This second part of the case study is a continuation of the last exercise on the PAT Center. After the last examination of the entire supporting structure and its main elements, we will now analyse individual elements more detailed. The moment is illustrated again on a specific component, and the internal forces in slabs as well as trusses are repeated.

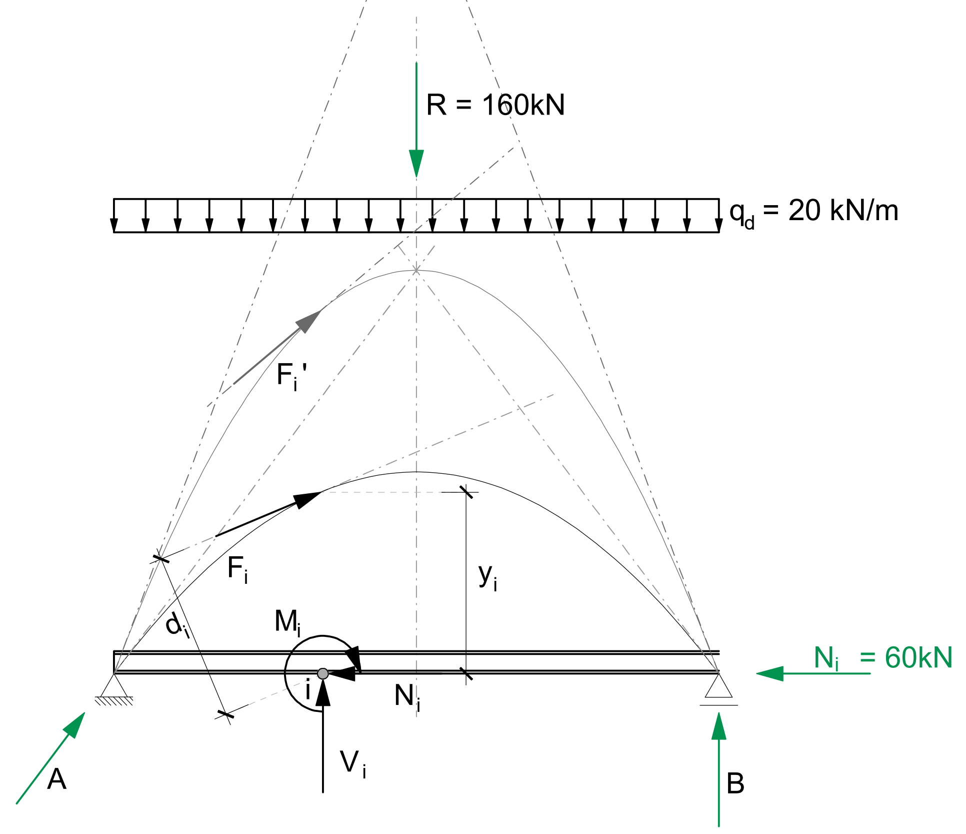
Task 1 Moment within a girder

The roof structure of the PAT Center can be interpreted as a series of individually articulated beams. Wherever a cable is attached, there is a hinge. We now look at the outermost part of the main girder. The force N_i acts in the whole element but is - for simplification - here given as an external force.

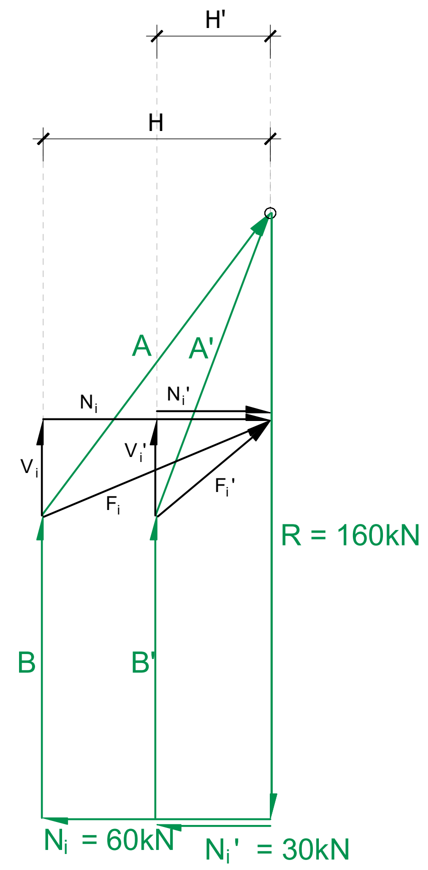
a) Draw the corresponding force diagram for the given situation. Find the direction and magnitude of the tangential force F_i using the tangent construction. Find the lateral force V_i by using graphic statics. (F_i corresponds to the addition of N_i and V_i).

b) Assume N_i is exactly half the size given in 1a). Show how the force diagram changes and use it to draw a second parabola into the form diagram. Describe the ratio of N_i (=H) to the height f of the parabola.

c) Calculate the occurring moment M_i in point i for the situation from 1a).



form diagram 1:100



force diagram 1cm ≙ 20kN

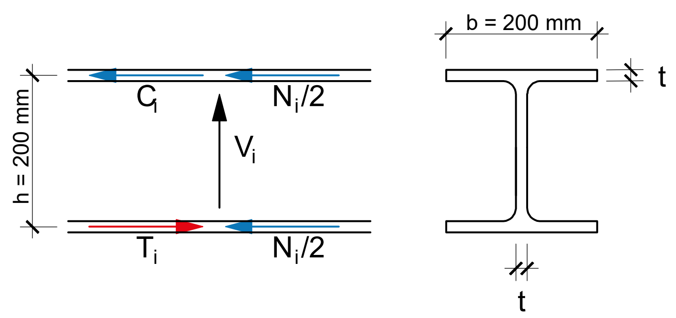
b) N_i and thus H are inversely proportional to the height f of the parabola: H = 1 / f

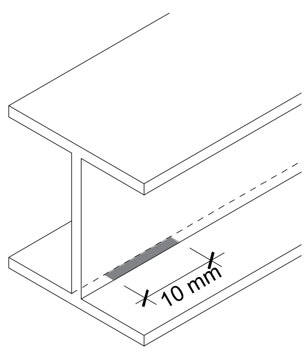
c) $M_i = H \cdot y_i$ = 60 kN · 2.4 m = 144 kNm

d) The main girder shall be constructed with the steel profile S235 as shown. The occurring moment M_i from 1c) results in the forces C_i and T_i in the upper and lower flange. The normal force N_i also acts in it. Determine the resulting flange forces.

e) Calculate the required cross-sectional area of the flange from the relevant flange force and determine its thickness t_{flange}. Round the value to whole mm.

f) The web shall be of the same thickness as t_{flange}. Check whether this can withstand the lateral force V_i acting in it. V_i is applied over a width of 10 mm.





1d)
$M_i = C_i \cdot h$
$C_i = M_i / h$ = 144 kNm / 0.2 m = 720 kN
$T_i = -C_i$ = -720 kN
$F_{upper\ flange} = C_i + N_i / 2$ = 720 kN + 30 kN / 2 = 750 kN
$F_{bottom\ flange} = T_i + N_i / 2$ = -720 kN + 30 kN / 2 = -690 kN

1e)
f_{cd} = 235 N/mm² / 1.05 = 223.8 N/mm²
$A_{req} = N_d / f_{cd}$ = 750 kN / 223.8 N/mm² = 3351.21 mm²
$A_{req} = b \cdot t$
$t = A_{req} / b$ = 3351.21 mm² / 200 mm = 16.76 mm ≈ 17 mm

1f)
$N_d / A_{ef} \le f_{cd}$
N_d = Vi = 25 kN
A_{ef} = 10 mm · 17 mm = 170 mm²
f_{cd} = 235 N/mm² / 1.05 = 223.8 N/mm²
N_d / A_{ef} = 147.06 N/mm² $\le f_{cd}$
147.06 N/mm² ≤ 223.8 N/mm²

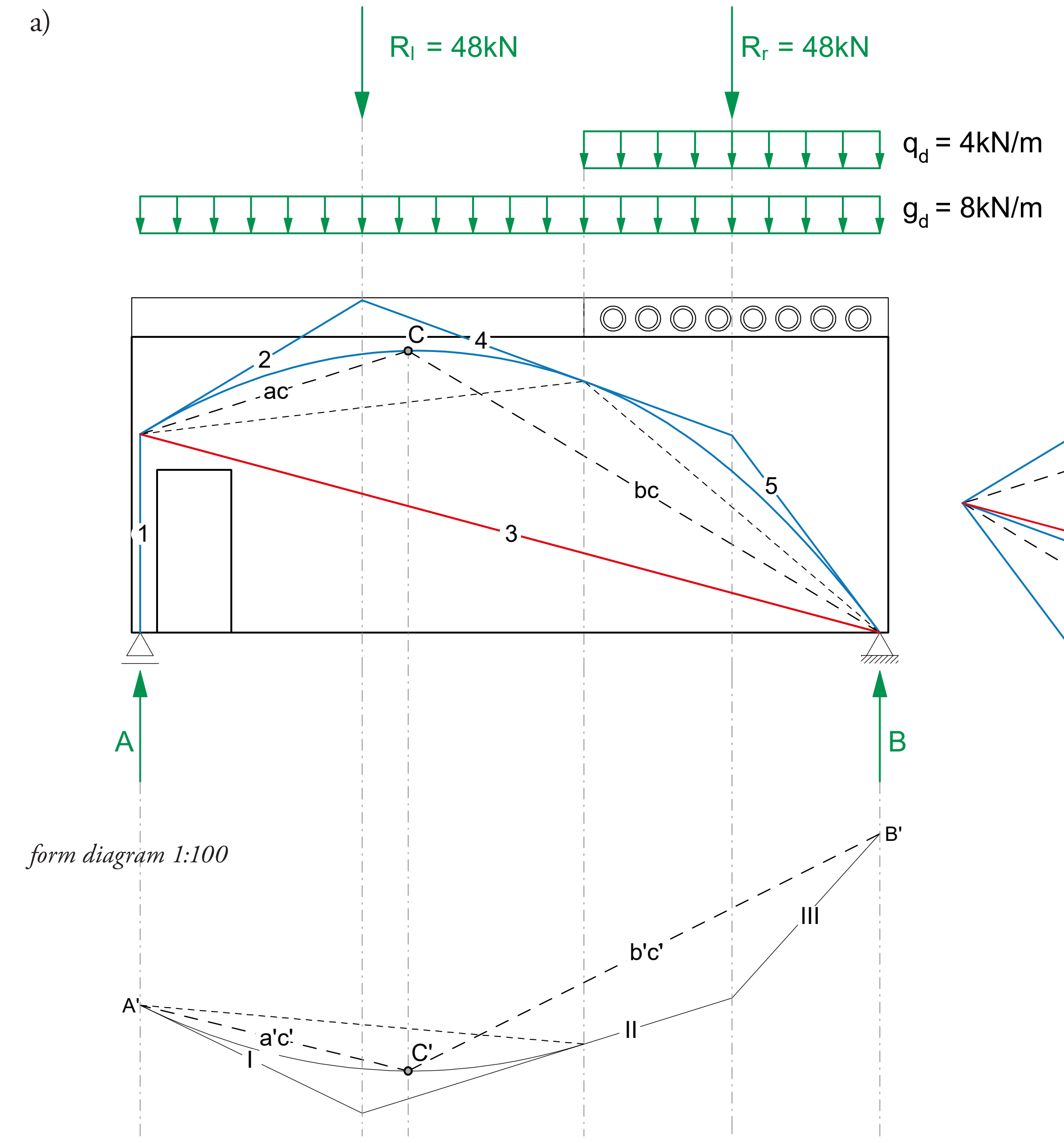
Task 2 Inner force flow

Two walls made of reinforced concrete with different supports or loads are given. These are used in the PAT Center for bracing and should therefore be able to absorb horizontal and unevenly distributed forces.

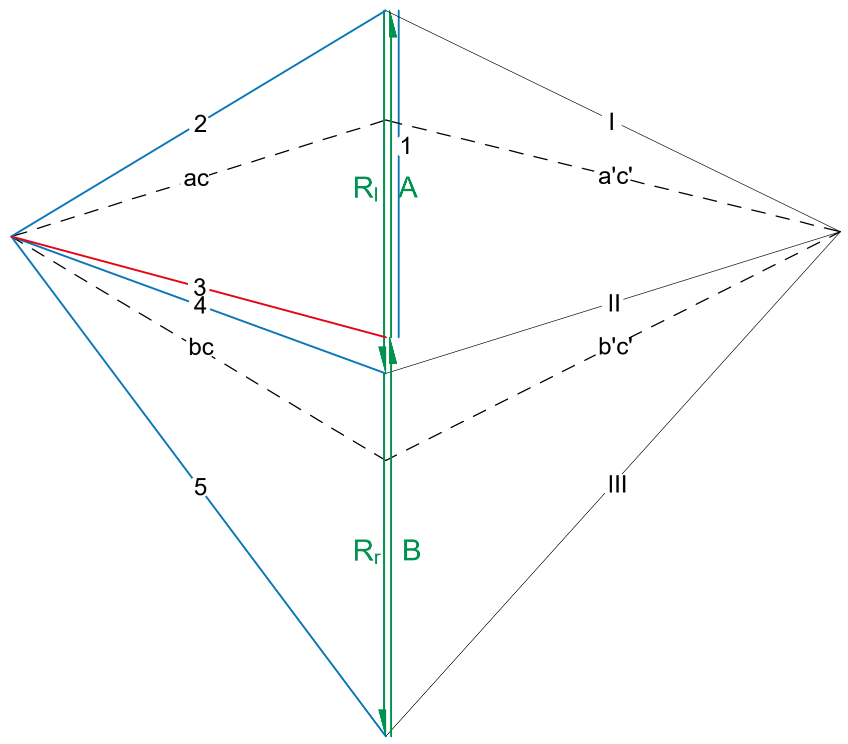
a) Find the resultants of the uneven load and determine a possible internal force flow in the form of an arch-cable structure through the given point C. Draw the corresponding force diagram and mark tensile forces with red and compressive forces with blue.

b) Find the supporting forces A and B and draw a possible internal force flow in the form of an arch-cable structure. Mind the openings in the wall. Check whether the inner static determinacy is fulfilled. Then draw the corresponding force diagram and mark tensile forces with red and compressive forces with blue.

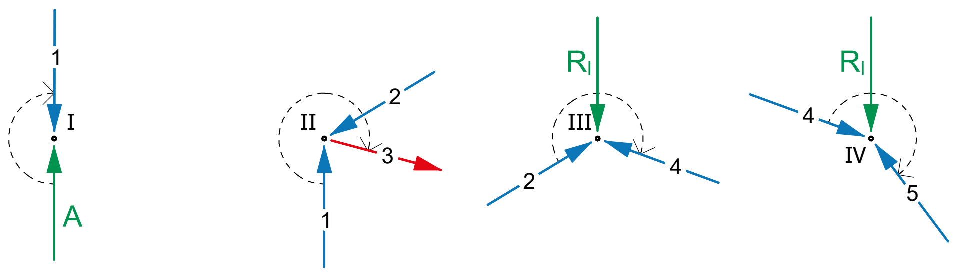
a)



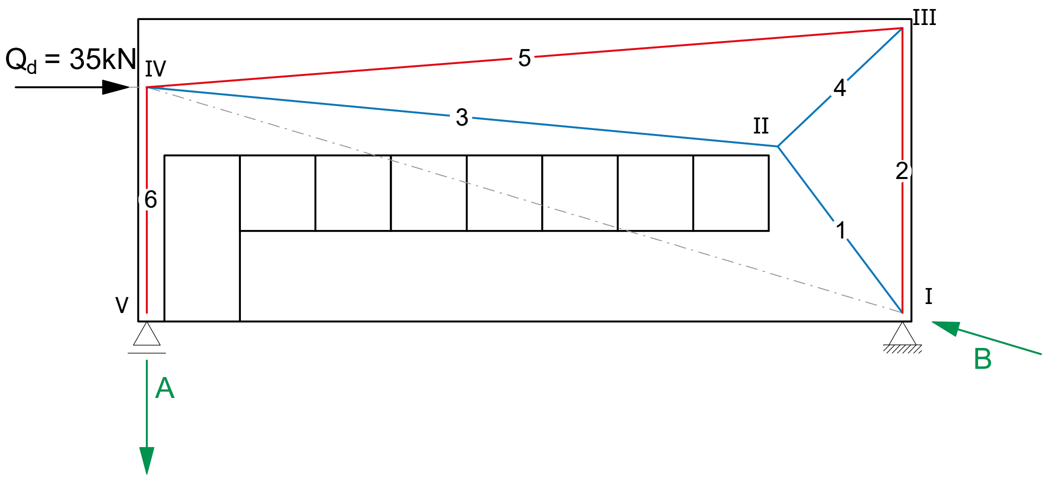
form diagram 1:100



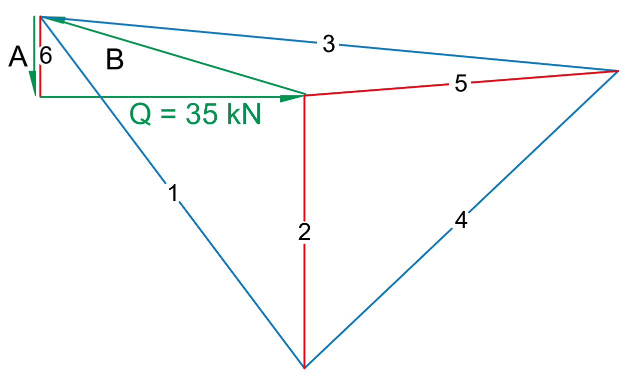
force diagram 1cm ≙ 10kN

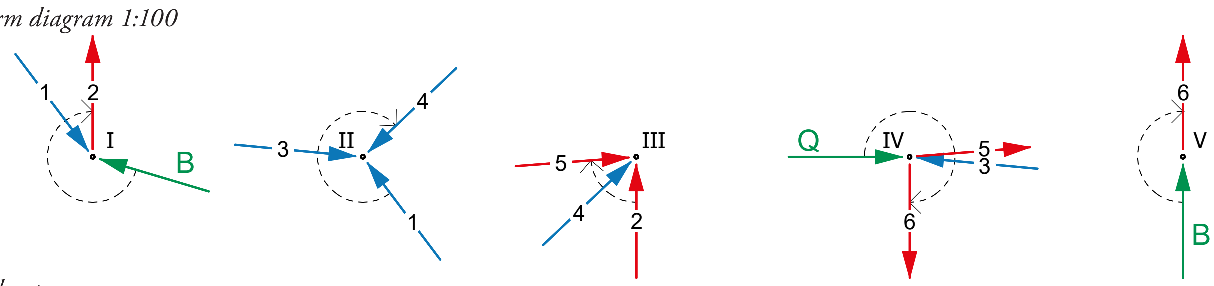


b)



form diagram 1:100



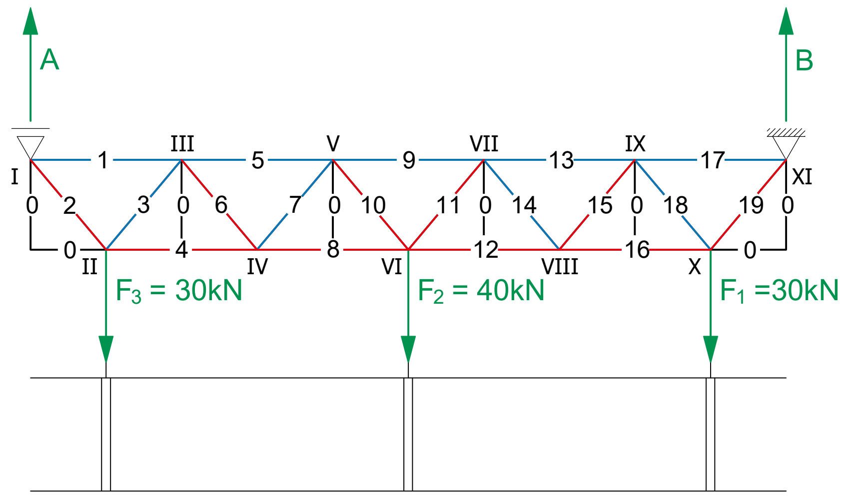


subsystem

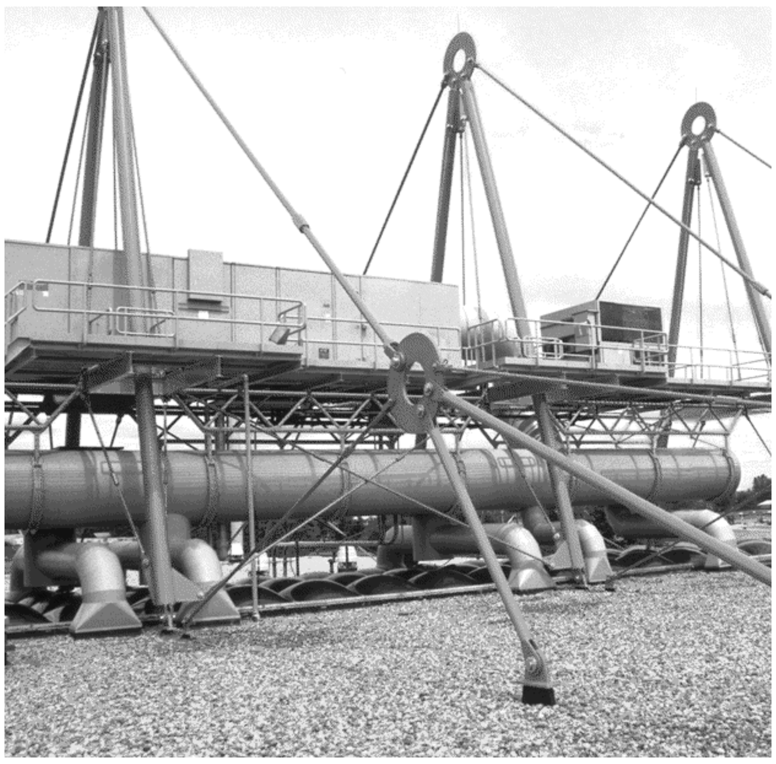
force diagram 1cm ≙ 10kN

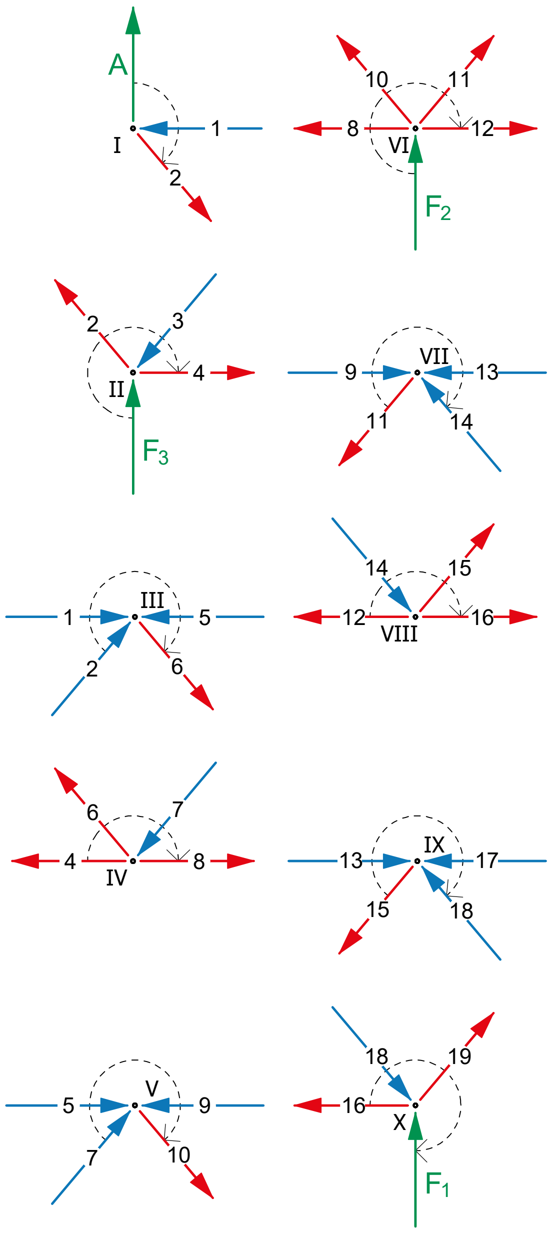
Task 3 Truss

a) The installation pipes of the PAT Center are suspended from the trusses above. Determine the two supporting forces A and B in the given situation. Draw the corresponding force diagram and mark tensile forces with red and compressive forces with blue. Determine the relevant tensile and compressive force in the truss and specify the position and the load of the respective segment.

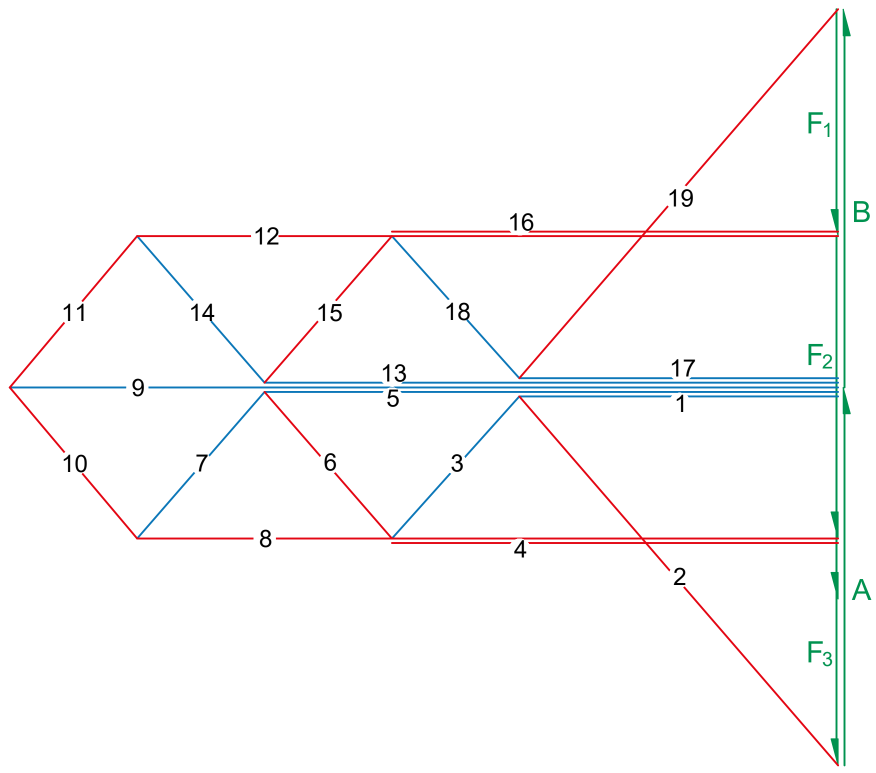


form diagram 1:200





subsystem



force diagram 1cm ≙ 10kN

	segment	load
tension	8 / 12	92.7 kN
compression	9	109.5 kN

Additional Task 1

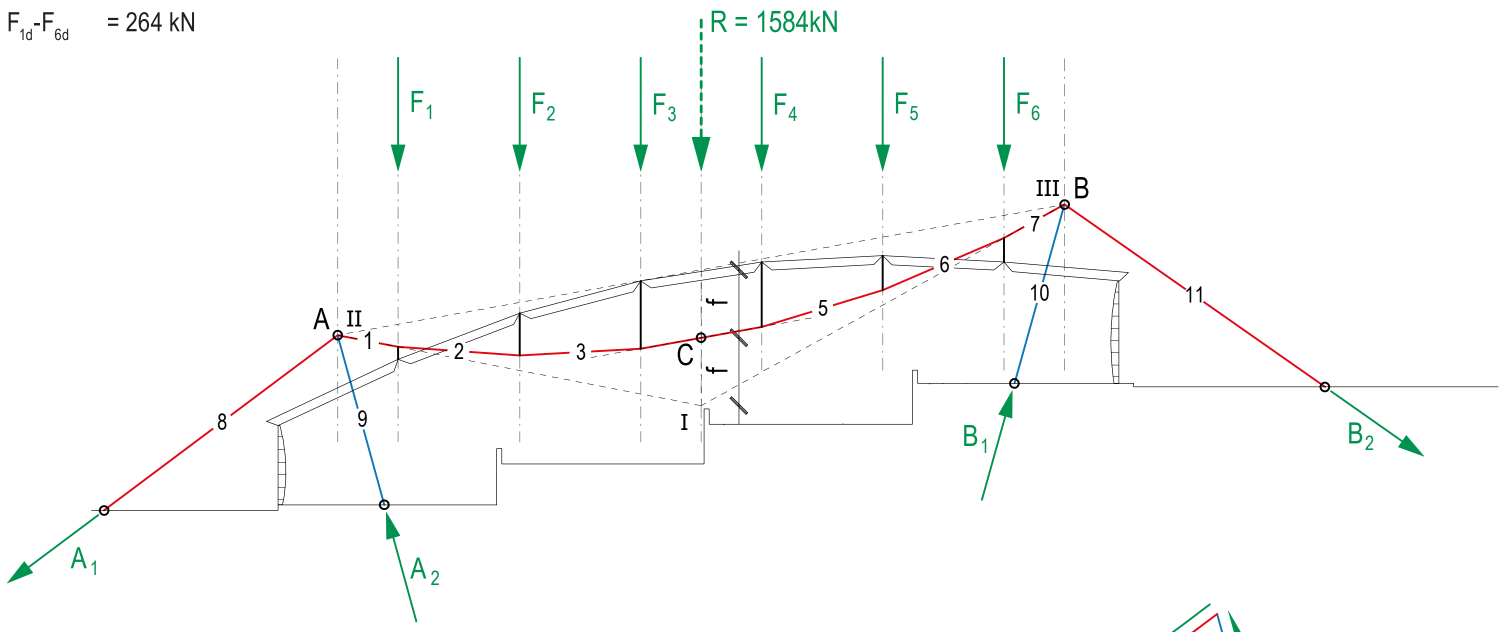
Dimensioning a roof construction

a) Find the shape of the main cable such that it passes through the points A, B and C. Draw the force diagram and determine the maximum force in the pylon and the backstay.

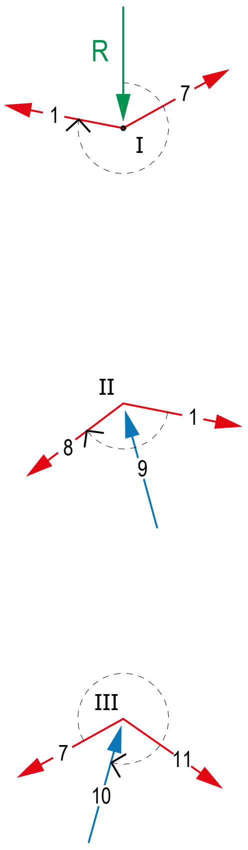
b) Calculate the cross-section of the pylon (S235) and find the coresponding ROR-profile in the steel profile chart.

c) The diameter D=89mm of the backstay (S355) is given. Do a stress check.

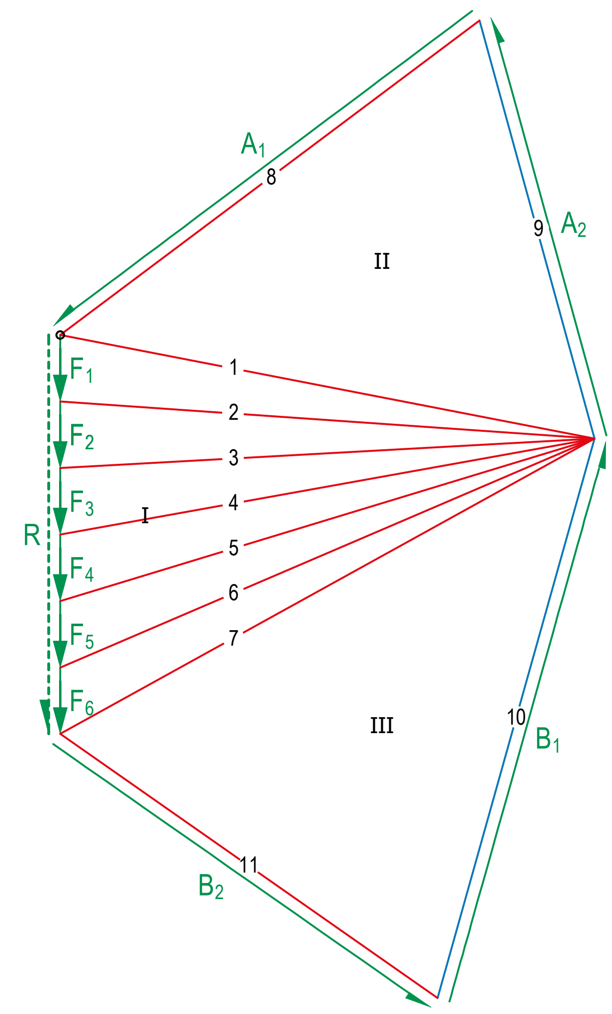
a)



form diagram 1:500



subsystem



$F_{max,\ pylon} = F_{10} = 2305$ kN

$F_{max,\ backstay} = F_8 = 2074$ kN

force diagram 1cm ≙ 300kN

b)

N_d = 2'305'000 N

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

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

A_{req} = 10'336.3 mm²

steel profile:

ROR 219.1 · 20

D = 219.1 mm

A = 12'500 mm²

c)

N_d = 2'074'000 N

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

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

stress:

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

σ = 333 N/mm²

comparison of stresses:

σ = 333 N/mm² ≤ 338 N/mm² = f_{td}