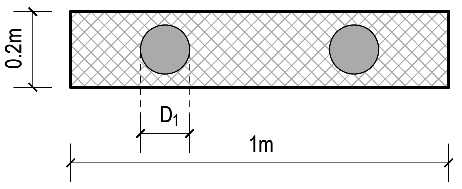
Task 1 Dimensioning of elements under tension

Given is the normal force N_d = 5900kN, which is distributed on several steel cables (steel S235) as shown in sections a) and b). (Assumption: the cables carry the full tension load, i.e. the stresses on the concrete can be neglected)

a) Calculate the minimum cable diameter D1 and D2 in steel S235 for the two cases shown in a) and b) (rounded to the next higher mm). The material values can be found in the formula sheet.

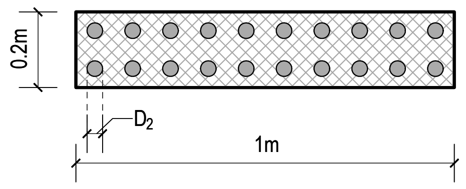
b) What could possible advantages and disadvantages of constellations a) and b) be? Specify your favorite choice and justify it.



Cross Section 1:20

N_d = 5'900 kN
f_{tk} = 235 N/mm^2
γ_M = 1.05

f_{td} = f_{tk} / γ_M = 223.8 N/mm^2
A_{req} = N_d / f_{td} = 26'361.7 mm^2
A_{Seil} = $A_{req} / 2$ = 13'180.9 mm^2
D = $\sqrt{4 \cdot A / \pi}$ = **129.5 mm ≈ 130 mm**



Cross Section 1:20

N_d = 5'900 kN
f_{tk} = 235 N/mm^2
γ_M = 1.05

f_{td} = f_{tk} / γ_M = 223.8 N/mm^2
A_{req} = N_d / f_{td} = 26'361.7 mm^2
A_{Seil} = $A_{req} / 20$ = 1'318.1 mm^2
D = $\sqrt{4 \cdot A / \pi}$ = **41.0 mm**

b) In the option 1.1 the effort is less because of the fewer elements. Option 1.2 shows a better force distribution at the crosssection.

Task 2 Different materials in tension and compression

To get a sense of how different materials behave in tension and compression, we compare the behavior of timber (spruce), steel (S235) and concrete (C20/25).

a) Refer to the formula sheet to find the characteristic values for tensile and compressive strengths, and the safety factors for each material and introduce them into the table.

b) Consider a tensile stress of N_d = 12kN. Calculate for the three materials the required square crosssectional area A_{req} and side length a required for N_d.

c) Repeat b) now with a compressive load of N_d = 12kN.

a)

	Wood Spruce	Steel S235	Concrete C20/25
γ_M	1.7	1.05	1.5
f_{tk}	14 N/mm^2	235 N/mm^2	1.5 N/mm^2
f_{td}	**8.2 N/mm^2**	**223.8 N/mm^2**	**1 N/mm^2**
f_{ck}	20 N/mm^2	235 N/mm^2	20 N/mm^2
f_{cd}	**11.7 N/mm^2**	**223.8 N/mm^2**	**13.3 N/mm^2**

b) Wood

N_d = 12'000 N
f_{td} = 8.2 N/mm^2
A_{req} = N_d / f_{td} = 1457 mm^2

Steel

N_d = 12'000 N
f_{td} = 223.8 N/mm^2
A_{req} = N_d / f_{td} = 53.6 mm^2

Concrete

N_d = 12'000 N
f_{td} = 1 N/mm^2
A_{req} = N_d / f_{td} =12'000mm^2

c) Wood

N_d = 12'000 N
f_{cd} = 11.7 N/mm^2
A_{req} = N_d / f_{cd} = 1020 mm^2

Steel

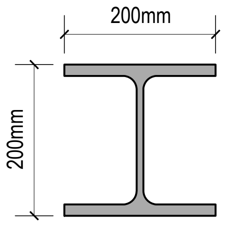
N_d = 12'000 N
f_{cd} = 223.8 N/mm^2
A_{req} = N_d / f_{cd} = 53.6 mm^2

Concrete

N_d = 12'000 N
f_{cd} = 13.3 N/mm^2
A_{req} = N_d / f_{cd} = 900 mm^2

Task 3 Stress check

Find the stresses for the steelprofile S235 for the given values.



Cross Section 1:10

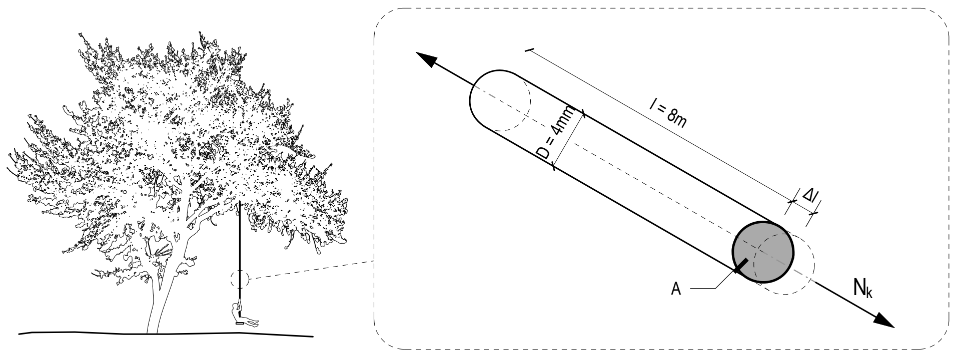
N_d = 1'500 kN
A_{eff} = 7810 mm^2

$\sigma = N_d / A_{eff} \leq f_{cd}$
f_{cd} = 223.8 N/mm^2
σ = **192.1 N/mm^2**

$\sigma \leq f_{cd}$ ok!

Task 4 Deformation

You hang a swing from a tree with thin steel cable S235 with a length l = 8m and diameter D = 4 mm. Assuming that the person on the swing weighs 80 kg (m_k), find the change in length of the cable in mm and in Δl %.



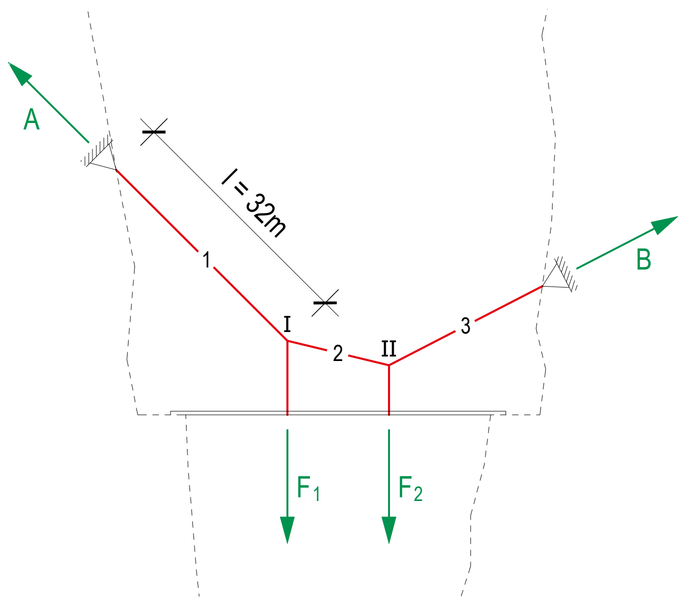
m_k = 80 kg
N_k = $m_k \cdot g$ = 785 N
A = $r^2 \cdot \pi$ = 12.57 mm^2
l = 8'000 mm
E = 210'000 N/mm^2

$\Delta l = (N_k / A) \cdot (l / E)$ = 2.38 mm
$\Delta l / l$ = 2.38 mm / 8'000 mm = 0.0003 = **0.03 %**

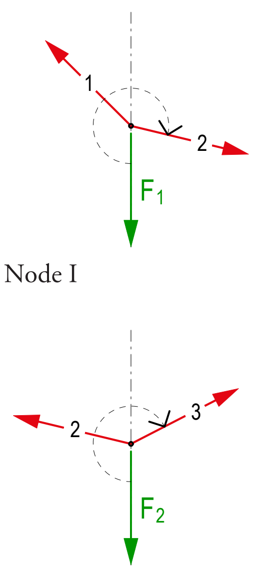
Task 5 Deformation

a) Draw the force diagram for the hanging bridge and enter the force in the main cable. Calculate the rope diameter and the change in length due to the stress for the member made of steel S235. Specify both the change in length Δl and the percentage of change in length in %. $F_{1d} = F_{2d}$ = 40 kN.

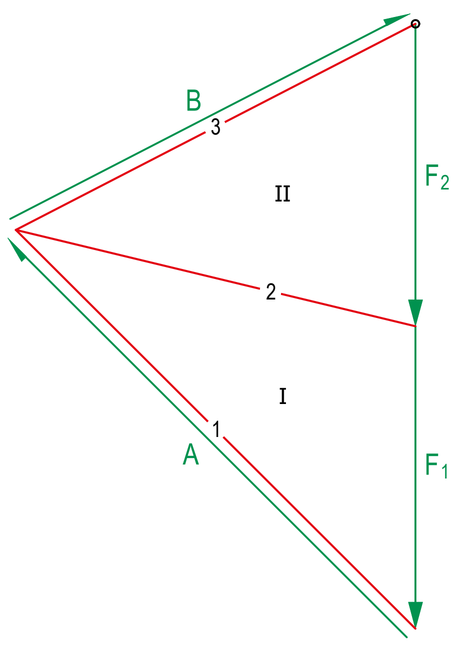
b) Describe how the change in length could affect the form- and force diagrams.



Form Diagram 1:1'000



FBD



1 cm ≙ 10 kN

Force diagram

N_d = 74'671 N
f_{td} = 223.8 N/mm^2

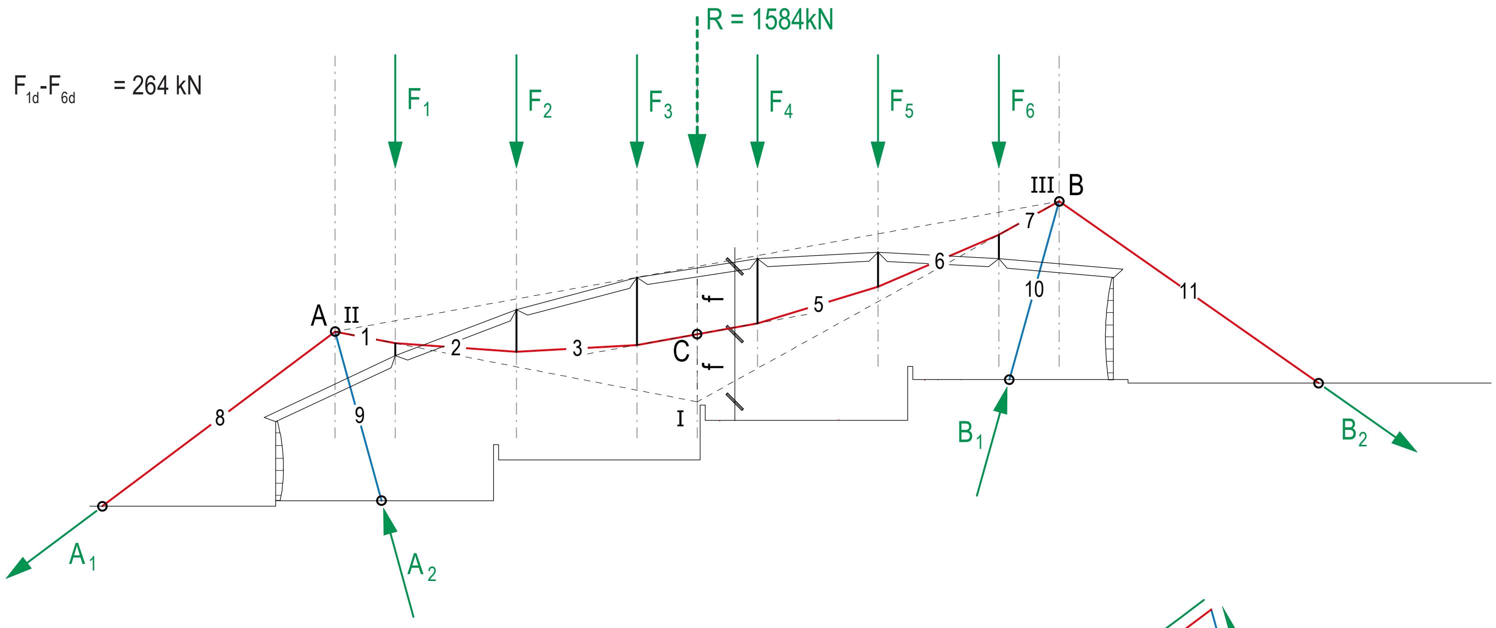
A_{req} = N_d / f_{td} = 333.6 mm^2
D = $\sqrt{4 \cdot A / \pi}$ = **20.6 mm ≈ 21 mm**

A = $r^2 \cdot \pi$ = 346.4 mm^2
l = 32'000 mm
E = 210'000 N/mm^2
N_k = N_d / γ_Q
Δl = $(N_k / A) \cdot (l / E)$ = 22.13 mm
$\Delta l / l$ = 32.9 / 32'000 = **0.10 %**

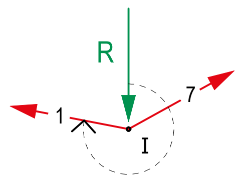
b) The deformation also changes form and force diagram so that the exact shape only can be found iteratively. As teh deformation is very small we usually neglect it.

Task 6 Dimensioning step by step

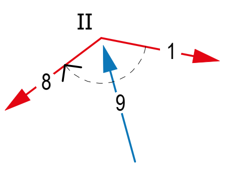
a) F_{1d}-F_{6d} = 264 kN



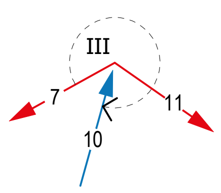
Form Diagram 1:500



Node I

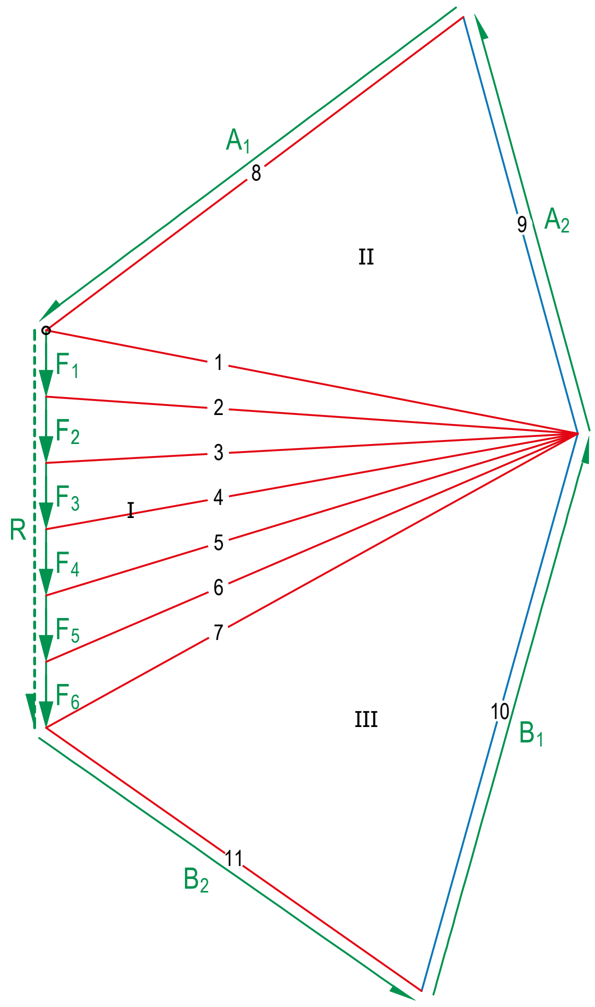


Node II



Node III

FBD



$F_{max,\ Pylon}$ = F_{10} = 2305 kN
$F_{max,\ Rückverank}$ = F_{8} = 2074 kN

1 cm ≙ 300 kN
Force Diagram

b) Starting position: N_d = 2'305'000 N

f_{cd} = f_{ck} / γ_M = 235 N/mm² / 1.05 = 223 N/mm²

Formula: A_{req} = N_d / f_{cd} = 2'305'000 N / 223 N/mm²

A_{req} = 10'336.3 mm²

Add values:

Steelprofile: ROR 219.1 · 20

D = 2191.1 mm

A = 12'500 mm²

Calculate:

Steelprofile:

c) Starting position: N_d = 2'074'000 N

A_{eff} = $(D/2)^2 \cdot \pi$ = $(89mm / 2)^2 \cdot \pi$ = 6221 mm²

f_{td} = f_{tk} / γ_M = 355 N/mm²/1.05 = 338 N/mm²

Formula:

Stress: σ = N_d / A_{eff} = 2'074'000 N / 6221 mm²

Add values: σ = 333 N/mm²

Stressanalysis: σ = 333 N/mm² ≤ 338 N/mm² = f_{cd}

Calculate:

Compare stresses: