodal Support	Maximal Eccentricity	$e_{\max}$	0.04347	m
		Initial Eccentricity	e_0	0.03140	m
		Gap	φ_0	$\frac{\pi}{180}$	rad
		Stiffness	C	30.000	kNm/rad

Example presumptions:

- Boundary conditions $u_x = u_y = u_z = \varphi_z = 0$ for $z = 0$
- The behaviour of the Scaffolding Nodal Support depends on a M-Phi diagram, where $M = eP_z$ in accordance with EN 12811-1 norm [1].

Consider infinitely rigid beam and determine maximal radial deflection $u_{r,\max} = \sqrt{u_{X,\max}{}^2 + u_{Y,\max}{}^2}$ of the structure in two cases:

- Firstly, consider a moment $\boldsymbol{M}_1 = [M_{1_x}, M_{1_y}, 0] = [0, 1, 0]$ acting around Y-axis.
- Secondly, consider more general moment $\boldsymbol{M}_2 = [M_{2_x}, M_{2_y}, 0] = [\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}, 0]$. See **Figure 1** for orientation.

Determine the above quantities using a beam with RO244.5x25 cross-section. Such beam is a suitable model of a physically unrealistic ideally rigid beam.

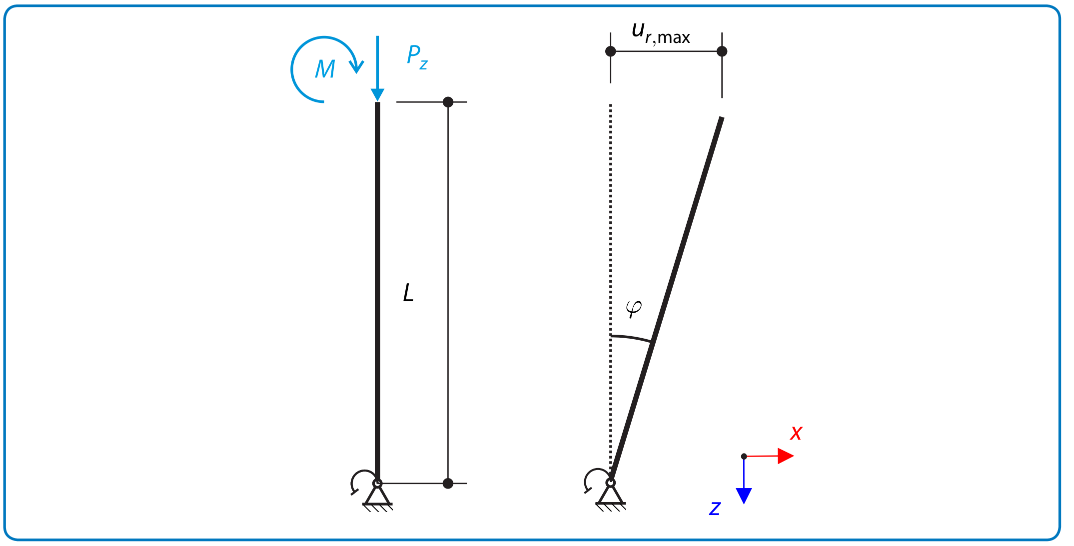

Figure 1: Problem Sketch and Solution

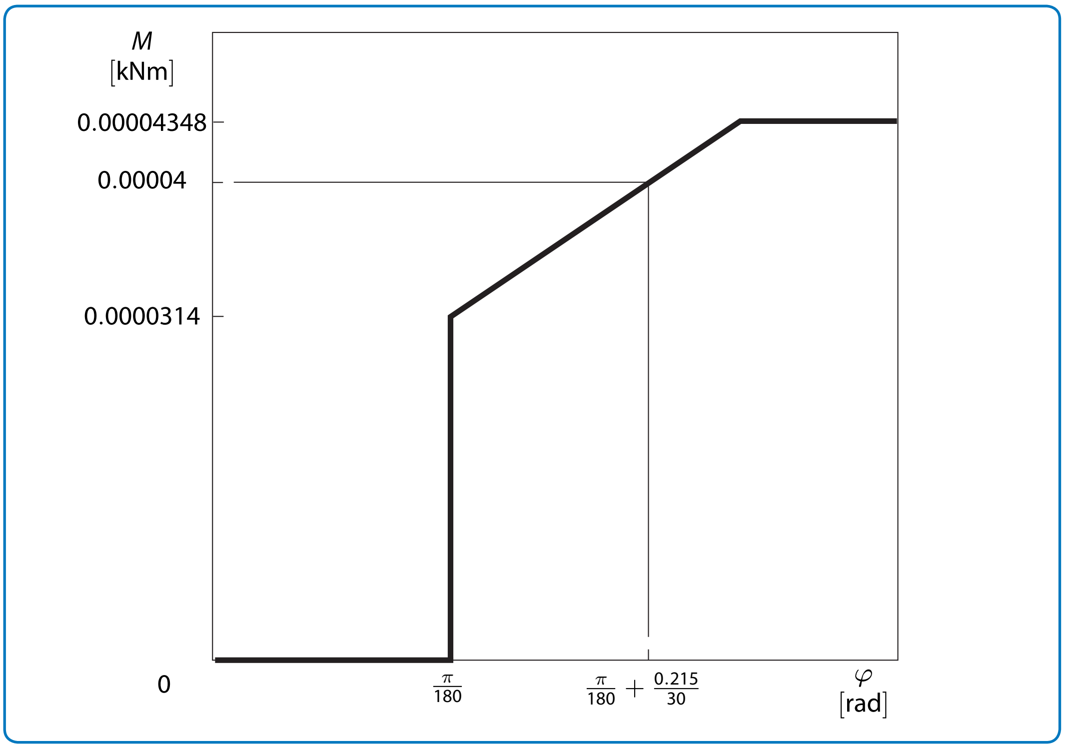

Figure 2: Relationship between magnitude of moment $M = eP_z$ and angle φ for $P_z = 1$ N. In this case the value of moment equals the value of Eccentricity. The same diagram is used in RFEM to define a non-linearity of Scaffolding Nodal Support.

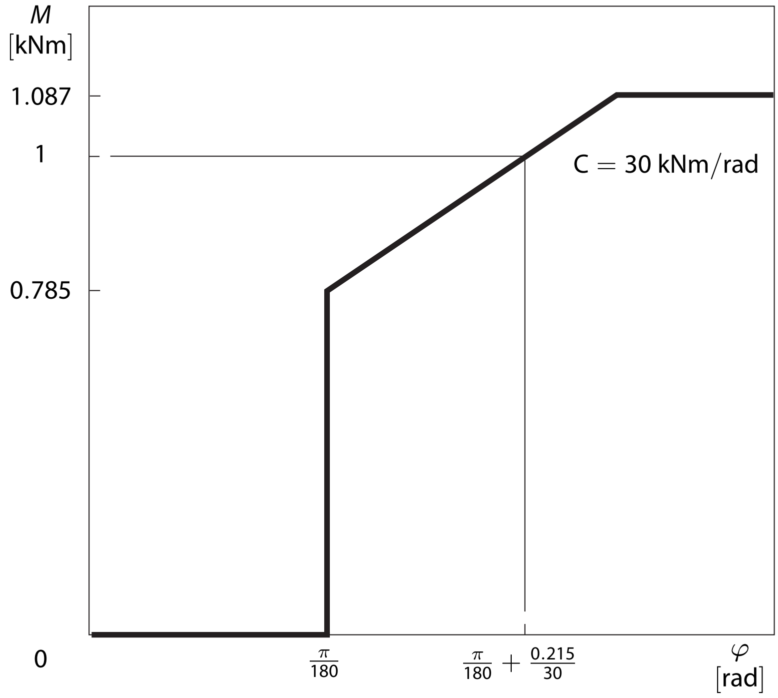

Figure 3: Relationship between magnitude of moment $M = eP_z$ and angle φ for $P_z = 25$ kN.

Analytical Solution

The problem presents a minimum scenario where the tube is considered rigid. We can seek the solution in the following form:

$$\varphi = \varphi_0 + \frac{|M_1| - P_z e_0}{C} = \frac{\pi}{180} + \frac{0.215}{30} \approx 0.2462 \text{ rad} \qquad (56-1)$$

This in turn yields the maximal radial deflection $u_{r,\max}$.

$$u_{r,\max}(\boldsymbol{M}_1) \approx l\varphi_1 \approx 24.62 \text{ mm} \qquad (56-2)$$

$$u_{r,\max}(\boldsymbol{M}_2) \approx l\varphi_2 \approx 24.62 \text{ mm} \qquad (56-3)$$

Please note that we have used 1st order theory approximation.

RFEM 5 Settings

- Modeled in RFEM 5.04.0059
- Geometrically linear analysis is considered
- The number of increments 5
- Support Conditions: Diagram - FZ′/PhiX′PhiY′ is given by **Figure 2**

Results

Structure File	Material Model	Element Size	Description
0056.01	Rigid	-	-
0056.02	Isotropic Linear Elastic	0.50 m	RO244.5x25 cross-section

Modeled using rigid beams

Load Case	Analytical solution	RFEM 5	
	$u_{r,\max}$ [mm]	$u_{r,\max}$ [mm]	Ratio [-]
Moment $\boldsymbol{M}_1$	24.62	24.62	1.000
Moment $\boldsymbol{M}_2$	24.62	24.61	1.000

Modeled using beams with RO244.5x25 cross-section

Load Case	Analytical solution*	RFEM 5	
	$u_{r,\max}$ [mm]	$u_{r,\max}$ [mm]	Ratio [-]
Moment $\boldsymbol{M}_1$	24.62	24.64	1.001
Moment $\boldsymbol{M}_2$	24.62	24.64	1.001

* Analytical solution was derived using rigid beams in all cases

References

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