SZÉCHENYI ISTVÁN EGYETEM
SZE - GYŐR

DESIGN OF STRUCTURES 2.

09. Approximating design of structures

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* Approximating design of structures
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  * Material properties
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  * Beams
  * Slabs
  * Other structures
  * Masonry structures

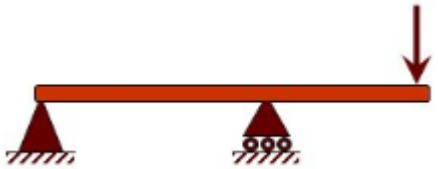
Modelling of structures

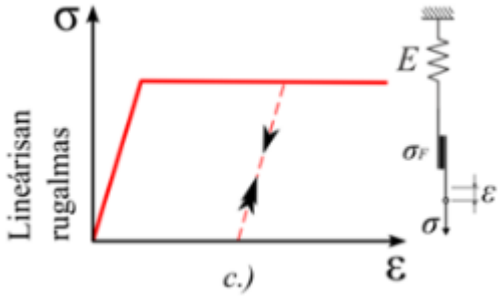
* The precise calculation of the load-bearing structures would be a very hard task
* Therefore simplified model is analysed instead of the real structure
* The basic requirements of this model are the followings:
  * It should be simple to deal with it
  * and sufficiently precise

Modelling steps

1. Mechanical model

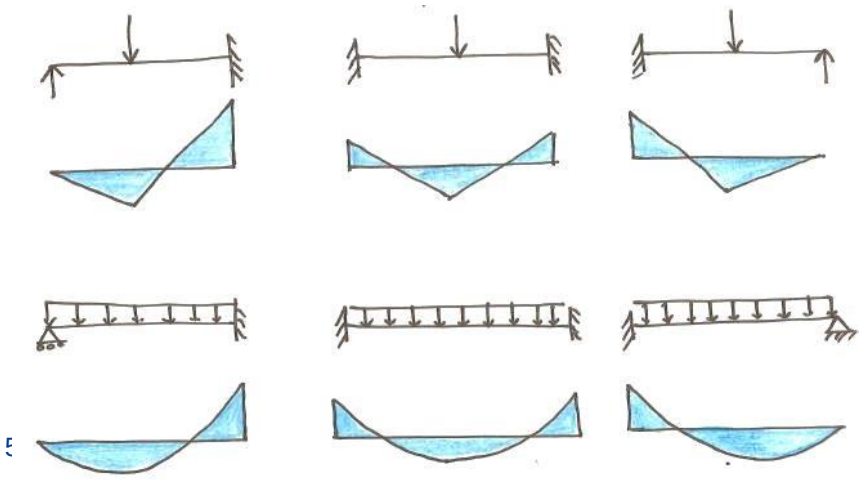
* Construction of the structural model:
  * Simplification are used in the mechanical model, for example: a beam can be modeled by its median, the supports can be modelled in points or lines
  * Real loads are replaced by fictive loads
  * The materials are idealized – for that purpose material models are used (for example: linear elastic or non-linear elastic models)





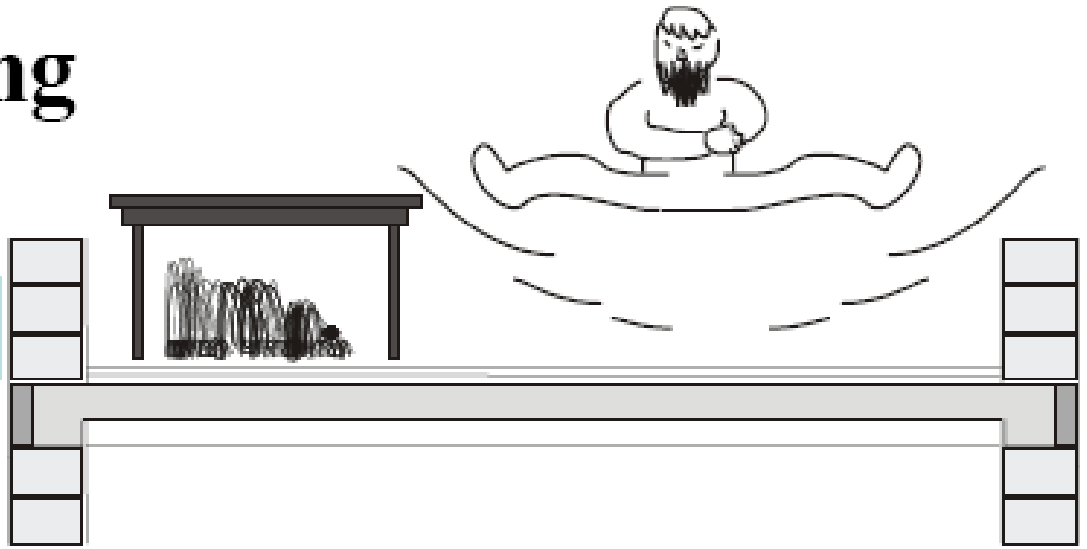
Modelling steps

2. Mathematical model
   * Determination of internal forces and deformations
   * Pl. $M=p\times L^2/8$ (relevant moment, $w=5/384/p*L^4/E/I$ (simply-supported beam)
3. Determination and checking the requirements:
   * $M_{Ed} \leq M_{Rd}$; $w_{Ed} \leq w_{Rd}$

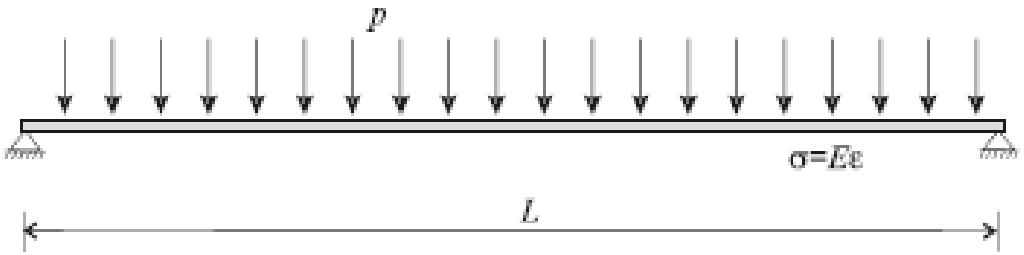


Modeling

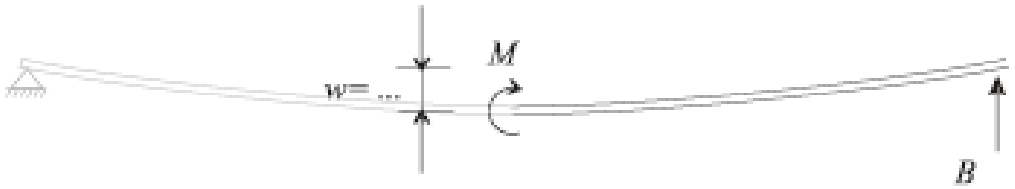
Structure



Mechanical model



Mathematical model



Requirements

$w \leq w_{max}$ $M \leq M_{Rd}$

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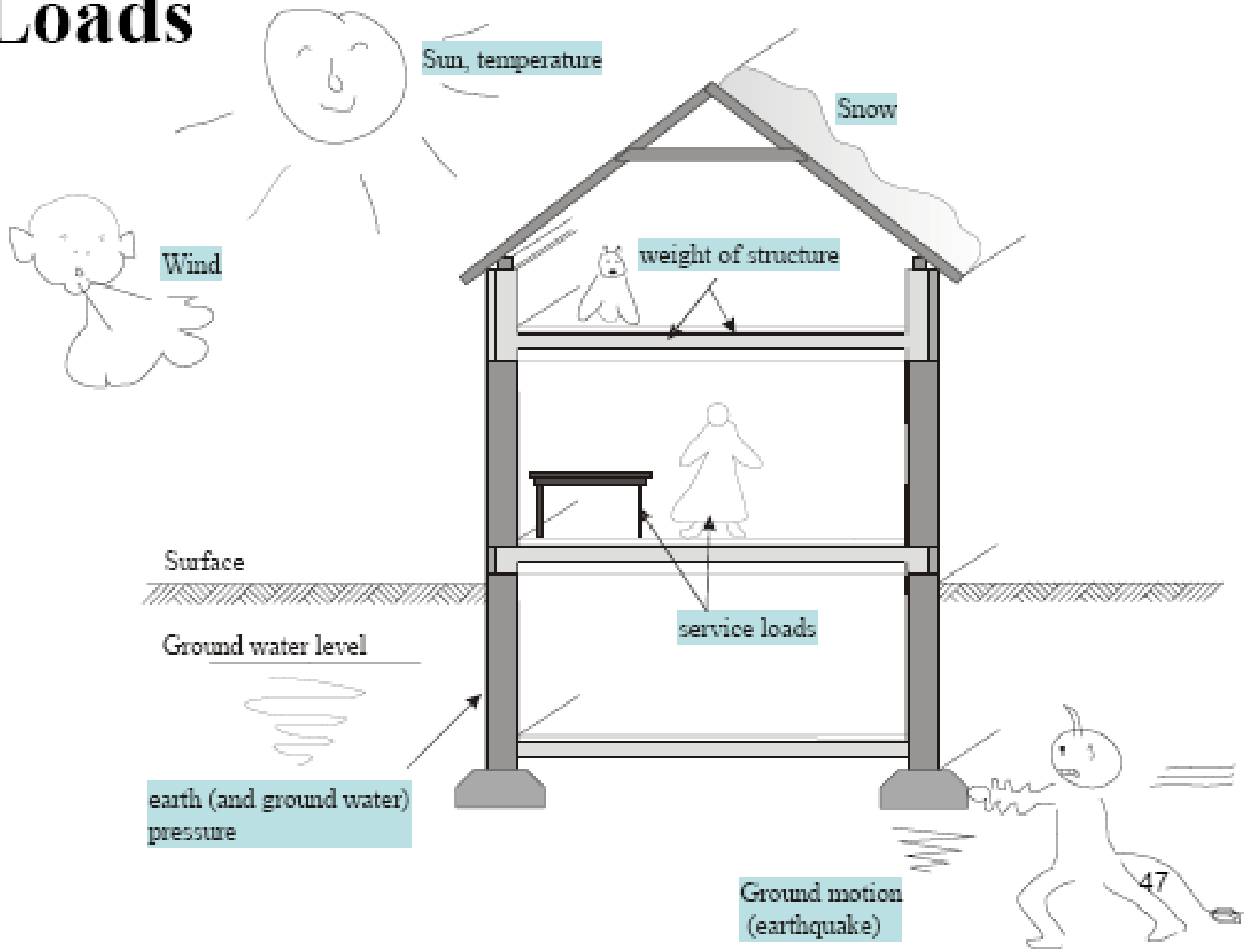
Loads


Sun, temperature
Snow
Wind
weight of structure
Surface
service loads
Ground water level
earth (and ground water) pressure
Ground motion (earthquake)

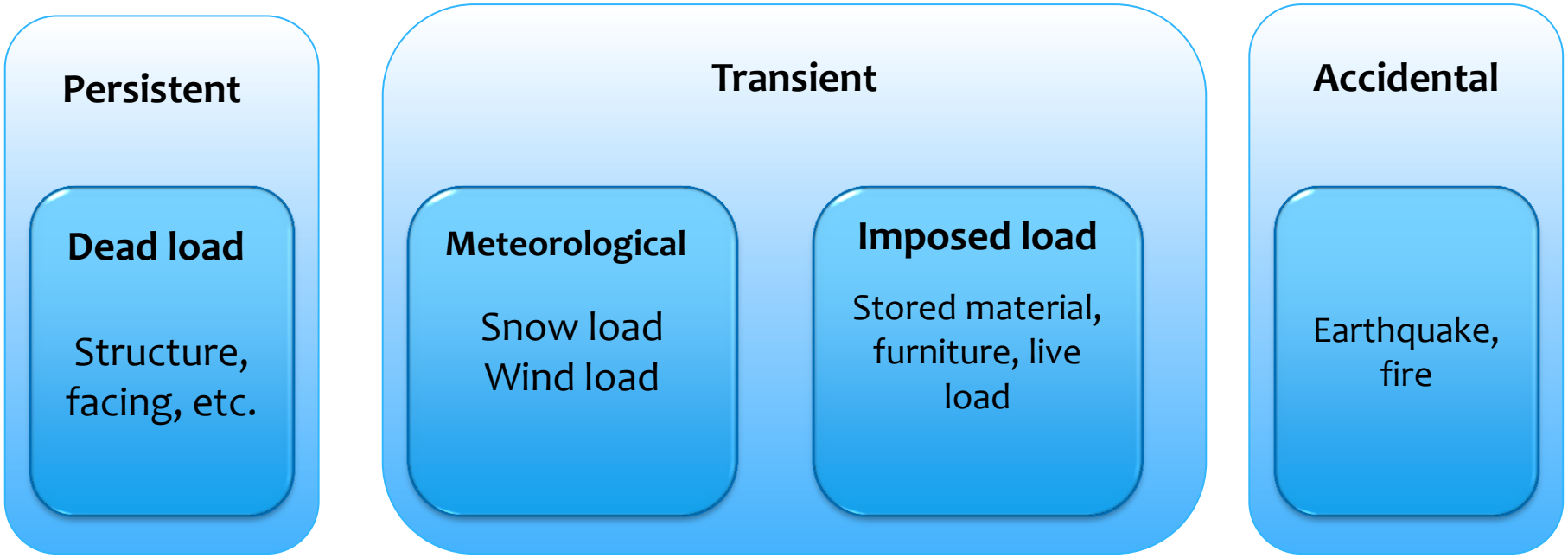
Approximating design of structures

* Including disciplines:
  * Conceptual plan
  * Draft plan
  * Building permit drawings
  * Construction documentation
* Approximating design of structural dimensions
* Limitation of these calculations

Structural standards

* MSZ Hungarian Standard: until 31. 12. 2010.
  * Lower safety level
* Eurocode MSZ-EN: from 01. 01. 2011.
  * Higher safety level

Approximating design - Loads



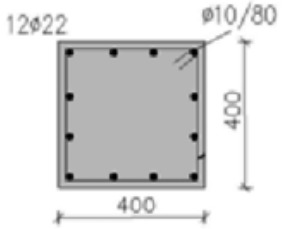
Approximating design - materials

Material	Property	MSZ	EC
Reinforced concrete C20/25	Compression strength	14,5N/mm^2	13,3N/mm^2
	Modulus of elasticity	15000N/mm^2	8500N/mm^2
Steel (S235)	Compression strength	200N/mm^2	235N/mm^2
	Modulus of elasticity	206000N/mm^2	200000N/mm^2
Wood (C30)	Compression strength	18-21N/mm^2	14,15N/mm^2
	Bending strength	20-25N/mm^2	18,5N/mm^2
	Modulus of elasticity	10000N/mm^2	12000N/mm^2

Columns, pillars

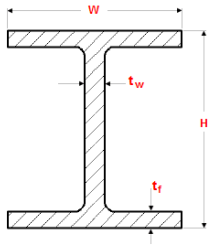
* RC columns:

$$A_c \approx \frac{N_{Ed}}{f_{c,d}}$$



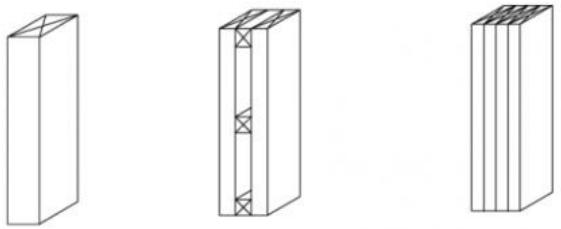
* Steel columns:

$$A_s \approx \frac{N_{Ed}}{(0{,}6 \approx 0{,}8) \cdot f_{y,d}}$$



* Wood columns:

$$A_f \approx \frac{N_{Ed}}{(0{,}6 \approx 0{,}8) \cdot f_{c,0,d}}$$



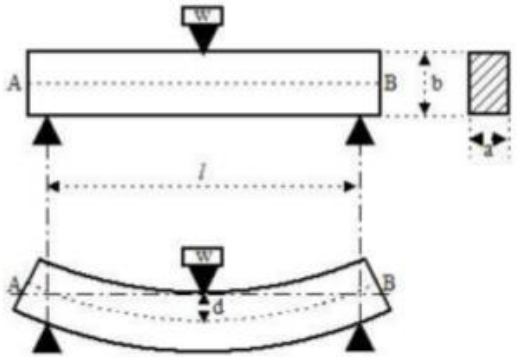
Beams

* Allowed deflection:

$$\omega_{eng} = \frac{l}{250}$$

* In the case of simply-supported beam:

$$w = \frac{5}{384} \cdot \frac{q \cdot l^4}{E \cdot I}$$



* Maximal bending moment:

$$M_{max} = \frac{q \cdot l^2}{8}$$

* Maximal stress from bending moment:

$$\sigma_{max} = f_{y,d} = \frac{M_{max}}{I} \cdot y_{max}$$

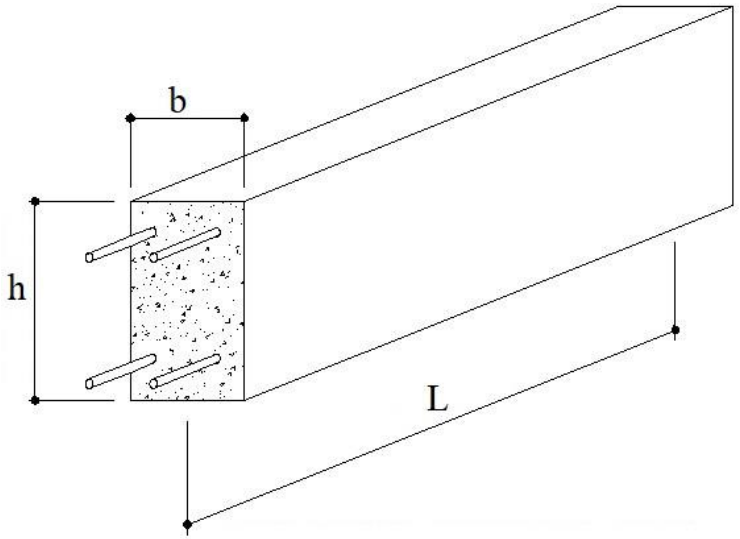
$$w \approx \frac{2 \cdot l^2 \cdot f_{y,d}}{10 \cdot E \cdot h}$$

$$\frac{l}{250} \approx \frac{2 \cdot l^2}{10 \cdot h} \cdot \frac{f_{y,d}}{E} \quad \Rightarrow \quad h \approx 50 \cdot \frac{f_{y,d}}{E} \cdot l$$

Reinforced concrete beam

* Substitution: $h \approx 50 \cdot \frac{13,3}{8500} \cdot l = \frac{l}{12,78}$

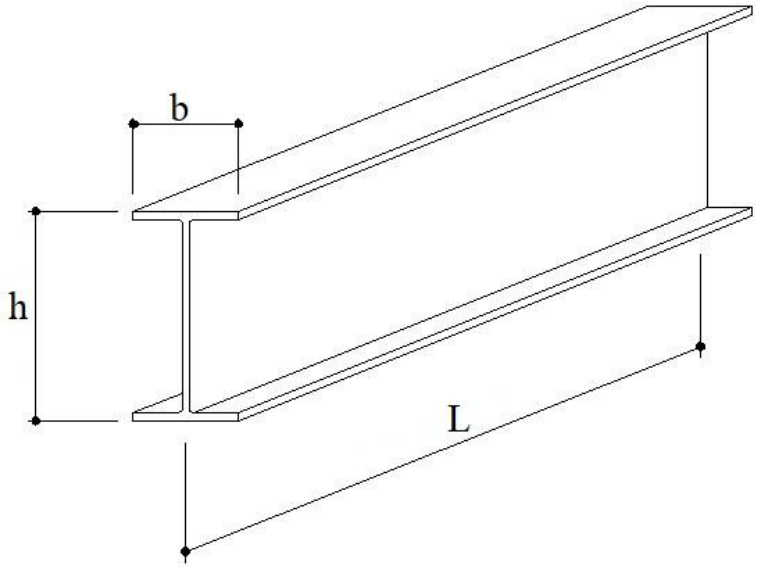
* In general: $h \approx \frac{l}{10}$ $h \approx \frac{l}{15}$



Steel beam

* Substitution: $$h \approx 50 \cdot \frac{235}{210\,000} \cdot l = \frac{l}{17{,}87}$$

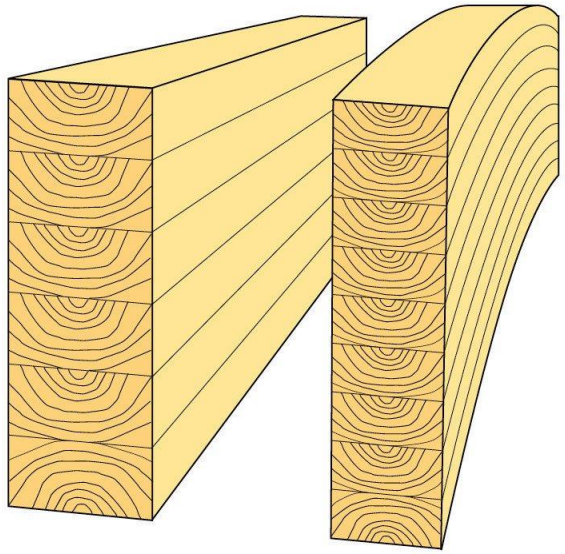
* In general: $$h \approx \frac{l}{15}$$



Wood beam

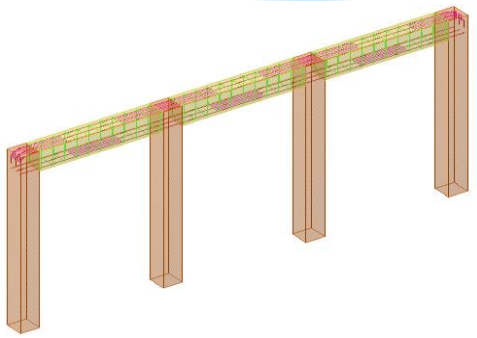
* Substitution: $h \approx 50 \cdot \frac{8{,}61}{7\,000} \cdot l \approx \frac{l}{16{,}3}$

* In general: $h \approx \frac{l}{15}$



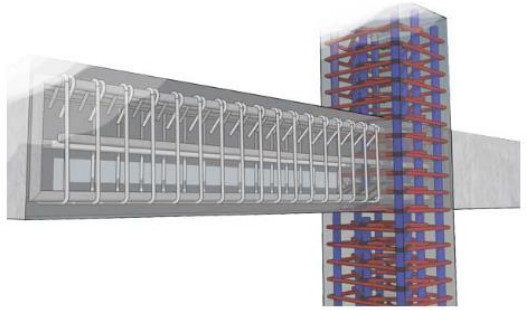
Other cases

* Continuous beams: $h \approx \frac{l}{20}$



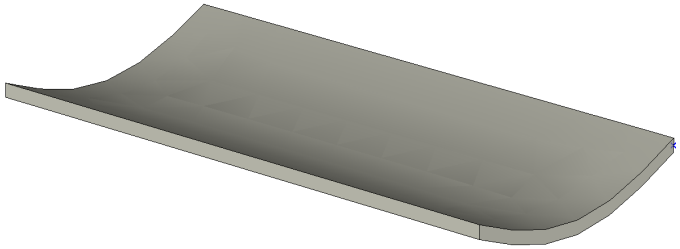
* Trusses: $h \approx \frac{l}{15}$ $h \approx \frac{l}{10}$

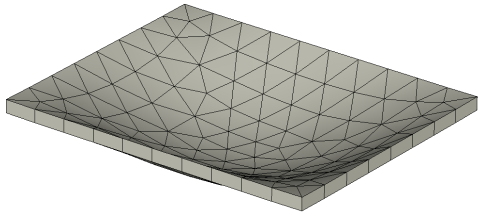
* Cantilevers: $h \approx \frac{k}{7,5}$

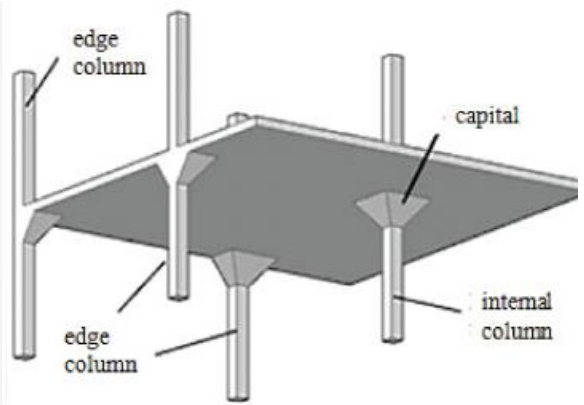


Slabs

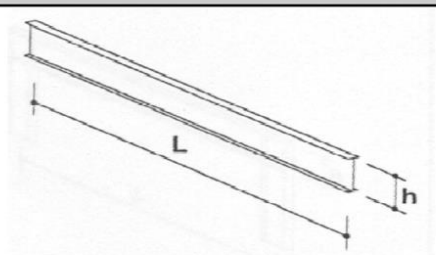
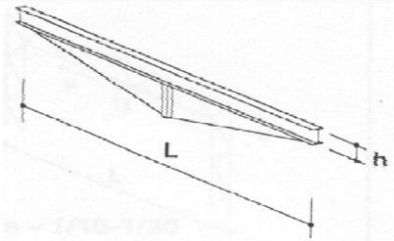
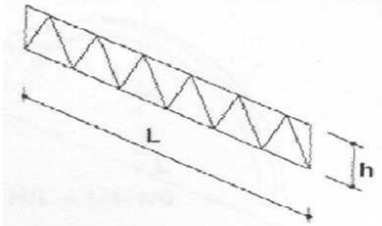
* One-way slab:
  * v = ℓ/20 ÷ ℓ/25
* One-way slab (multispan)
  * v = ℓ/25 ÷ ℓ/30
* Two-way slab:
  * v = ℓ/25 ÷ ℓ/30
* Mushroom slab:
  * v = ℓ/25



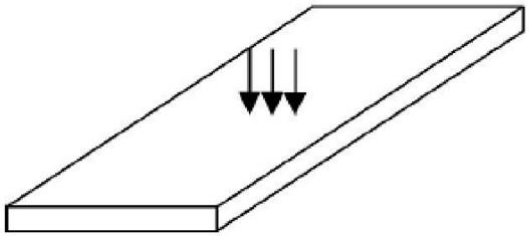
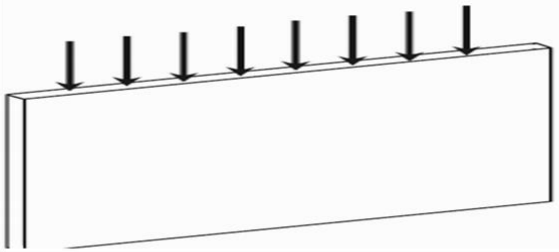
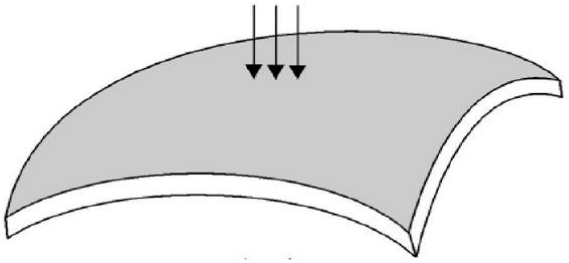




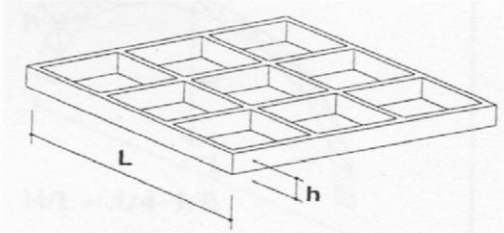
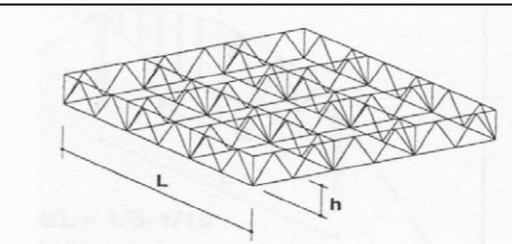
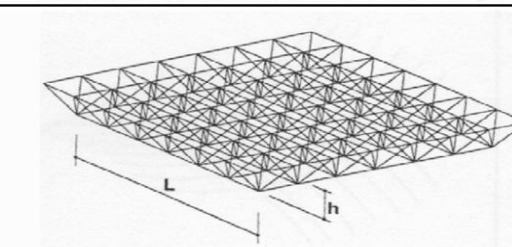
Other structures

Structure type		L – Span (m)	h/L
Prestressed beam		3-50	1/20-1/30
Hanger structures		6-60	1/35-1/50
Trusses		8-75	1/10-1/15

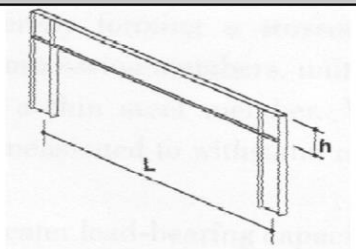
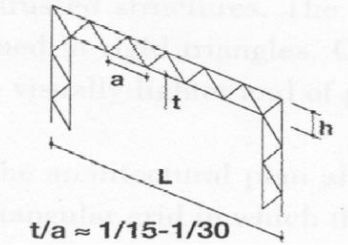
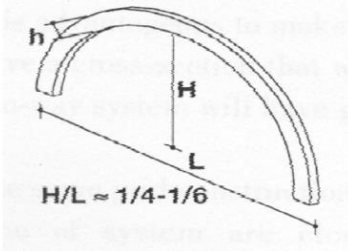
Other structures

Structure type		L – Span (m)	h/L
Slab prestressed		5-50	1/15-1/40
Walls (loaded in plane)		5-30	1/5 - 1/10
Shell		40-200	1/400 - 1/500

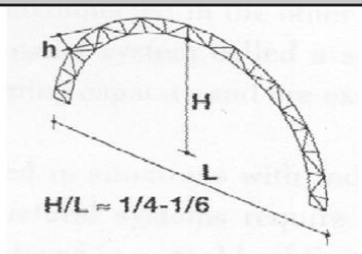
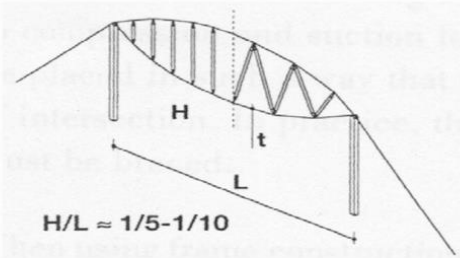
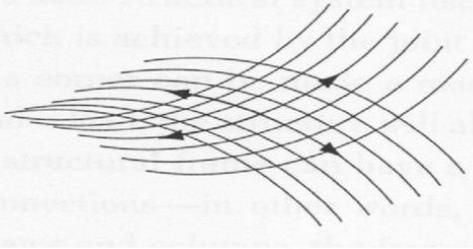
Other structures

Structure type		L – Span (m)	h/L
Ribbed slab, waffle slab		10-70	1/25-1/35
Hierachal space truss		10-90	1/15-1/20
Other space trusses		20-120	1/15-1/30

Other structures

Structure type		L – Span (m)	h/L
Frame		5-40	1/30-1/40
Frame truss		8-55	1/10-1/20
Arch		25-70	1/50-1/70

Other structures

Structure type		L – Span (m)	h/L
Truss arch		40-120	1/30-1/50
Cable truss structure		20-150	1/1000- 1/10000
Cable structures		20-150	1/1000- 1/10000

Masonry structures

* There are bricks with high compression strength ($f_b \approx 15$MPa)
* For example: Porotherm N+F, YTONG P4
* There are brick with lower compression strength: ($f_b \approx 10$MPa)
* For example: Porotherm HS-system, YTONG P2
* There is a minimal dimensions for masonry columns
* Load-bearing masonry walls: v=25/30/38cm

POROTHERM 38 N+F **külső teherhordó** 	38x25x23,8 **feles:** 38x12,5x23,8	k=0,49W/m²K	18 9	7	16 32
Habarcsigény: 20 l/m² Testsűrűség: 800 kg/m³ Üregtérfogat: 55% alatt Csomagolás: 60 db/rakat					
POROTHERM 30 N+F **belső teherhordó** 	30x25x23,8 **feles:** 30x12,5x23,8	k=0,69W/m²k	15 7,5	7	16 32
Habarcsigény: 16 l/m² Testsűrűség: 800 kg/m³ Üregtérfogat: 55% alatt Csomagolás: 80 db/rakat					
POROTHERM 25 N+F **teherhordó falazóblokk** 	25x37,5x23,8	——	18	7	11
Habarcsigény: 13 l/m² Testsűrűség: 800 kg/m³ Üregtérfogat: 55% alatt Csomagolás: 60 db/rakat					

Thank you for your attention!