SZÉCHENYI ISTVÁN EGYETEM
SZE - GYŐR

# DESIGN OF STRUCTURES 2.

## 2. Structural materials

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# Content

* Function of structures
* The role of structural engineer
* Aspects of material choice
* Structural materials
  * Wood
  * Brick
  * Reinforced concrete
  * Iron and steel

# Function of structures

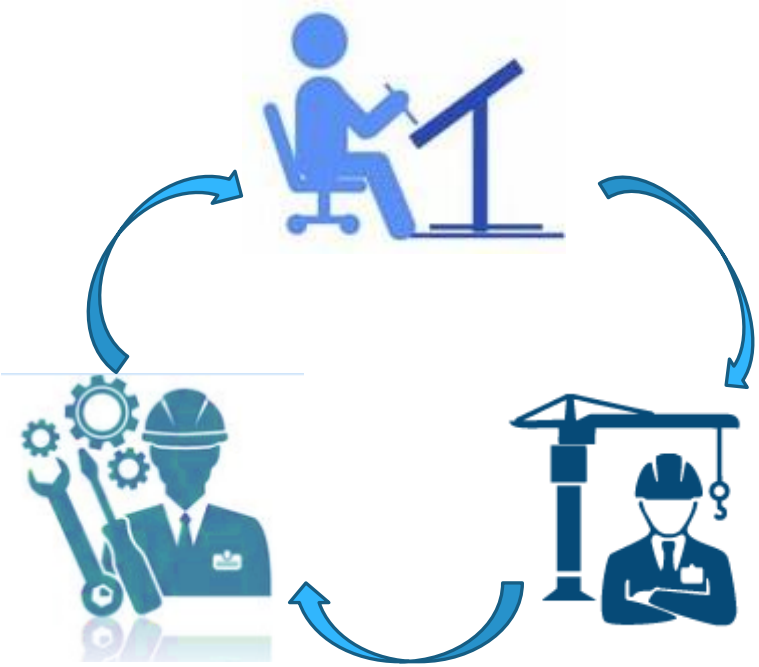
* The building loads and effects are taken by load-bearing structures
* The loaded structure
  * Can not move
  * Can not be shifted and rotated
  * Can not be fractured
  * Can not be damaged by any sufficient deformation or crack
* **The main requirement for the entire building is to keep it's balance.**

# Function of structures

* The structure has to fulfill its function during the whole lifetime and has to ensure the possibility for
  * maintainance
  * conservation
  * renovation
  * and reconstruction
* **Life-Time Engineering:** designing for the whole lifetime (flexible usability, efficiency, environmentally conscious use)

# The role of structural engineer

* In the past – Architect
* Nowadays – disciplines – structural engineer
* Disciplines: they consider the project mainly from the point of view of their own profession
* The cooperation is very important to take the different aspects of the disciplines into account



# The role of structural engineer

* The object of structural engineering is to design a load-bearing structure with **complex optimization** in order to fulfill the requirements defined in the building program and ensure an economical solution
* The structrual and architectural design objects can not be treated separately, the structure is more or less a significant part of the building (based on the type of the project)
* The structure can not be judged based only on static aspects as well

# Structural engineering

*„Structural engineering is more than science and technology: it has much to do with art, thinking, sense and talent. The scientific calculation is only the final touch proving that the structure satisfies the requirements and has proper strength."*

E. Torroja

# Material choice

* Structural design begins with the choice of its material
* In this process controversal aspects have to be considered
* **Strength**
  * Absolute value
  * Relative value: the maximal force that can be taken by a unit mass of a material: $F/\lambda$
* **One-strength materials:**
  * Materials which have only compression-strength:
    * Brick, stone, unreinforced concrete
  * Materials which have only tensile-strength:
    * Rope, awning

# Material choice

* **Price (energy need for production and operation)**
* **Aesthetic requirements, texture of the material**
* **Transport**
* **Preparation of the construction company**
  * Machines, qualification of the staff
* **Fire protection**
* **Maintainance**
* **Possibility for reconstruction**

# Structural materials

* In the beginnings: natural materials (earth, clay, wood, stone) – used in original form
* Later: working and processing of the materials
* The most important stuctural materials:
  * – wood
  * – clay (brick)
  * – concrete, reinforced concrete
  * – steel

# Structural materials

| Material | Elastic modulus | Strength | Specific gravity | Relative strength | Price of strength |
|---|---|---|---|---|---|
| | E | f | γ | $\frac{f}{\gamma}$ | Steel=1 |
| | [kN/mm²] | [N/mm²] | [kN/mm³] | | |
| Steel | 200 | 500 | 78 | 1 | 1 |
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| Glass | 70 | 45 | 24 | 0,25 | - |
| Polyester | 30 | 500-10000 | 22 | 4 | 3 |
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# Wood

- One of our ancient building materials with stone and clay
- Natural, it can be used directly for building without any processing
- It has significant tensile strength
  - Until the XIX. Century trusses and beams were built only from wood

# Wood

- From the second part of the XX. Century its significancy in architecture has increased
- The wood is widespread used, because
  - It is a nenewable raw material
  - Its extraction is simple, processing has low energy demand
  - It is natural, environmentaly friendly material
  - One can choose from numerous different species with different properties which makes possible to find the best type for the purpose
  - There are efficient preservatives due to the development of the chemicals industry
  - There are several new materials (glued laminated timber)

# Wood - advantages

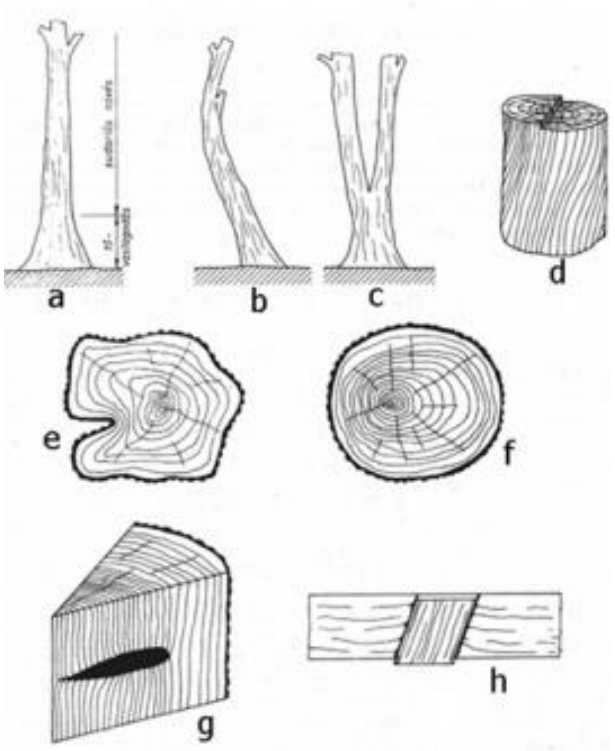
* Wood has high tensile and compression strentgh parallel to the grain compared to its dead weight
* Wide span structures can be built with low fundation requirements in an economical way
* It can be built in a simple way (easy processing, low weight, dry assembling technology)
* It is flexible (can be reconstruced or reused)

# Wood - Advantages

* It has good corrosion resistance (it depends on the tree species)
* There is no need for expansion
* It has good acoustical and thermal characteristics
* Long and different shaped timbers can be produced from glued laminated timber
* Can be used advantageously in areas exposed to earthquakes
* Aesthetic

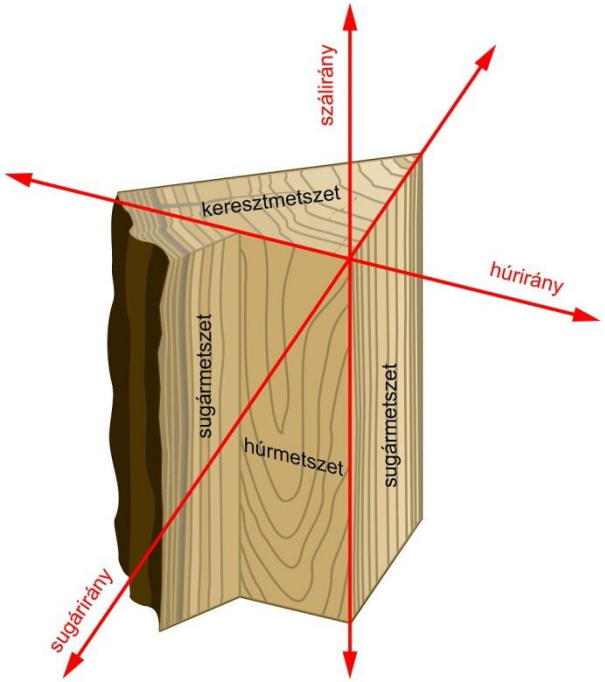
# Wood - disadvantages

* Natural material – the mechanical properties have large standard deviation
* Wood defects decrease the processing possibilities and strentgh
* Its shear strength, compression and tensile strength is low perpendicular to the grain, the proper strength of the joints can be hardly fulfilled
* It is aging (its strength is decreasing over time)
* Viscous material (deformations are increasing over time)



# Wood - disadvaantages

* anisotropic material (mechanical properties depends on the grain direction)
* It is sensible to moisture (swelling-shrinking, the higher moisture content causes decrease in strength and increase in deformations)
* Joints are flexible, relative movements can occur between jointed elements
* Glued laminated timber is sensible to lateral buckling
* Burnable material; with small cross-section and without any preservatives its fire resistency is very low



# Wood - Disadvantages

* Pests and illnesses can cause significant decrease in strength

* The cross sectional size and length of sawn elements is limited and can be used only for timbers with straight axis
* The maximal width of glued laminated timber is also limited (in Hungary it is 22 cm)

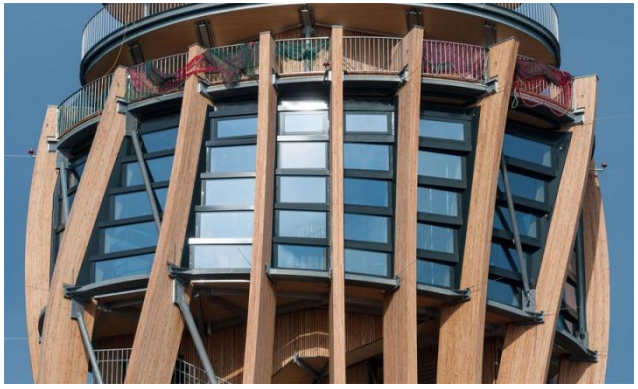
With the choice of the tree species, with proper processing, design and use of preservatives these disadvantages can be eliminated

# Fields of use

* Traditional roof structures from sawn wood
* Roof structures from glued laminated timber (warehouse, sport hall, industrial and agricultural factories, temples, sport facilities…)

# Fields of use

* Residental buildings
* Public buildings
* Engineering structures (towers, retaining walls)
* Additional structures (pergolas, ballustrades, canopies, indoor stairs)



# Brick

* One of our ancient materials
* Brick wall – inhomogeneous material
  * Brick – higher strength
  * Mortar – lower strength
* It does not have tensile strength

# Brick - Advantages

* High compression strength
* Good thermal characteristics
* Low price
* Low energy demand, traditional technology
* Aesthetics
* Flexible use – straight and arched walls, vaults

# Bricks - Disadvantages

* Porous material – sensible to moisture
* It does not have tensile strength – it may couse cracks and other damages in the joints
* Weight

# Fields of use

* Walls, columns, vaults
* In the past: foundations
* Nowadays: claddings

# Concrete – reinforced concrete

* Romans made concrete from hydraulic-setting cement
* Nowadays reinforced concrete is a significant building material
* – and includes the advantages of the two materials
* Concrete has mainly compression strength,
  * **it is a one-strength material**
* In reinforced concrete we use reinforcement for tension
* With the use of these two materials RC is already
  * **a two-strength material.**

# Reinforced concrete - Advantages

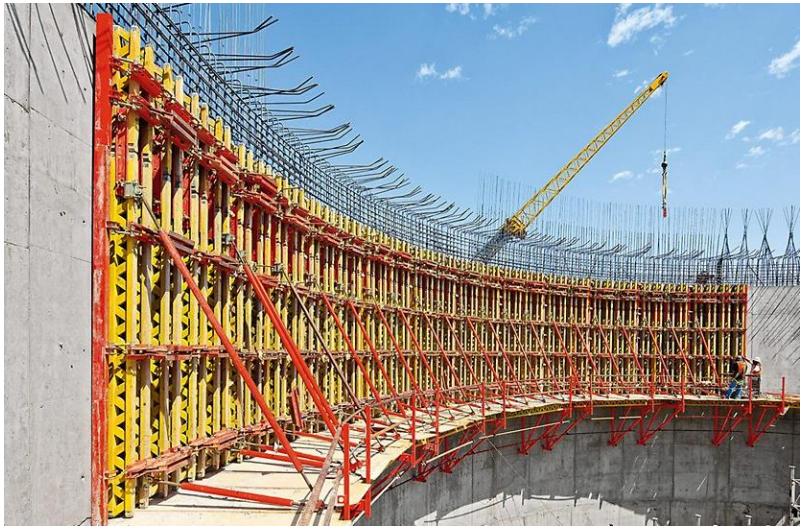
* Variable shape can be constructed
* Structures with advantageous statical behaviour can be easily built
* It makes possible to build more-supported, multi-storey, complex one- or doubly curved surfaces in an economical way

# Reinforced concrete - Advantages

* Concrete mixture with proper cement content protects the reinforcement from corrosion
* It has high fire resistancy
* The structure has enough load-bearing capacity after the concrete cracked and deformed due to the plastic behaviour – the chance for unpredictable failure is very low
* Low price, the raw material (aggregate) can be found almost everywhere, while its steel demand is low
* Maintainance costs are very low (near to zero) compared to the other structural materials

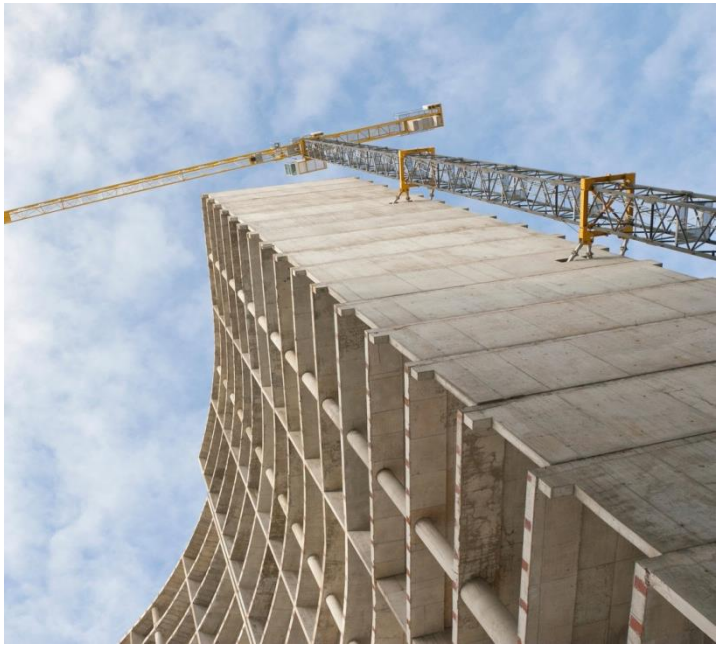
# Reinforced concrete - Disadvantages

* High falswork and formwork costs
* Can be done only in frost-free weather
* Long hardening period
* The reinforcement can be hardly checked after the structure is done
* Reconstruction, renovation is hard
* It has relative bad thermal and acoustic characteristics
* Cracks always occur
* High dead weight



# Fields of use

* Buildings and structures with almost any function
* Wall, columns, slab, roof, shells, stairs, foundations, etc.
* Architectural concrete (exposed or fair-faced conrete)



# Iron and Steel

* The first type of use in building industry: tension-rod
* Iron structural elements: columns and beams in the XIX. century
* (for example: Western Railway Station, Hungarian Academy of Sciences etc.)
* Industrial revolution: increasing use of iron and steel

# Iron and Steel

The second half of the XIX. Century:

* Hot-rolled steel products:
  * Production of plates and profiles
  * riveted trusses
* In the beginning of the XX. Century: welding
* Until the second world war the steel was used widespread for slabs, stairs and frames

* The use of steel in building industry was significantly confined from the 1950's in Hungary
* In 1970's the goverment's program for lightweight structures gave a new impetus to the use of steel
* However its use stayed limited compared to other countries

# Steel – Advantages

* High tensile strength
* Easily processed (hot rolled technology)
* High strength – small cross section – slender structures
* Simple assembling – quick building
* High precision
* Can be easily automatized
* Independent of weather

# Steel - Disadvantages

* Low fire resistancy – by 550 °C it losts its load-bearning capacity with large deformations – fire protection needed
* Corrosion protection
* High price
* Dead weight is significant in the construction point of view
* Transport and lifting work and cost
* Visible joints

# Fields of use

* Wide span halls: public buildings
* Industrial halls, warehouses
* Railway stations
* Wide span structures (span is longer than 24 m)

# Fields of use

* Tall buildings (more than 12 storey)
* Inaccessible sites
* Displaceable buildings
* Reconstruction

# Structural materials

| Material | Elastic modulus | Strength | Bulk density | Relative strength | Price of strength |
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# Thank you for your attention!