

Introduction Objective

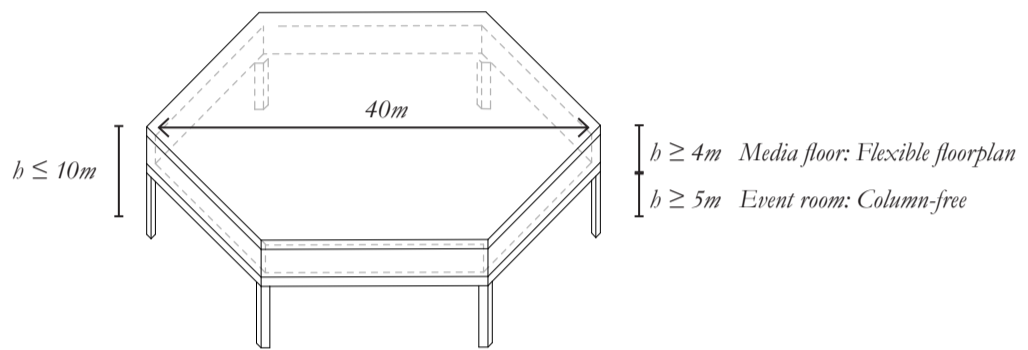
The exercises of Structural Design III deepen the understanding of the relationship between force, form and material with the help of graphic statics. These exercises illustrate the design process of a structure built from one of the main building materials: steel, reinforced concrete, timber and masonry. We will look at the following design steps: brief discussion of the concept, calculation of the relevant loads, global equilibrium, internal force flow, variations of topology-topology-geometry, design for both vertical and horizontal loads and material properties.

For further reading, the following literature is recommended:

- Script «Tragwerksentwurf III-IV», Page 1 - 24: Erläuterungen zum Konstruieren in Stahlbeton
- Script «Tragwerksentwurf III-IV», Page 80 - 84: Erläuterungen zum dreidimensionalen Tragwerkskonzept vom Wohnhaus Forsterstrasse
- Script «Tragwerksentwurf III-IV», Page 139 - 152: Materialanhang zum Beton, Stahlbeton und Spannbeton

Architectural conditions

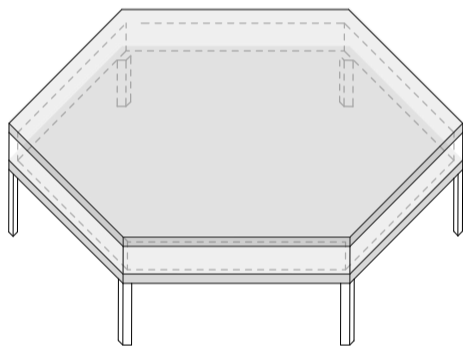
The following architectural conditions are given: The height of the building does not exceed 10 meters. The event room on the ground floor is column-free and has a minimal height of 5 meters. The upper floor for media representatives has a flexible floorplan with a minimal height of 4 meters.



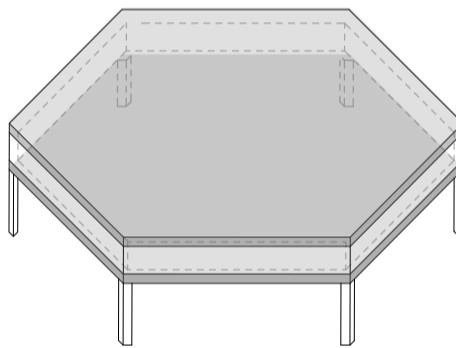
Pre-dimensioning

The table on page 1 of the attachment «Lasten und Kennwerte» offers reference values for the slenderness of structures. Below are three different initial thoughts for the roof construction. Evaluate with the help of the table if these initial thoughts fulfill the architectural conditions.

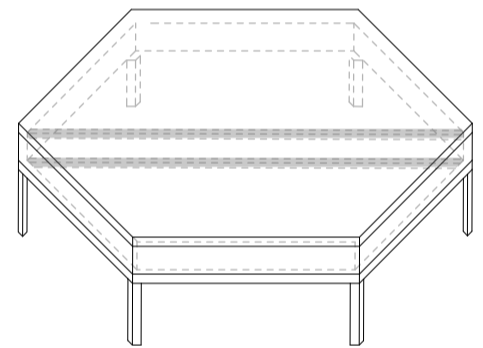
Slabs in reinforced concrete



Slabs in prestressed concrete



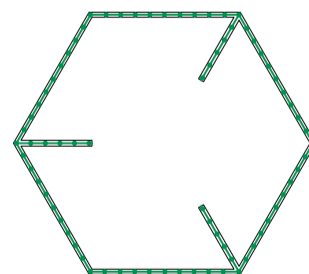
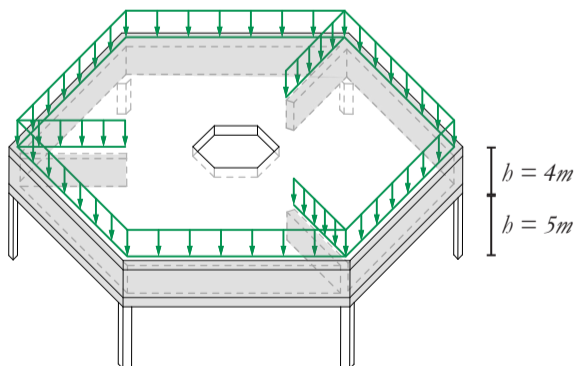
Beam in prestressed concrete



Help: File «Lasten und Kennwerte» → P.1

Idea for the structural design

It is decided to install walls (10m * 4m * 0.3m) on the media floor in order to reduce the span and thus the thickness of the roof structure to 50 cm. In the following tasks you will develop and analyze different variants of this decision. Calculate the dead load as well as the live loads applied on the structure (illustration on the left). Then calculate the forces in all load-bearing walls (illustration on the right).



Help: area of hexagon: $(3\sqrt{3} * l^2) / 2$ l : length of a side →

Task 1 Transfer of vertical loads: design variation 1

The Structure is a slab-wall system supported on 6 columns.

1a Global equilibrium & qualitative forceflow

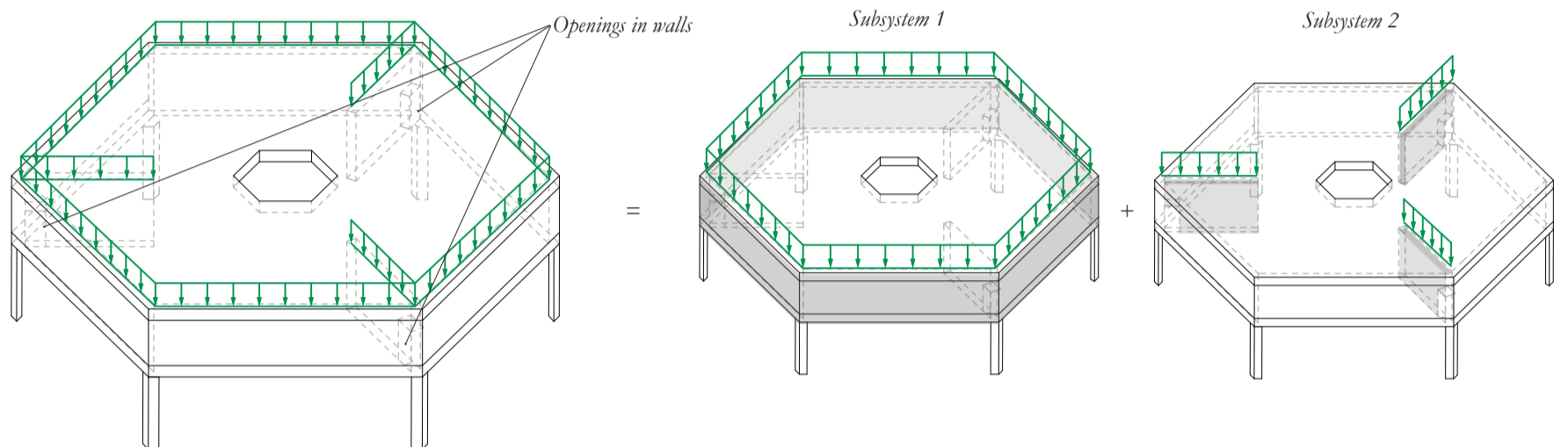
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«Script TE
3-4» P.83,
«Faustformeln»
P.243

→

In order to better understand the force flow in a complex three-dimensional structure, it is possible to subdivide it into separate subsystems acting together for forming a global equilibrium state.

In the axonometry drawings below, draw a possible qualitative force flow as well as the reaction forces for the given load case.

Use the two given subsystems (subsystem 1: periphery walls and subsystem 2: interior walls) in order to develop the three-dimensional qualitative force-flow in 2 steps. Use the colours red for tension, blue for compression and green for the reaction forces in the supports.

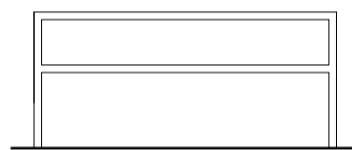


1b Quantitative forceflow

Subsystem 1

Wall section

Force plan (1cm:250kN)

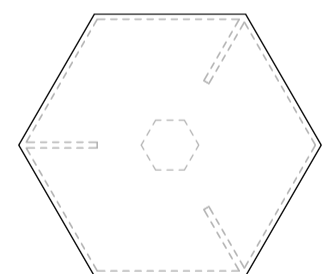
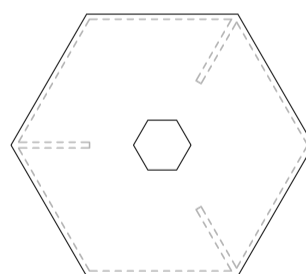
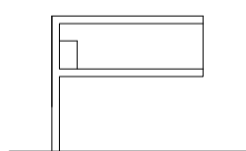


Subsystem 2

Wall section

Floor plan (upper roof)

Floor plan (lower roof)



Force plan (1cm:3000kN)

Force plan (1cm:3000kN)

Force plan (1cm:3000kN)

1c Is there only one possible path of internal forces within the structure?

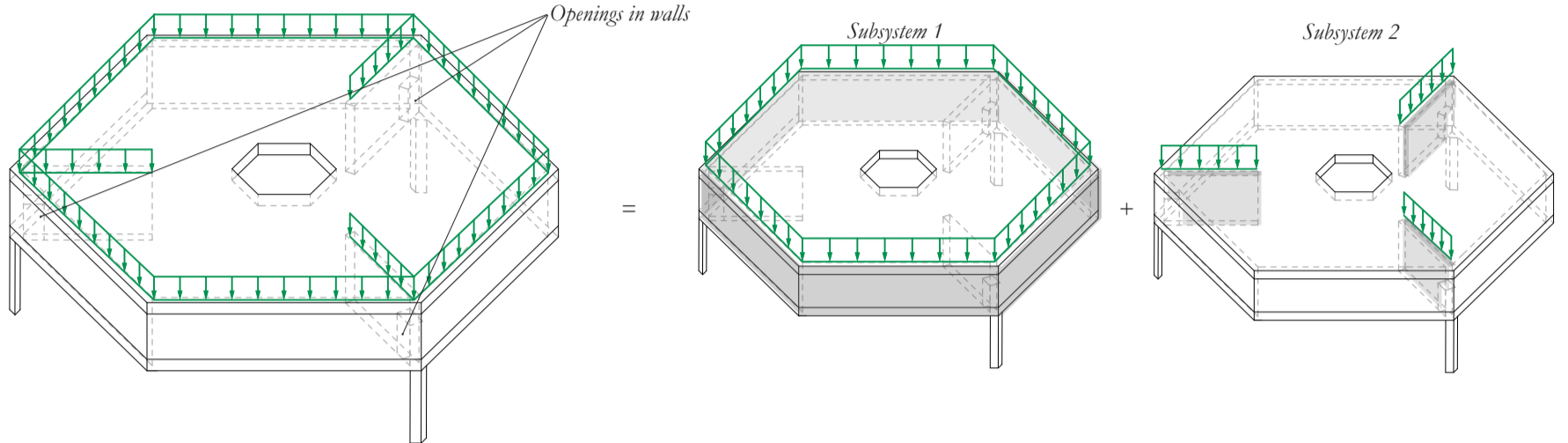
1d What are the advantages of using post-tensioning?

Task 2 Transfer of vertical loads: design variation 2

The Structure is a slab-wall system supported on 3 columns.

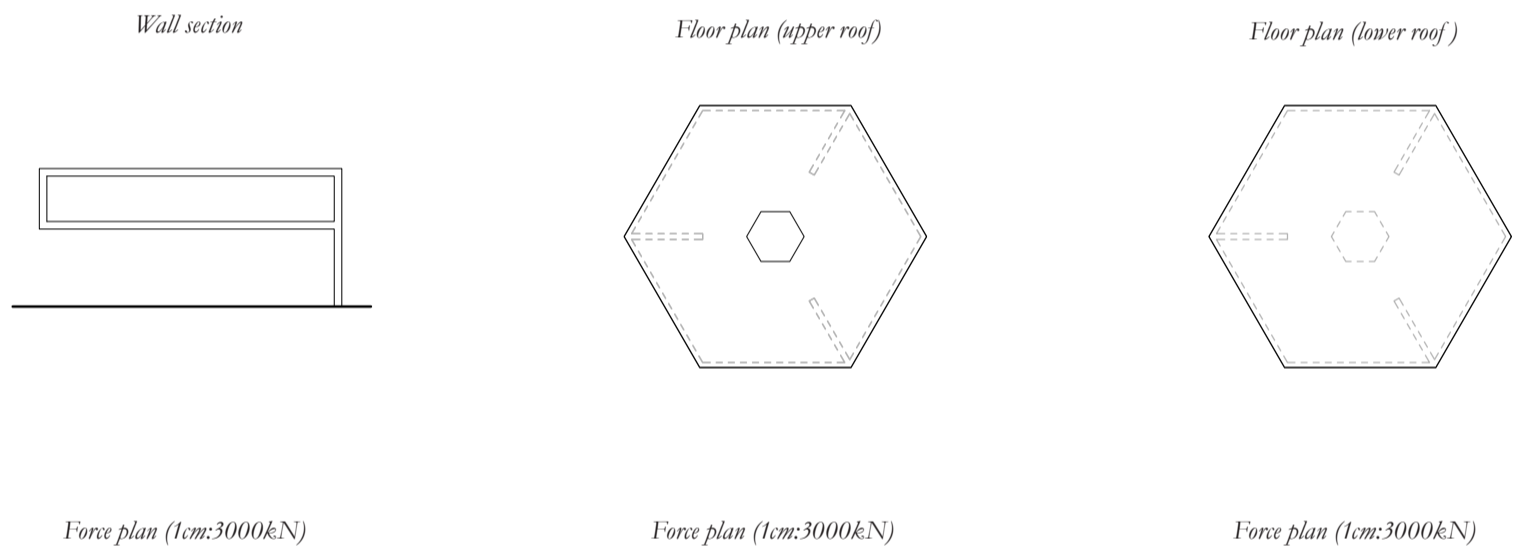
2a Three dimensional qualitative forceflow

To obtain a flexible floor plan, the numbers of columns are reduced to only 3. Draw in the axonometry drawings below, a possible qualitative force flow as well as the reaction forces for the given load case. Use the two given subsystems (periphery walls and interior walls) in order to develop the three-dimensional qualitative force-flow in 2 steps. Use the colours red for tension, blue for compression and green for the reaction forces in the supports.



2b Quantitative forceflow

Subsystem 1



Subsystem 2

2c Dimensioning of elements

Determine the cross-sectional area of a column. Reinforced concrete C25/30 is used.

Help: File «Lasten und Kennwerte» → P.4

Help: «Skript TE 3-4» p.17, diagram 17, Concrete cover

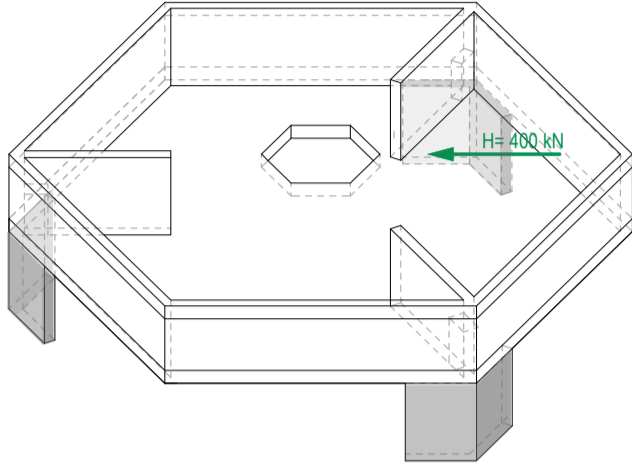
Determine if buckling occurs. Square full-profiles are used. To simplify, the critical lengths can be assumed to be the actual length of the element. ($l_{cr} = l$)

Help: File «Lasten und Kennwerte» P.9

Task 3 Transfer of horizontal forces

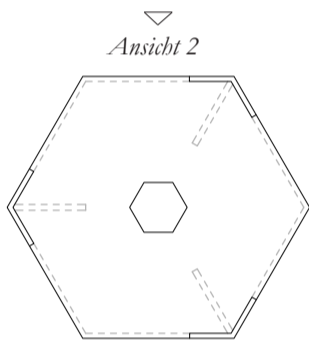
- 3a** Evaluate the structure of the previous page with the case of horizontal forces. Discuss possible improvements to achieve adequate stability under horizontal forces.
- 3b** Below are two possible solutions to achieve horizontal stability. Draw a possible force flow for both variants under horizontal forces. Use the colours red for tension, blue for compression and green for the support forces.

Variant 1



Floor plan (upper roof)

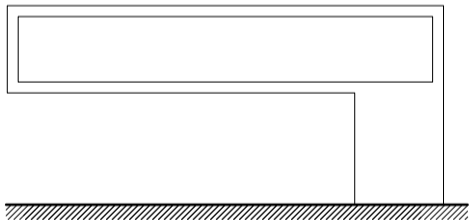
Force plan (1cm:100kN)



Ansicht 2

View 1

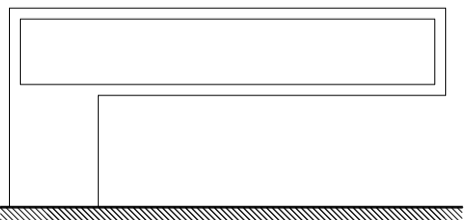
View 1



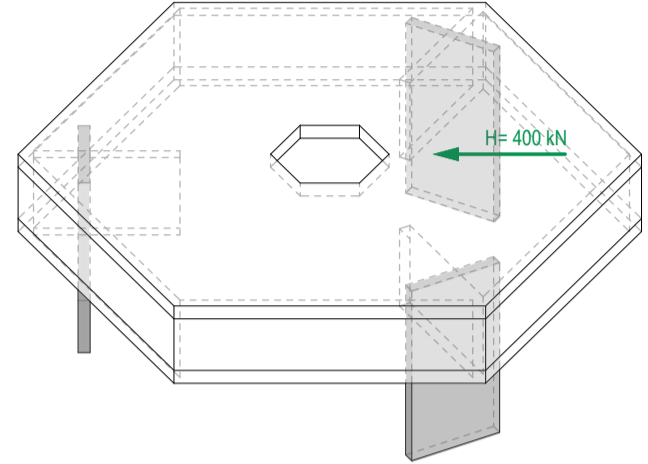
Force plan (1cm:100kN)

View 2

Force plan (1cm:100kN)

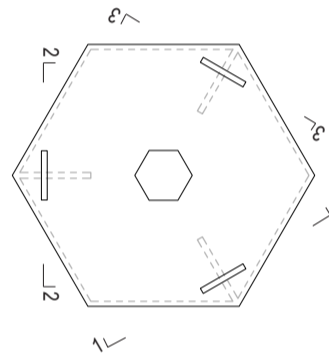


Variant 2



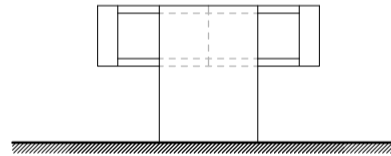
Floor plan (lower roof)

Force plan (1cm:100kN)



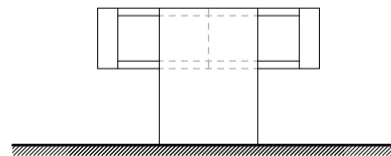
Section 1-1

Force plan (1cm:100kN)



Section 2-2

Force plan (1cm:100kN)



Section 3-3

Force plan (1cm:100kN)

