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BUILDING CONSTRUCTIONS 1

Requirements for walls

www.epszerk.bme.hu

Budapest University of Technology and Economics
Faculty of Architecture Department of Building Constructions

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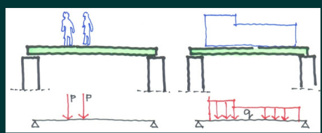
strength requirements (OTÉK: stability, mechanical strength)

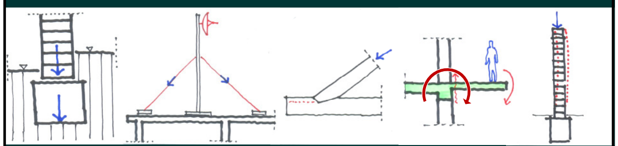
concepts: ● loads

the size, distribution, direction and nature of the load is determinative



concentrated distributed

● loads



pressure tension shearing bending combined loads

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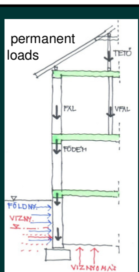
forces, loads

loads: permanent and live loads
(+ additional)

imposed load: flat = 1.5 kN/m²



1. vertical forces

the strength of the wall is determined by
- the wall material (building block + mortar),
- wall cross section
- slenderness+

limit force of wall – central pressure (for estimation, traditionally calculated)

$N_h = F \times \sigma_h \times \varphi$ *

where N_h = limit force (1Mpa=10kp/cm²=1N/mm²)
F = wall cross section (cm², mm²)
σ_h = wall limit stress (kp/cm², N/mm², Mpa)
φ = reduction factor, on basis of the wall slenderness (m/v) and supports (0,7 - 0,5)

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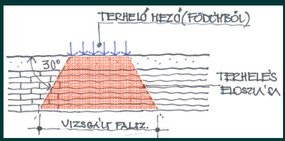
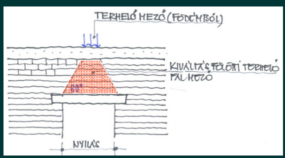
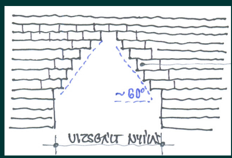
arching of walls



load distribution in a solid wall part



zone loading the lintel



arching (self-arching)

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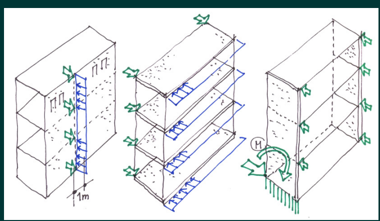
2. taking horizontal forces (box effect)



walls absorb the wind loads

rigid slabs take on the load ("discs")

stiffening transverse walls transmit the loads to the foundations

- wind suction
- wind pressure
- soil motion (earthquake)
- dynamic impacts (transport e.g. subway)

masonry structure cannot take tension!
(masonry ≠ wall)

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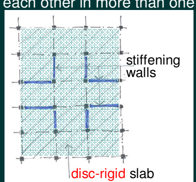
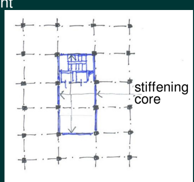
3. stiffening

wall-type structure buildings:
- rigid slab „disk” (ringbeam + slab)
- layout of load-bearing and stiffening walls

frame-type buildings: with stiffening walls or stiffening core
rules for the placement of stiffening walls:

*
- between pillars
- in the same place on all floors
- the axes of the stiffening walls should intersect each other in more than one point





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fire protection requirements (OTÉK: fire safety)

fire protection goals in architecture

life protection and community value protection goals – state regulatory task (in Hungary: Decree 54/2014. (XII.5) of Ministry of Interior on National Fire Prevention Rules and its Fire Protection Technical Guidelines

proprietary value protection goals – governed by insurance policies

life protection goals:

- protecting people in the building – ensuring escape and rescue
- protecting the life of firefighters and ensuring the safety of the intervention

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fire protection features of construction products

goal: maintaining the building's stability for a specified period of time, limiting the spread of fire, serving the safety of escape and rescue

classification methods:

- fire class (reaction-to-fire) – description of the fire behavior of a building material or a construction product (flammability, how difficult it is to ignite, rate of smoke development, burning dripping)
  A1, A2 B, C, D, E (F) s1, s2, s3 d0, d1, d2
- fire resistance limit – duration for which a building structure withstands the fire impact (R, E, I performance features + duration in minute – 15…240 minutes)

load-bearing capacity in case of fire

preservation of integrity (burning through)

thermal insulation capacity in case of fire

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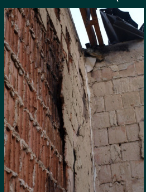
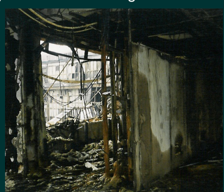
fire protection features of construction products

examples:

- 30 cm thick load-bearing wall plastered on both sides: A1, REI 240
- partition wall with 2x2 layers of plasterboard: A2, EI 90
- sandwich panel with steel armature and PIR or phenolic foam core: B, EI 30
- laminated (wood) board load-bearing wall structure: D, REI 30





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thermal insulation and vapor barrier requirements

(OTÉK: energy saving and thermal protection; hygiene, health and environmental protection)

goal:

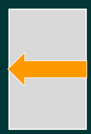
- to ensure adequate temperature and air conditions (for the intended purpose) (together with other means!)
- protection of external walls
- energy conservation

thermal equilibrium takes place between spaces spearated by wall

features:

thermal conductivity, thermal conductivity factor:
amount of heat that gets across the 1 m^2 surface of a 1m thick wall in 1 hour at 1 K° temperature difference

* denoted: „λ" (W/mK°)



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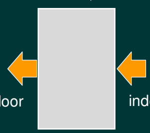
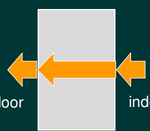
heat transfer, heat transfer factor:
amount of heat arriving from the air to the 1 m^2 surface of a wall (and vice versa) in 1 hour at 1 K° temperature difference

* denoted: „α" (W/mK°)

„α_i" = 8 (indoor) „α_e" = 24 (outdoor)



thermal transmittance = heat transfer + heat conduction
denoted: „U" (W/mK°)

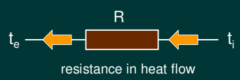


heat flow:
heat transmission resistance of a structure:

$$R = \frac{d}{\lambda} \text{ (m}^2\text{K°/W)}$$

heat transmission resistance of heat transfer:

$$R = \frac{1}{\alpha} \text{ (m}^2\text{K°/W)}$$



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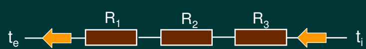
heat flow through the structure

$$q = \frac{1}{R} \times \Delta t = \frac{1}{R} \times (t_i - t_e)$$

for multilayer walls

$$q = \frac{1}{\Sigma R} \times \Delta t$$

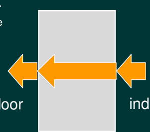


$$\text{thermal transmittance} = \frac{1}{\Sigma R}$$

heat transfer coefficient

$$U = \frac{1}{\frac{1}{\alpha_i} + \frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2} + \frac{d_n}{\lambda_n} + \frac{1}{\alpha_e}} \text{ (W/mK°)}$$ *

Requirement for walls : 0,24 (0,45) W/mK°



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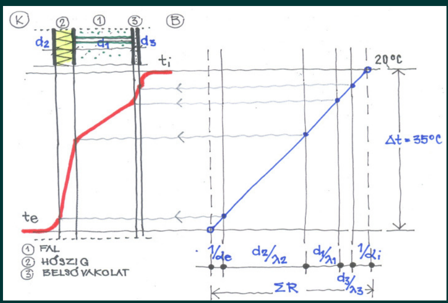
how to draw temperature drop diagram *



own scale (m=1:10) resistance scale (R)

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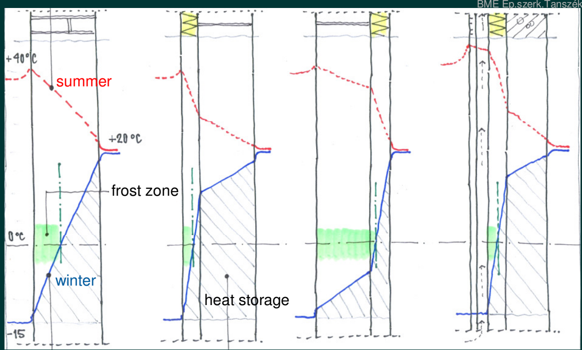

homogeneous wall layered (sandwich) wall double-layer ventilated wall

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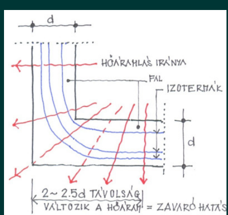
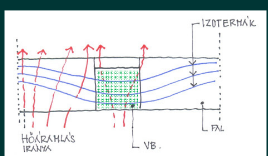
thermal bridges

essence: multidimensional heat flow (uneven temperature distribution)

reasons: • geometric shape (wall corner, "T„wall connection…)
* • change in materials – materials with different thermal conductivity
• uneven distribution and coverage of (inner) surface temperature • combination of the above effects



wall corner (geometric shape)



change in materials: ceramic block wall + reinforced concrete

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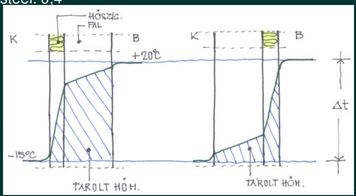
heat storage

● the characteristic of wall structures to store the absorbed heat
heat attenuation, delay: heat spare in winter, „cold" spare in summer

● heat storage capacity: $\Delta q = m \times c \times \Delta t$ (kj)
[m= wall weight (kg) c = specific heat of wall (kj/kgK°)]

● the zone of the wall structure is involved in the heat storage, where R = 0.15-0.2
● specific heat of some constructions: - silicate materials: 0.84-0.95, wood: 1.7-3.0, steel: 0.4



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vapor protection requirements

the vapor in the air acts as a gas and exerts pressure on the space enclosing structures

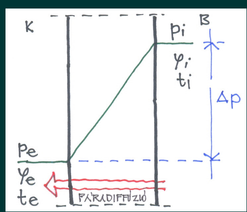
● from the higher pressure to the lower pressure point
● pressure relief taking place inside the wall ⟶ moisture diffusion

moisture diffusion depends on

● Δt, temperature difference
● Δp, pressure difference
● permeability of the wall (solid, porous)
● capillarity of the wall
● surface finish of the wall

relative humidity

$$\varphi = \Phi_r / \Phi_t$$



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characteristics of moisture diffusion

● water vapor transport factor: „δ" (kg/m,s,pa)
● water vapor transport resistance (for 1 layer): $R_{v1} = d_1 / \delta_1$ (m² s pa/ kg)
● water vapor flow (for multilayer wall): $g = (p_i - p_e) / \Sigma R_v$

● vapor drop diagram:
shows the distribution of water vapor pressure in the structure

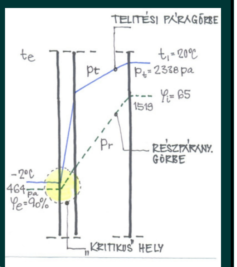
condensation:
if the pr and pt curves are intersected

surface condensation: the wall surface temperature is low (t_i - t_{fi}) > 2.5°C

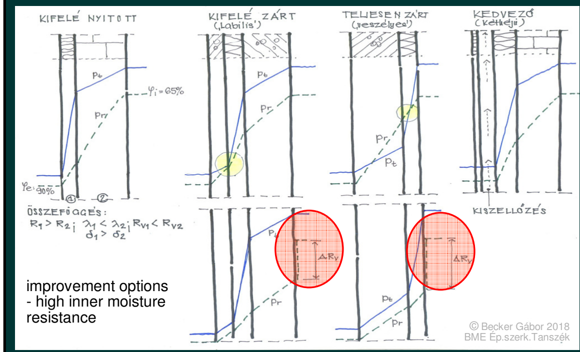
mold: capillary condensation in the pores

preventing condensation:

● wall structure should be open outwards from the vapor diffusion point of view
*● material with high water vapor transport resistance on indoor surface (plastic paint, wallpaper)
● ensuring ventilation from the outside (double-shell wall)



outward open | outward closed | closed | advantageous



improvement options
- high inner moisture resistance

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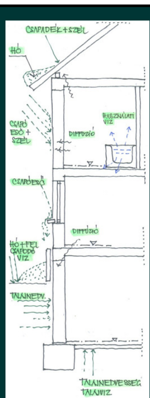
moisture protection requirements

- forms of moisture: vapor (steam), liquid, ice
- spaces should be protected from moisture,
  protection inside the enclosing structures, against:
  - rain
  - snow and water splashing back to the footing
  - domestic water
  - moisture in the ground
  - construction moisture
- against condensation: with proper sizing of thermal and vapor insulation



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sound insulation requirements – basic concepts

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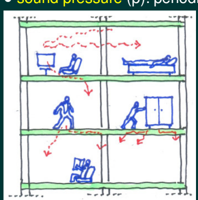
- airborne sound: noise born and transmitted in the air (e.g. speech, instrument)
- structure-born sound: noise resulting from footsteps on the floor, moving the furniture, hammering

Sound properties:

- frequency (Hz): number of vibrations per second
  hearing range: 16 - 16.000 (20.000) Hz
- sound pressure (p): periodic change in atmospheric pressure of air



- sound pressure level: the magnitude of the (average) pressure change in relation to a reference value, unit of measure: dB (decibel)
- noise loads
  - on facades: traffic (road, rail, air), industrial noise, noise of passers-by
  - on interior separation structures: speaking, walking, media, household appliances and building engineering

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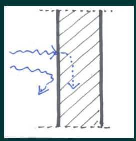
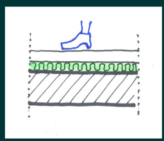
Sound insulation:

- against airborne sounds with airborne sound insulation
- against structure-born sounds with impact sound insulation

*

airborne sound insulation:
-with mass
-or: multi-layered structures





impact sound insulation: structural / vibration insulation (e.g.: mass-spring system)

- airborne sound insulation capacity of walls: weighted sound reduction index, denoted: R_W measured in lab, R'_W measured on site (dB)
- measuring range: sound reduction index is measured from 50 to 5000 Hz
- hearing range: 16-20 000 Hz

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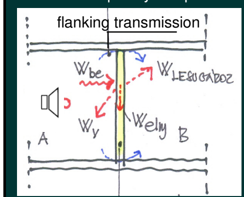
requirements – basic design data:

- allowed sound pressure level for flats:
  night 30 dB, day 40 dB
- sound insulation requirements for residential buildings:
  between apartments: $R'_W + C \geq 52$ dB (for all elements!)
  R'_W : sound reduction index on site, R' < R !
  C: „spectrum adaptation term” corrective value, < = 0, features the frequency composition of the noise (value is -1…-5 for heavy walls)



- sound insulation of enclosing structures is affected by:
  specific mass (favorable > 450-480 kg/m²), compactness, rigidity, structure, etc.
- interesting fact:
  the airborne sound insulation of a facade wall
  -may be reduced by 2-4 dB in case of hard foam + plaster system
  -may be improved by 4-10 dB in case of multi-layered walls

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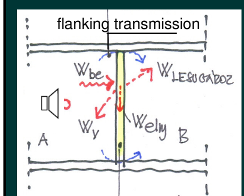
requirements – basic design data:

- allowed sound pressure level for flats:
  night 30 dB, day 40 dB
- sound insulation requirements for residential buildings:
  between apartments: $R'_W + C \geq 52$ dB (lab value: $R_W+C \geq 56$ dB)
  staircase/corridor wall: $R_W+C \geq 52$ dB (=lab value)



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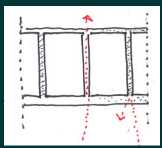
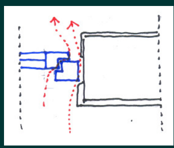
airtightness requirements

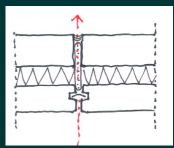
- on the exterior space separating structures, Δp and wind (suction and pressure) cause air exchange
- the air exchange is basically between the wall and joining doors/windows (wall + frame, frame + wing) and the gaps of larger elements (panels)
- the degree of air exchange depends: on the wall size, porosity and gap design



homogeneous wall: standing gaps filled, airtight plaster



wall-frame, frame-wing gaps sealed



sandwich panel: panel gaps in the outer concrete shell

strength requirements – forces, loads
- vertical forces, pressure, arching
- taking horizontal forces, ensuring stiffness

fire protection requirements, fire protection goals in architecture
- fire protection features of construction products: fire class, fire resistance limit

thermal insulation and vapor barrier requirements
- heat conductivity (λ), heat transfer factor (α), thermal transmittance (U),
- temperature drop diagram, frost zone, condensation options
- thermal bridges: geometric or change in material (especially the combinatio
- heat storage – mass
- vapor protection requirements: diffusion, relative humidity
- characteristics of vapor diffusion: condensation, on surface, condensation p
- vapor drop diagrams – single- and double-shell walls

moisture protection requirements
noise control basic concepts, requirements: acoustic absorption, insulation
airtightness requirements