SZÉCHENYI ISTVÁN EGYETEM
SZE - GYŐR

DESIGN OF STRUCTURES 2.

05. Design aspects

Kitti Ajtayné Károlyfi
Assistant lecturer

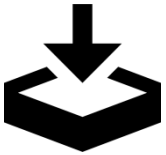
2019. 10. 17.

Content

* Types of stresses
* The role of span
* Changes in stresses
* Structural model
* Simplification assumptions
* Calculation of loads
* Classification of structures

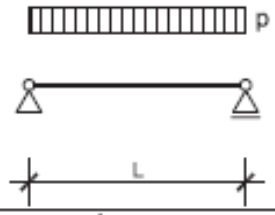
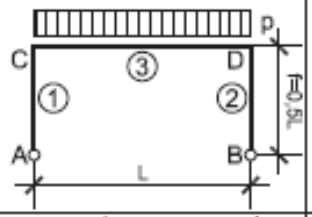
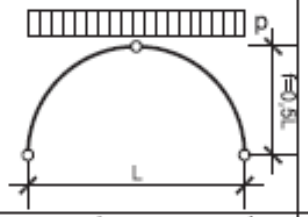
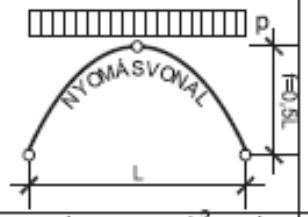
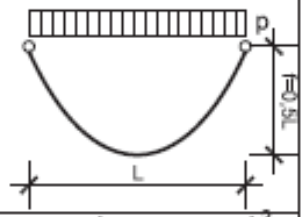
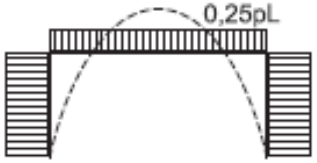
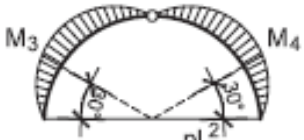
Types of stresses

* The type and value of stresses depends on
  * The loading
  * Statics of the structure



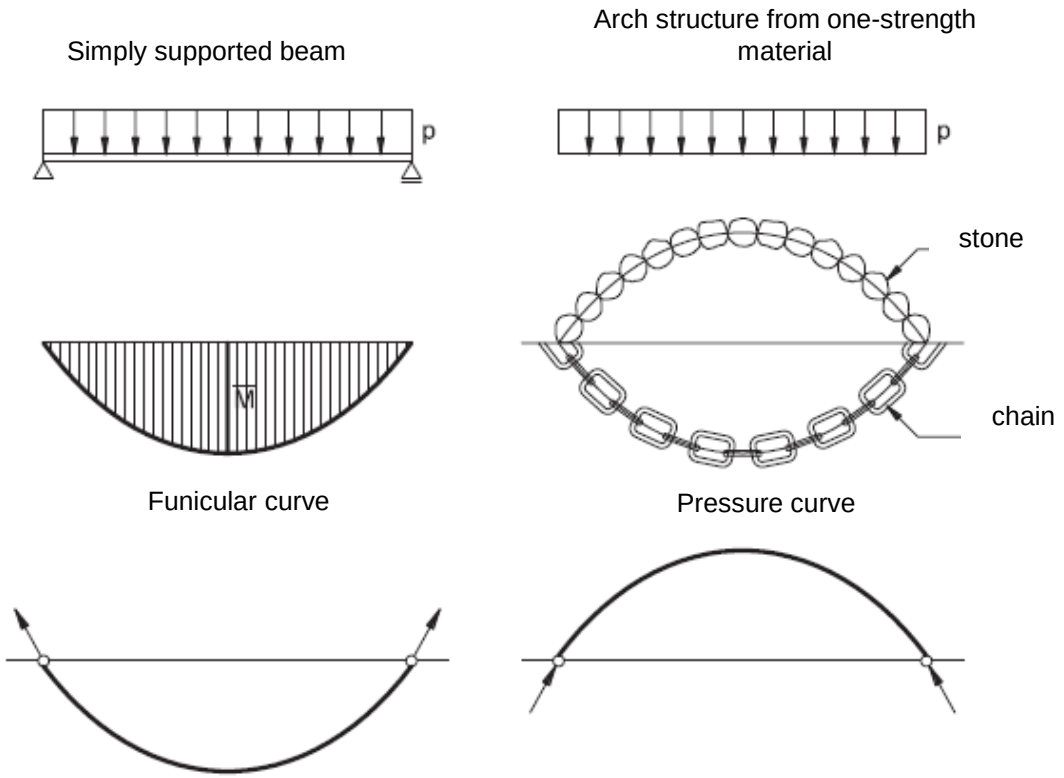
* The total load of the structure is usually taken into account as a main, characteristic load
* Different stresses may occur in different structures under this main load

Types of stresses

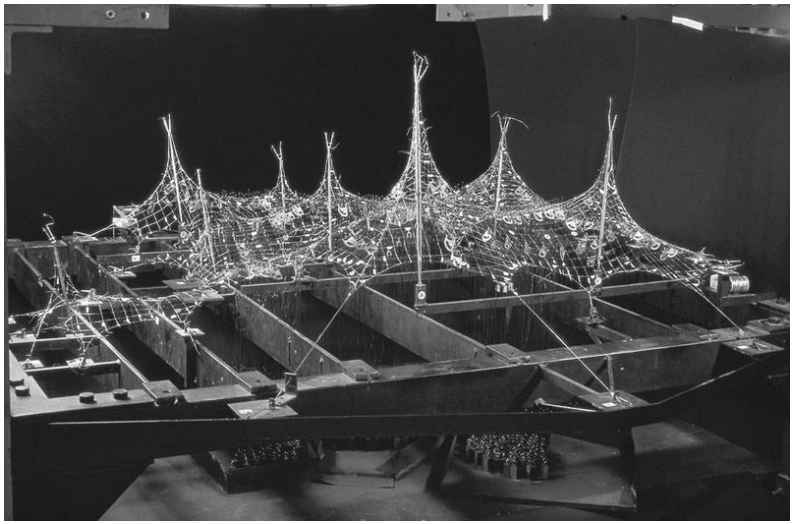
	Simply supported beam	Frame	Circular beam	Arch	Rope
					
	$A_y=\frac{pL}{2}$; $A_x=0$	$A_y=\frac{pL}{2}$; $A_x=\frac{pL}{8}$	$A_y=\frac{pL}{2}$; $A_x=\frac{pL}{4}$	$A_y=\frac{pL}{2}$; $A_x=\frac{pL^2}{2f}=\frac{qL}{4}$	$A_y=\frac{pL}{2}$; $A_x=\frac{pL^2}{8f}$
N			 N_{max}= 0,56pL	 N_A= 0,61p ; N_C= 0,25pL	 $N_A=\sqrt{A_x^2+A_y^2}$= 0,61p
T	 T_{max}= 0,5pL				
M	 $M_{max}=\frac{pL^2}{8}$	 $M_1=M_2=M_C=\frac{pL^2}{16}$	 $M_3=M_4=\frac{pL^2}{32}$		

Types of stresses

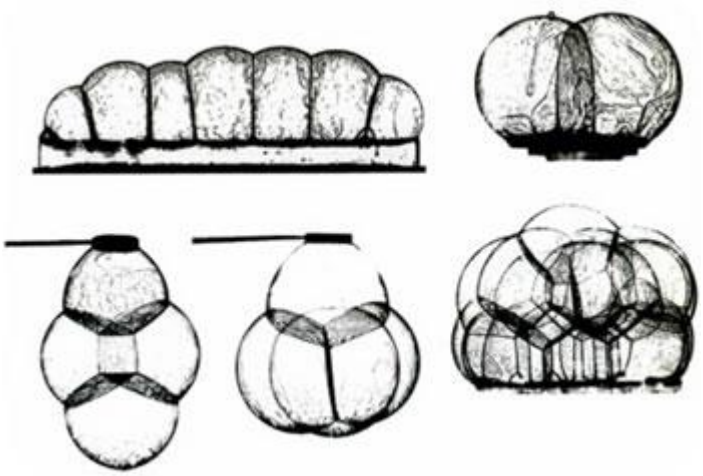
In structures with the shape of funicular or pressure curve only tension or compression occurs, bending moment does not.

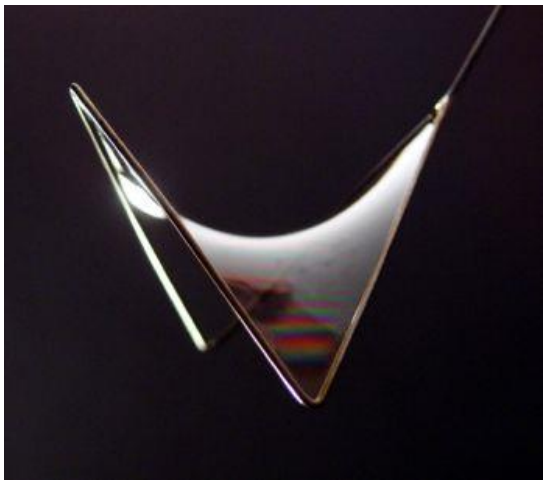


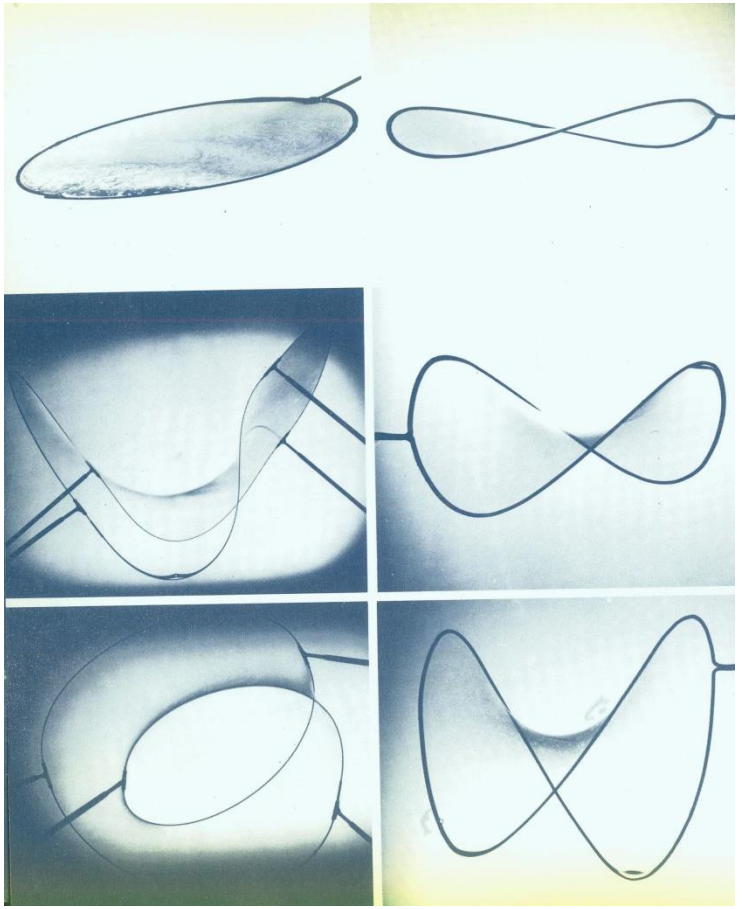
Form finding methods



Form finding methods







Changes in stresses depending on statical model

It is important in the statical model point of view:

* The types of joints (hinged/fix)
* The types of supporting
* Use of cantilevers
* One or two-way load bearing

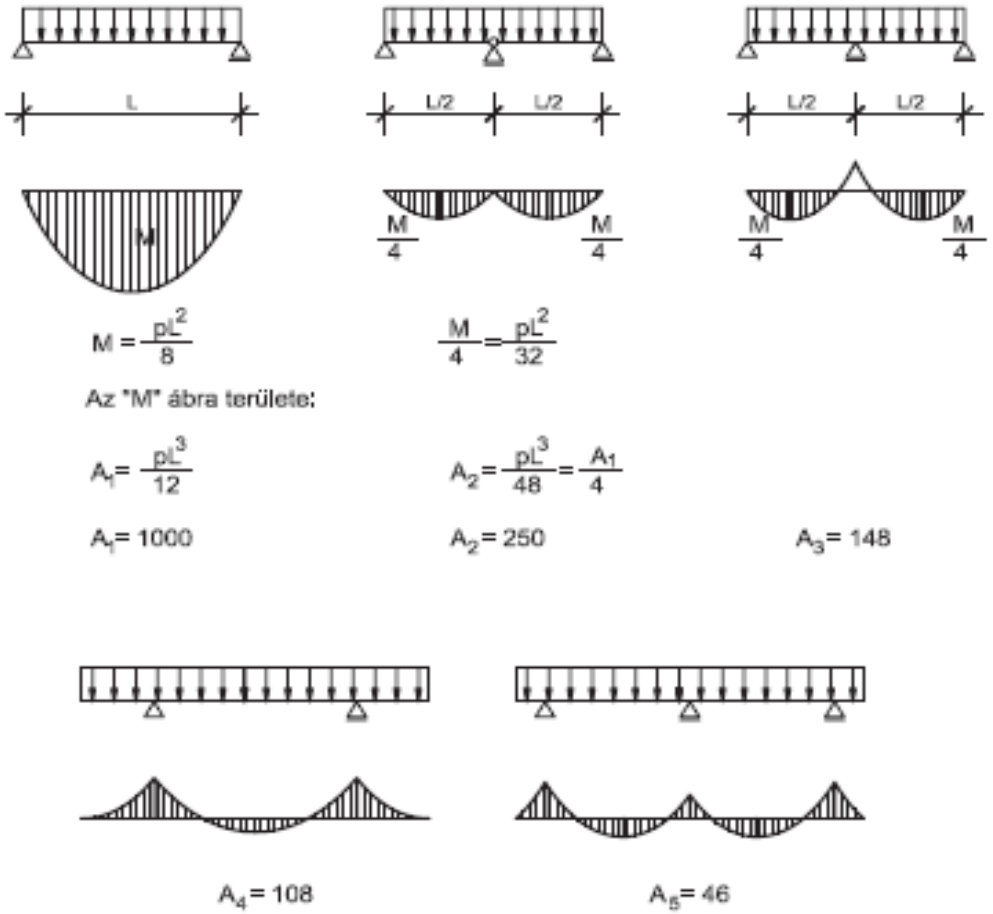
The role of span

In the case of identical structural model and loading:

* The stresses increase with the increase of the span

In the case of uniformly loaded, bended structures:

* Shear forces increase linearly with increasing span
* Bending moment increase quadratically with increasing span



Changes in stresses

Examinations of different structures with the same materal, cross section and loading → correlations between the structural model and span

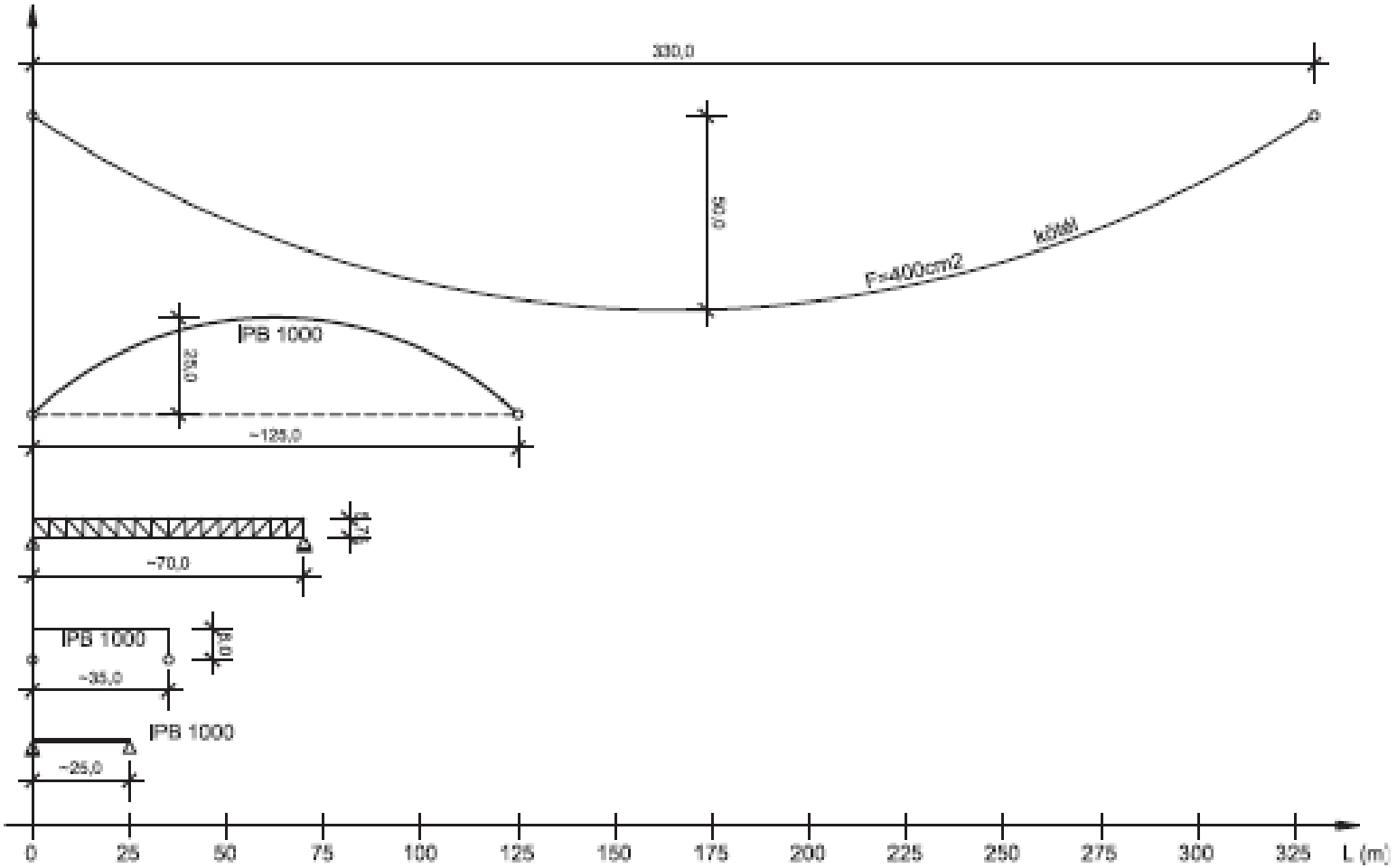
Example:

* Height: 1 m
* Standard hot-rolled steel section
* Beams in 6 m distance of axles
* Live load: 3,0 kN/m^2
* Dead load: 2,0 kN/m

Main load: p=6 × 3+2=20 kN/m

→ Structures without shear force and bending moment are less sensible to the span – it is more favourable for wide span structures

Changes in stresses

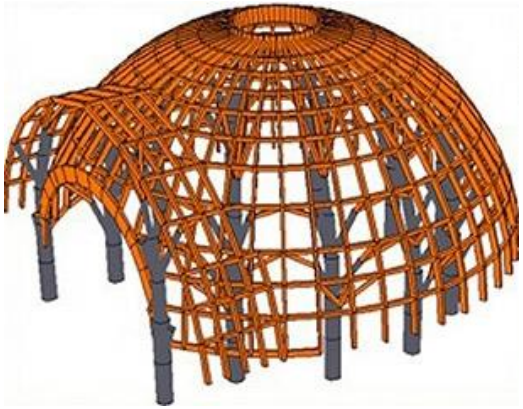


Structural model

Building

Simplification to the benefit of safety

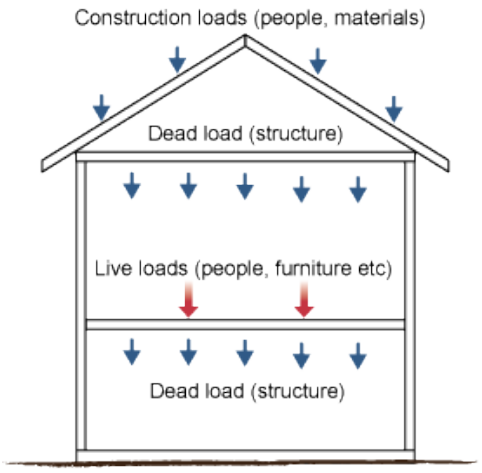
Structural model

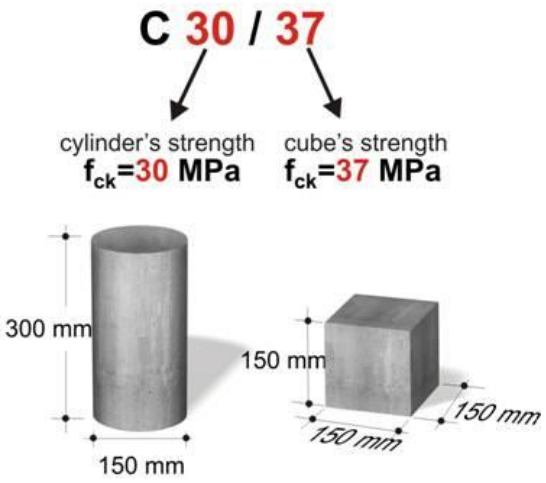


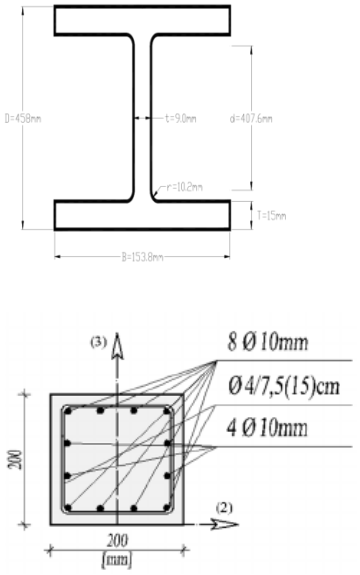
Design objects

In each part of the structure we have to

* Define the stresses caused by loads and actions
* Design the materials and cross sections capable of these stresses







Model construction

Most important questions:

* What kind of loads may occur?
* How does the structure behaviour?
* What is the role of the different parts in the mechanism?
* How are the different parts of the structure connected?
* In what way are the loads trasmitted?

Model construction

* The calculation work needed for the task and the success of the project depends on the model construction
* Model construction includes:
  * Highlighting the main characteristics and actions of the structure
  * And neglecting the less important actions without reducing safety

Model construction

* In more complex situations the calculation can be done based on more models
* Simplification of the joints:
  * hinged
  * fixed
* neglecting the possible bending moments for the benefit of safety

Design of structures

We have widespread knowledge about the calculation of structures based on:

* Theroetical research
* Results of experiments
* Experiences from the practice

The entire building can be taken into account with approximation of different depths

Design of structures

* Instead of the examination of the „accurate” model, usually simpler models are used with approximations to the benefit of safety

* Approximate calculation can be also used in computer aided design for checking of the results with a precision of 80-90%.
  * Input data: geometry, material properties, loading

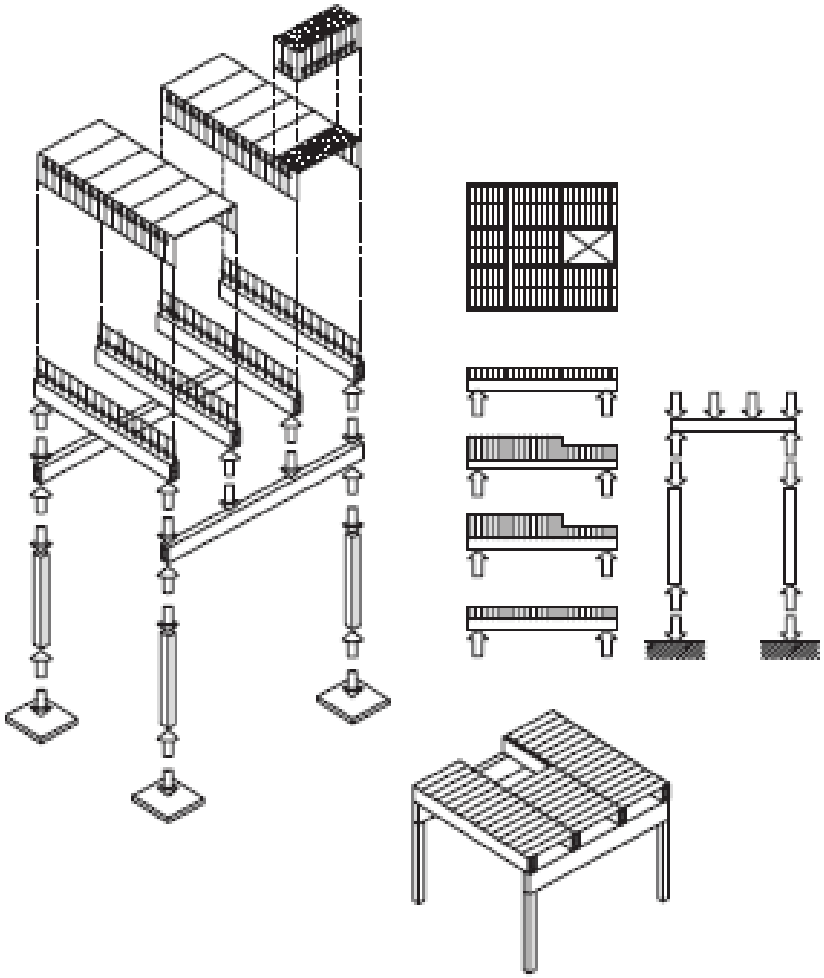
Simplification assumptions

* Spatial structures can be replaced by more planar structures
* Typical rectangular structures:
  * Vertical walls and columns
  * Vertical slabs
  * Which are perfectly rigid in their own plane

Simplification assumptions

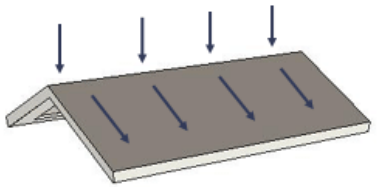
* The transmission of the loading should be examined top-down

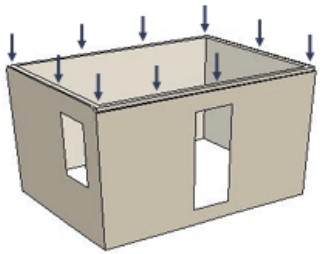
* Examination of the proper load transfer between the horizontal and vertical structural elements

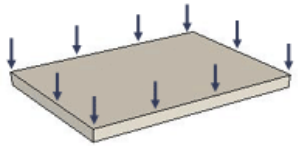


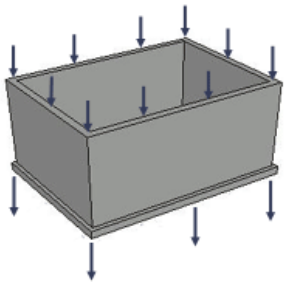
Simplification assumptions

* Usually there is an assumption for the joints:
  * The load transfer is frictionless
  * Which means that the friction should not be taken into account for load transfer
  * The hierarchy of the structural elements is a key factor in examination of the load transfer





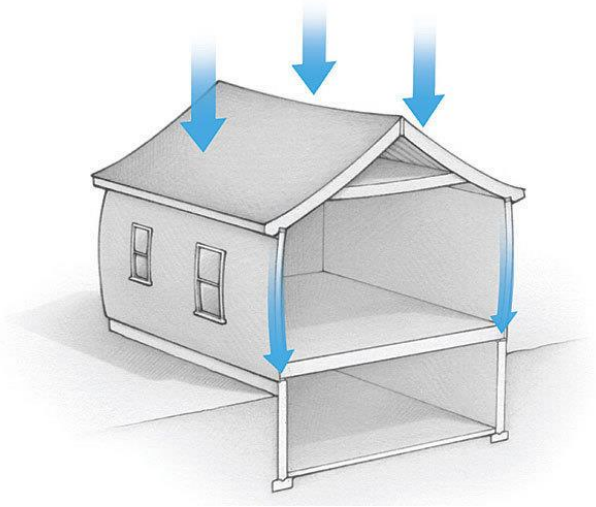




Calculation of loads

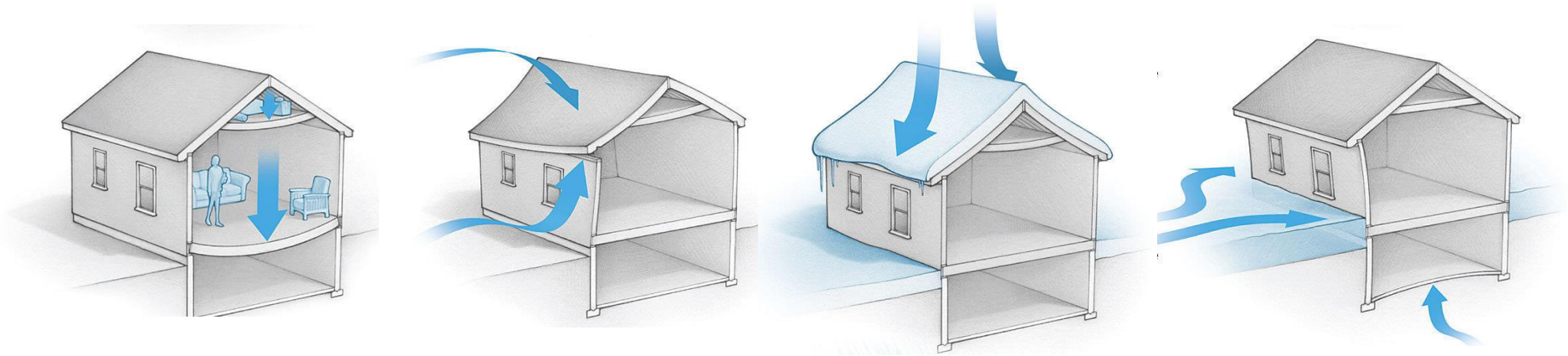
Tasks of the „weight analysis”:

* Permanent actions:
  * Defining the self-weight of the structures
  * And the loads from additional structures
    * In the case of slabs: distributed surface load
    * In the case of beams: distributed linear load
    * In the case of concentrated actions: point load



Calculation of loads

* Variable actions:
  * Live loads
  * Wind loads, snow load
  * Additional actions
* Design values of the actions = Normal value x safety factor



Calculation of loads

Approximation of loads:

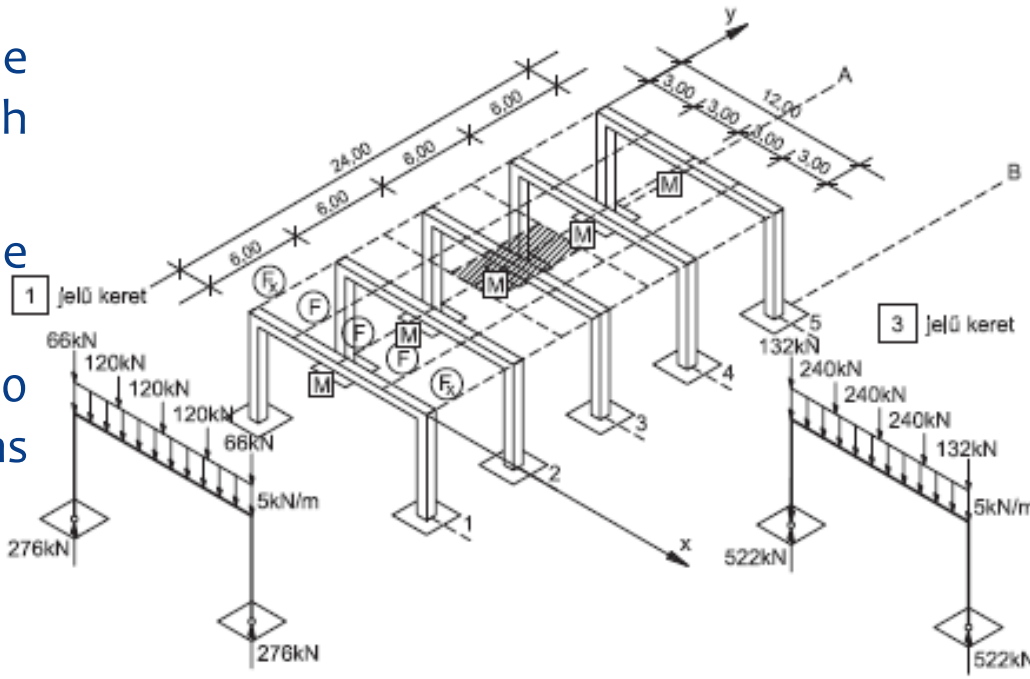
* Leightweight roof structure (wood or metal) : 3,0 kN/m^2
* Slabs:
  * Residence: 12,0 kN/m^2
  * Public building: 15,0 kN/m^2
* Wind load (compression and suction)
  * Until the height of 20 m: 1,0 kN/m^2

Calculation of loads

* Determination of the load transfer requires defining
  * the joints
  * the structural model of the entire building
  * and the structural model of the different elements.

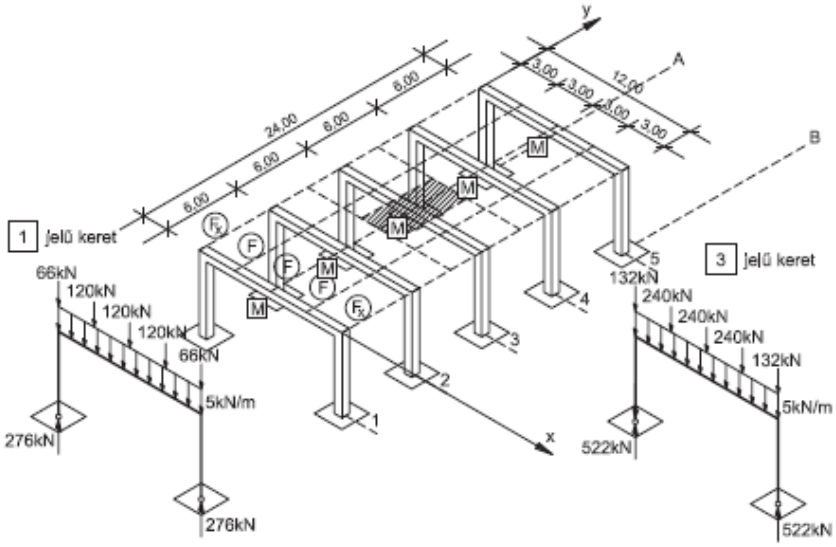
Calculation of loads

* Hall structure
* Simply supported roof beams in „x” direction rest on the girders in „y” direction (marked with „F”)
* The girders trasmit the loads to the beams marked with „M”, which transmit them to the columns
* The design value of the loading of the roof structure is 12,0 kN/m^2,
* The dead load of the girders is 4,0 kN/m, and the dead load of the beams is 5,0 kN/m



Calculation of loads

* The loading of the girders marked with „F”: (span: 6,0m, distance of axle: 3,0 m)
  * pF = 3 · 12 + 4 = 40 kN/m
* The point load at the end of the girders:
* Intermediate girders:
  * Q1 = 40 · 3 = 120kN
* Extreme girders:
  * Q1 x = (1,5 · 12 + 4) · 3 = 66kN
* The point load of the columns „A” and „B” from the intermediate beams („M2”)
  * P2 = 2 · (66 + 120 + 60) + 6 · 5 = 522 kN
* The point load of the extreme columns from the beams marked with „M1”:
  * P1 = 66 + 120 + 60 + 6 · 5 = 276kN



Classification of structures

Structures can be classified based on their:

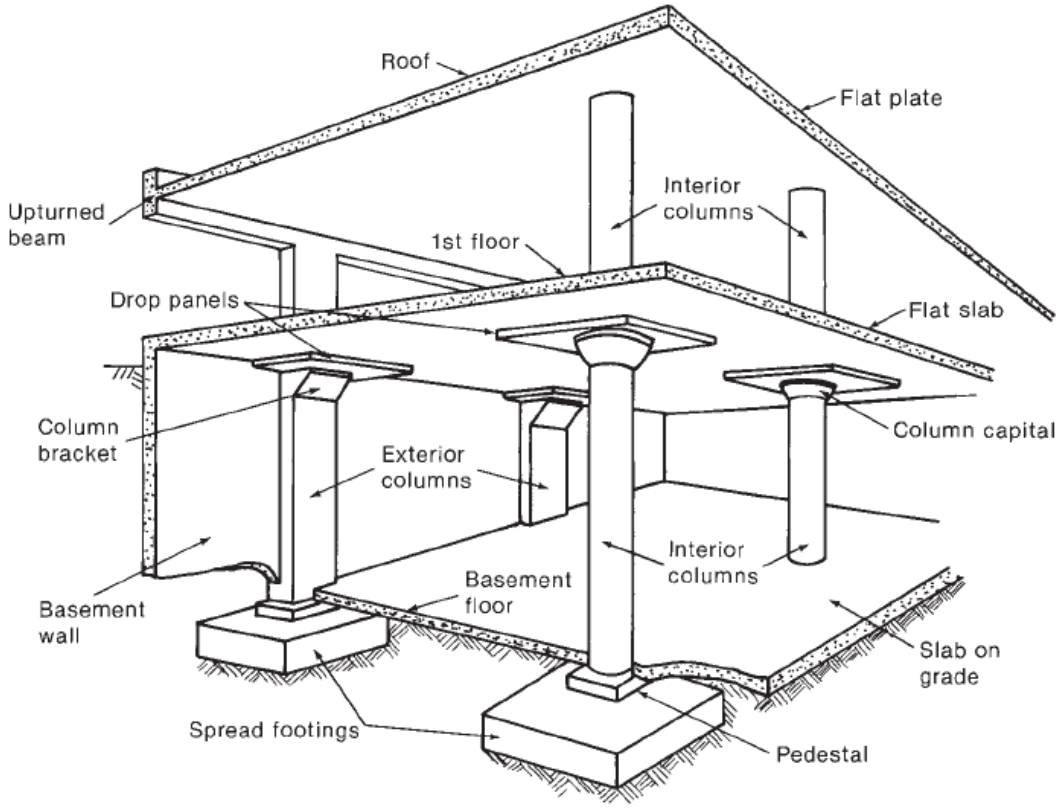
1. function
2. material
3. load path
4. main stresses
5. direction of load-bearing
6. shape

1. Function of the structure

* The primary task of the load-bearing structures is to transmit the loads to the ground in a way that the building can keep its equilibrium without any significant movement, deformation or crack

1. Function of the structure

* Foundations
* Vertical load-bearing structures:
  * Walls, columns, pillar
* Horizontal load-bearing structures:
  * Slabs, beams
* Roof structure
* Stairs



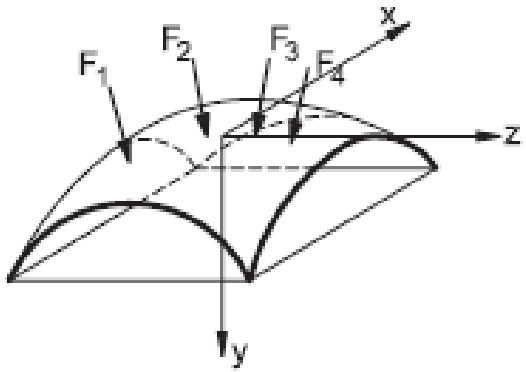
2. Material of the structure

* – stone, brick
* – timber, glued-laminated timber
* – iron, steel, aluminium
* – concrete, reinforced concrete
* – composite materials
* – glass

3. Load path

Structures with spatial load path

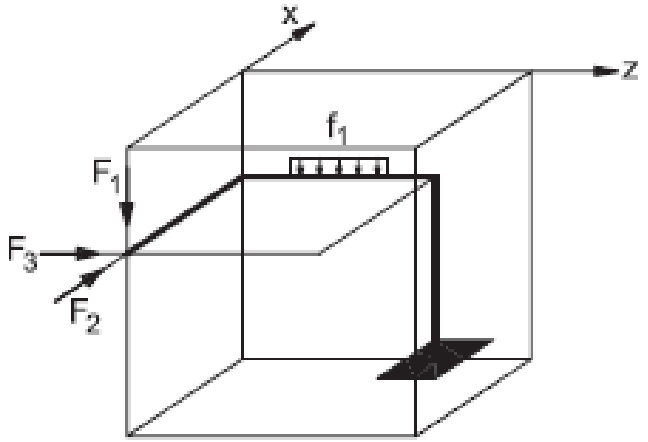
* The axis of these structures is not planar
* Those planar structures, which are loaded not only in their own plane, can be taken into account as a spatial structure in the load path point of view
* Usually spatial structures are divided planar structural elements and a system of these parts is analyzed

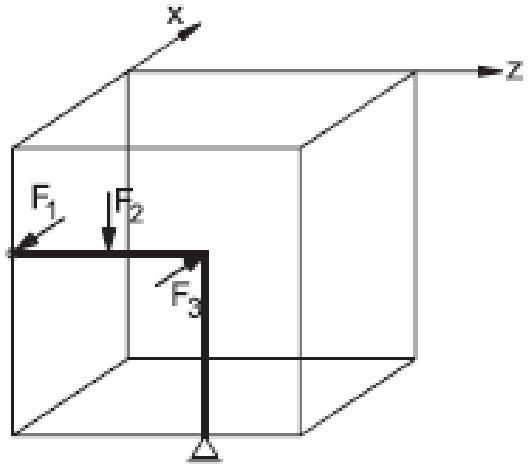


3. Load path

Structures with planar load path

* The axis of the structure is planar, and the perpendicular sizes of the cross section do not affect the load path
* These structures have planar load path: the actions and reactions are vertical as well (in the plane „yz”) and forces have only planar components (Fy and Fz)

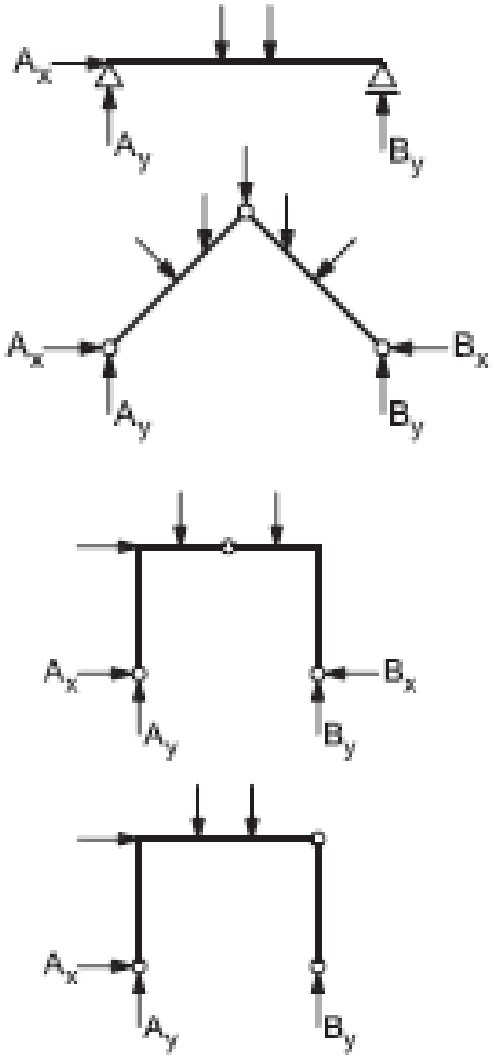


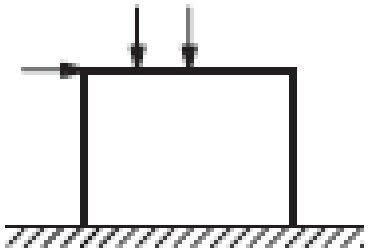


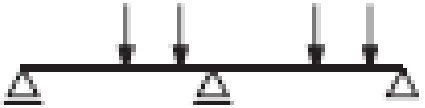
3. Load path

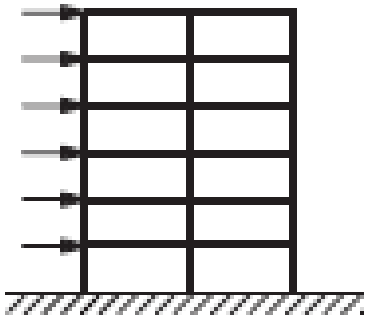
* Internal forces of the structure are calculated using the static equilibrium equations – these are **statically determinate structures**
* The structure is statically indeterminated, when the static equilibrium equations are insufficient for determining the internal forces and reactions on that structure
* In this case there are different methods for calculation of the internal forces - for example: displacement method

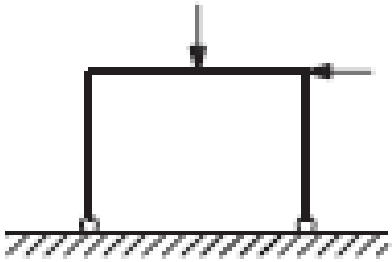
3. Load path



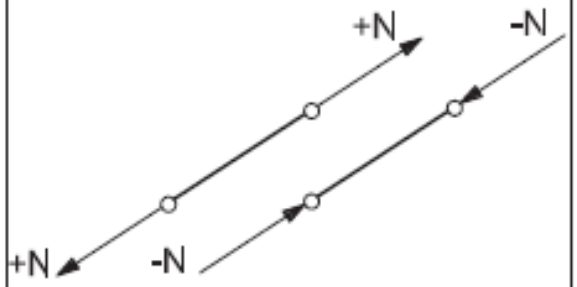
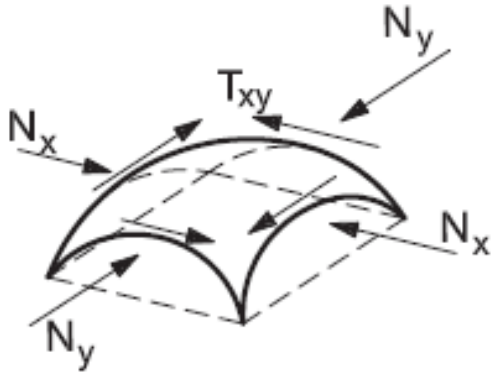
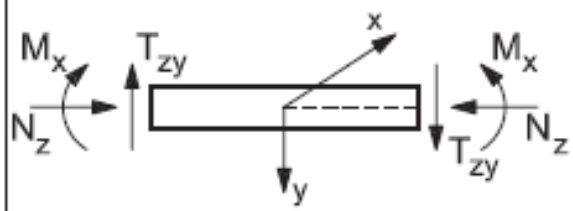






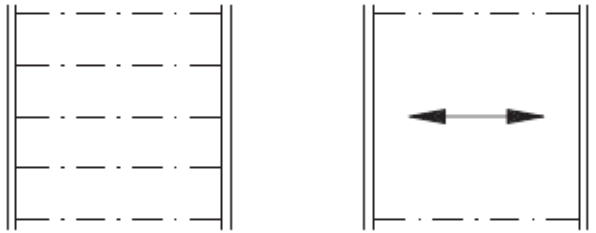


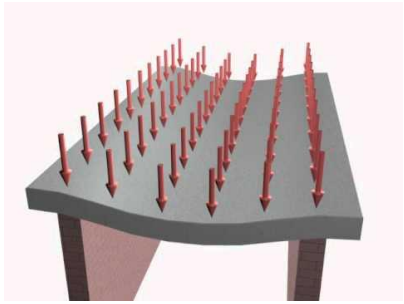
5. Main stresses of structures

Structures without shear force (Only normal force)	Structures without bending moment (forces occur only in the plane of the structures)	Bended structures		
				
N	N_x, N_y, T_{xy}	síkban	N, T_{zy}, M_x^{zy}	
		térben	N	T_{zy}; M_x^{zy} T_{zx}; M_x^{zy} M_x^{zy} = Mcs

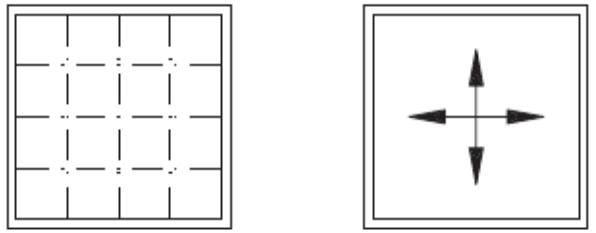
6. Direction of load-bearing

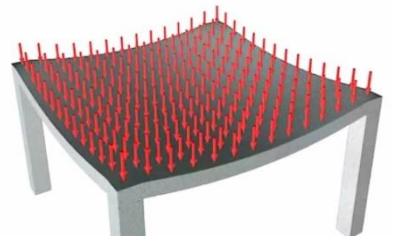
* The two-way slabs are more favourable in load-bearing capacity and cost point of view
* – the absolute value of the highest stresses are smaller
* – it has a better load distribution for the supports
* – the structure is rigid in their own plane





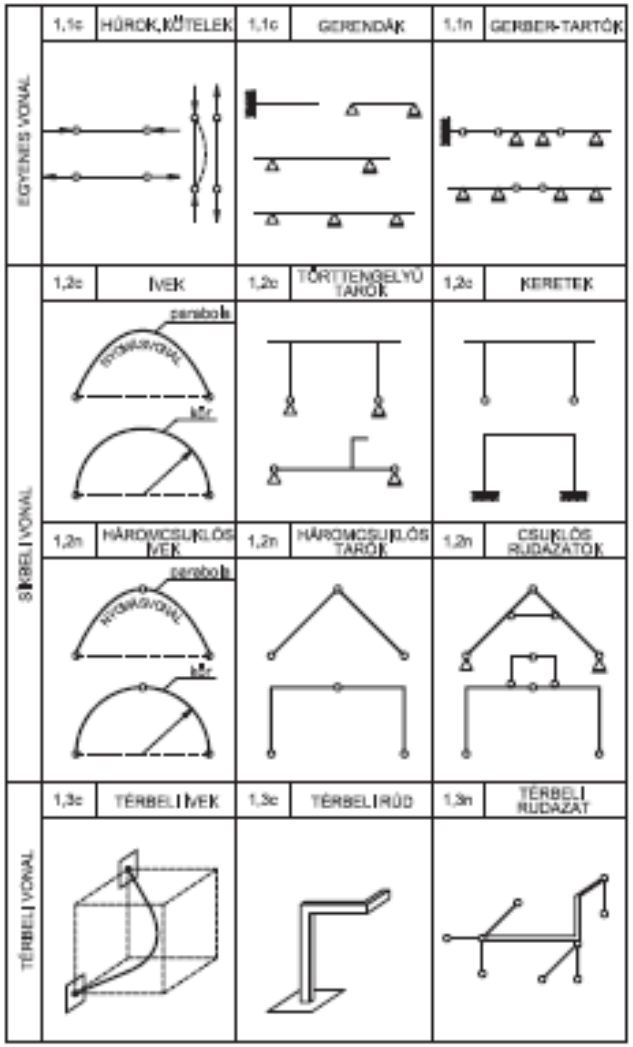
a) One-way slab

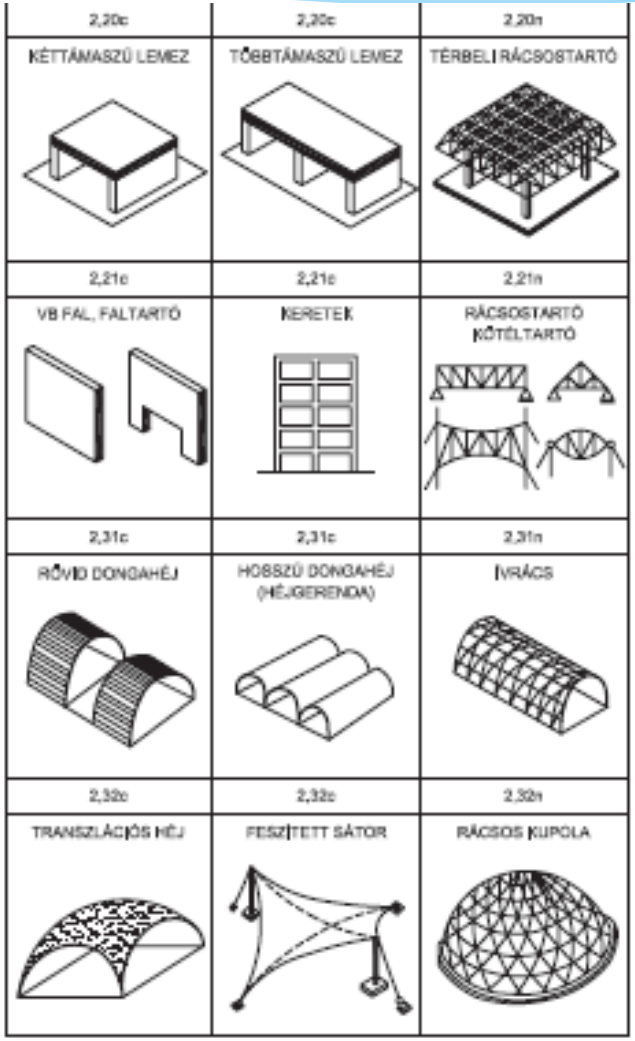




b) Two-way slab

7. Shape of structures





Thank you for your attention!