0080 – Cable with Concentrated Forces

Description

A cable in the initial position according to **Figure 1** is loaded by two concentrated forces F. The self-weight is neglected. Determine the normal forces in the cable. The problem is described by the following set of parameters.

Material	Steel Cable	Modulus of Elasticity	E	210000.000	MPa
		Poisson's Ratio	ν	0.300	–
Geometry		Length - First Part	a	3.000	m
		Length - Second Part	b	4.000	m
		Cable Sag	h	2.000	m
		Cable Diameter	d	0.030	m
Load		Force	F	20.000	kN

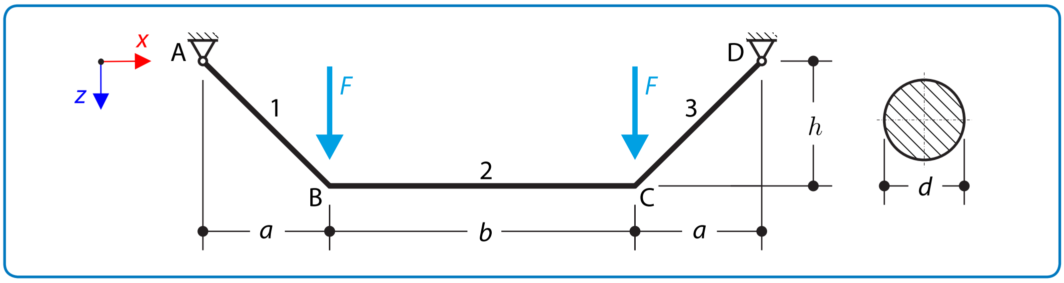

Figure 1: Problem Sketch

Analytical Solution

The normal forces in the cable can be determined by means of the section method and the equations of equilibrium. At first, the reaction forces at the support A, R_{Az} in z-direction and R_{Ax} in x-direction, are calculated from the moment equilibrium for points D, equation **(80 – 1)** and B, equation **(80 – 2)** respectively,

$$R_{Az}(2a+b) - F(b+a) - Fa = 0 \quad \Rightarrow \quad R_{Az} = F, \qquad (80-1)$$

$$R_{Ax}h + R_{Az}a = 0 \quad \Rightarrow \quad R_{Ax} = F\frac{a}{h}. \qquad (80-2)$$

Due to symmetry, the horizontal components of reaction forces have the opposite values and the vertical components have the same

$$R_{Ax} = -R_{Dx}, \qquad (80-3)$$
$$R_{Az} = R_{Dz}.$$

The normal forces calculated on the initial configuration are equal to

$$N_1 = N_3 = \sqrt{R_{Ax}^2 + R_{Az}^2}, \qquad (80-4)$$
$$N_2 = R_{Ax}. \qquad (80-5)$$

These normal forces cause the elongination of appropriate cable parts[1]

$$\Delta L_1 = \frac{N_1 L_1}{EA}, \qquad (80-6)$$
$$\Delta L_2 = \frac{N_2 b}{EA}. \qquad (80-7)$$

Thus, it is neccesary to update the initial geometry by means of the calculated elonginations ΔL_1 and ΔL_2 and recalculate the normal forces. The updated quantities are denoted with a bar, more precisely

$$\bar{a} = a - \frac{\Delta L_2}{2}, \qquad (80-8)$$
$$\bar{L_1} = L_1 + \Delta L_1, \qquad (80-9)$$
$$\bar{h} = \sqrt{\bar{L_1}^2 - \bar{a}^2}. \qquad (80-10)$$

The normal forces are further recalculated as

$$\bar{N_1} = F\sqrt{1 + \frac{\bar{a}^2}{\bar{h}^2}} \approx 36.025 \text{ kN}, \qquad (80-11)$$
$$\bar{N_2} = F\frac{\bar{a}^2}{\bar{h}^2} \approx 29.963 \text{ kN}. \qquad (80-12)$$

RFEM 5 and RSTAB 8 Settings

- Modeled in RFEM 5.09.01 and RFEM 8.09.01
- The finite element length is $l_{FE} = 0.100$ m
- The number of increments is 10
- Isotropic linear elastic model is used

[1] The length of the first part of the cable is defined as $L_1 = \sqrt{a^2 + h^2}$ and the cross-section area of the cable is $A = \frac{\pi d^2}{4}$.

Results

Structure Files	Program	Entity
0080.01	RFEM 5	Member – Cable
0080.02	RSTAB 8	Member – Cable

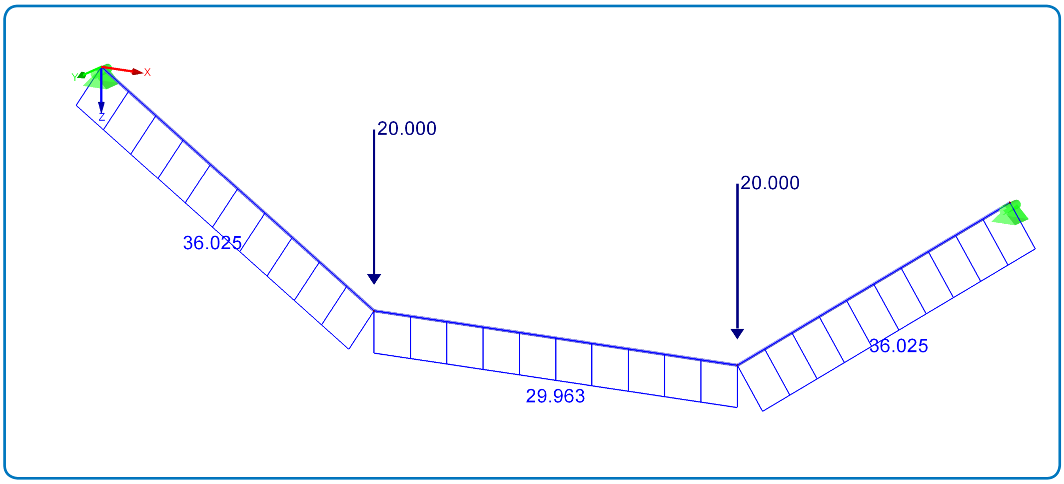

Figure 2: RFEM 5 / RSTAB 8 Results - normal force N [kN]

Quantity	Analytical solution	RFEM 5	Ratio [-]	RSTAB 8	Ratio [-]
$\bar{N}_1$ [kN]	36.025	36.025	1.000	36.025	1.000
$\bar{N}_2$ [kN]	29.963	29.963	1.000	29.963	1.000