Program: RFEM 5

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

Verification Example: 0055 – Scaffolding Nodal Support

0055 – Scaffolding Nodal Support

Description

Consider 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_{2_Y}	$\frac{\sqrt{2}}{2}$	kNm
		Force	P_Z	50.000	kN
Support properties	Scaffolding Nodal Support	Maximal Eccentricity	$e_{\max}$	0.025	m
		Stiffness	C	20.000	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 ČSN EN 12811-1 norm [1]. See **Figure 2**.

Consider infinitely rigid beam and determine maximum 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.

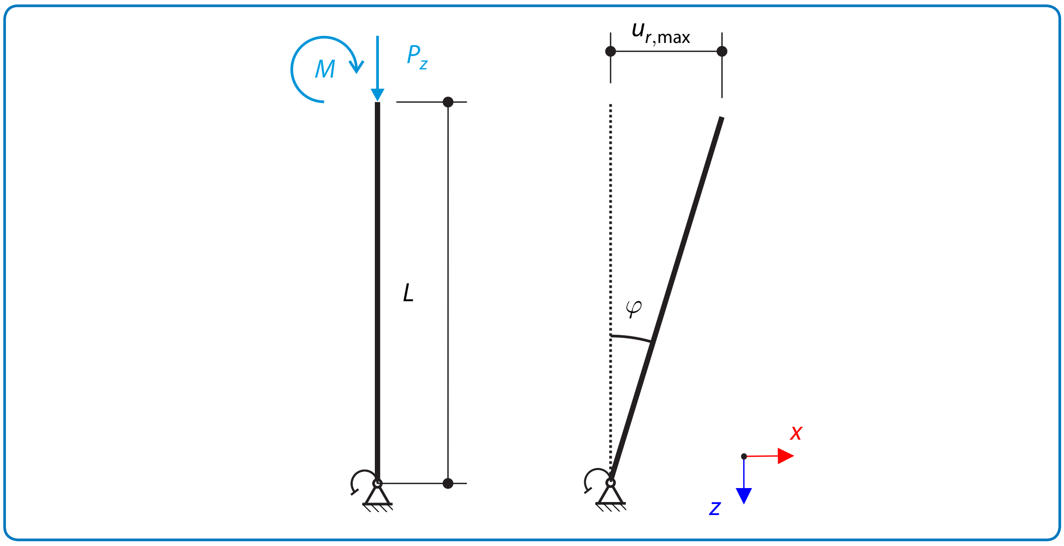

Figure 1: Problem Sketch and Solution

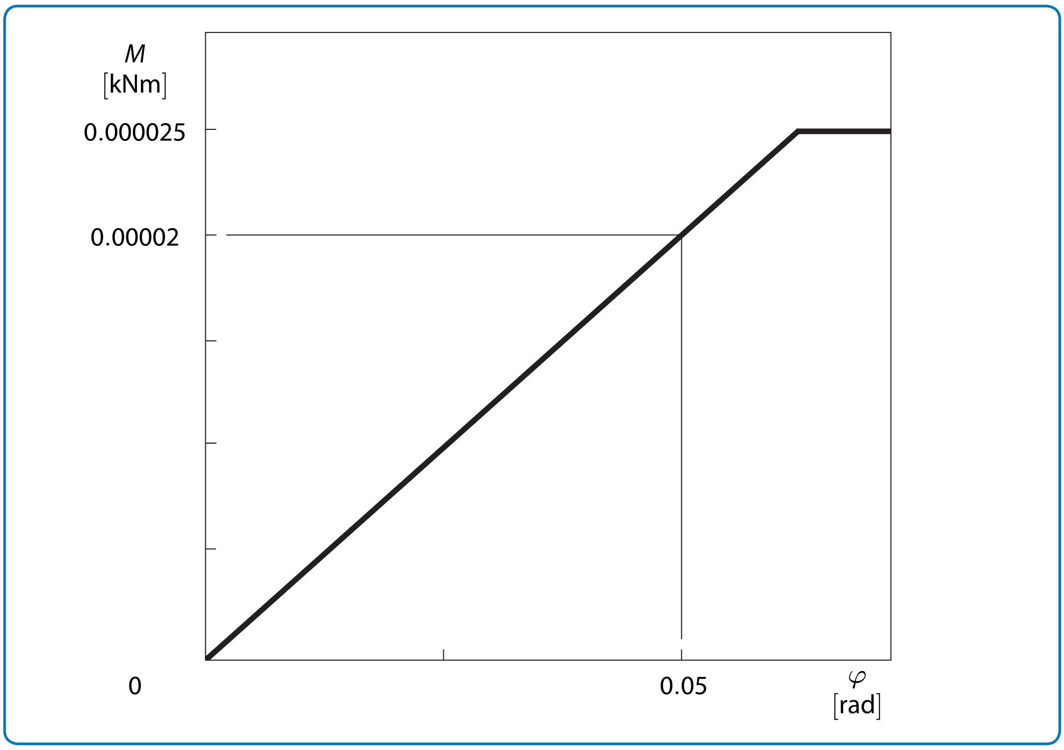

Figure 2: Relationship between magnitude of moment $M = eP_z$ and angle φ for $P_z = 1$ N. In this case the value of moment equals the value of Eccentricity. The same diagram is used in RFEM to define a non-linearity of Scaffolding Nodal Support.

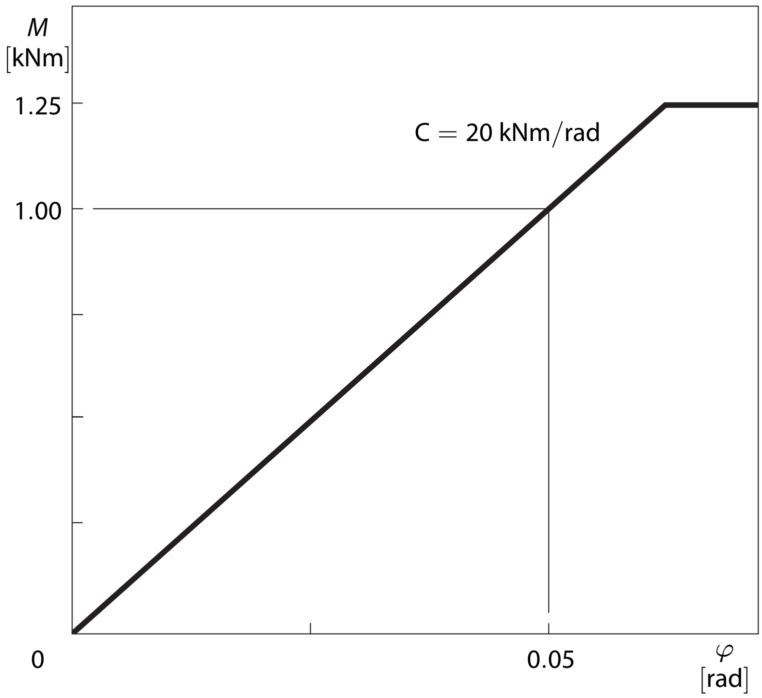

Figure 3: Relationship between magnitude of moment $M = eP_z$ and angle φ for $P_z = 50$ kN.

Analytical Solution

The problem presents a simplified model where the tube is considered rigid. Thus we can get the solution of both cases immediately by reading the values from **Figure 3**.

$$\varphi_1 = \frac{|\boldsymbol{M}_1|}{C} = \frac{1}{20} = 0.05 \text{ rad} \quad (55-1)$$

$$\varphi_2 = \frac{|\boldsymbol{M}_2|}{C} = \frac{1}{20} = 0.05 \text{ rad} \quad (55-2)$$

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

$$u_{r,\max}(\boldsymbol{M}_1) \approx l\varphi_1 \approx 50.00 \text{ mm} \quad (55-3)$$

$$u_{r,\max}(\boldsymbol{M}_2) \approx l\varphi_2 \approx 50.00 \text{ mm} \quad (55-4)$$

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

RFEM 5 Settings

- Modeled in RFEM 5.04.0024
- The element size is $l_{FE} = 0.50$ m
- 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	Description
0055.01	Rigid	Default Z-axis
0055.02	Rigid	Inverted Z-axis
0055.03	Isotropic Linear Elastic	RO244.5x25 cross-section

Modeled using rigid beams

Load Case	Analytical solution*	RFEM 5	
	$u_{r,max}$ [mm]	$u_{r,max}$ [mm]	Ratio [-]
Moment $\boldsymbol{M}_1$	50.00	50.00	1.000
Moment $\boldsymbol{M}_2$	50.00	50.00	1.000

Modeled using rigid beams and inverted Z-axis

Load Case	Analytical solution*	RFEM 5	
	$u_{r,max}$ [mm]	$u_{r,max}$ [mm]	Ratio [-]
Moment $\boldsymbol{M}_1$	50.00	50.00	1.000
Moment $\boldsymbol{M}_2$	50.00	50.00	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 $\boldsymbol{M}_1$	50.00	50.02	1.000
Moment $\boldsymbol{M}_2$	50.00	50.02	1.000

* Analytical solution was derived using rigid beams and 1st order theory in all cases

References

[1] ČSN EN 12811-1, *Dočasné stavební konstrukce - Část 1: Pracovní lešení - Požadavky na provedení a obecný návrh.* 2004.