

# **BUILDING REHABILITATION**

## **2. FLOORS, ROOF STRUCTURES**

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associate professor

BME Department of Building Constructions

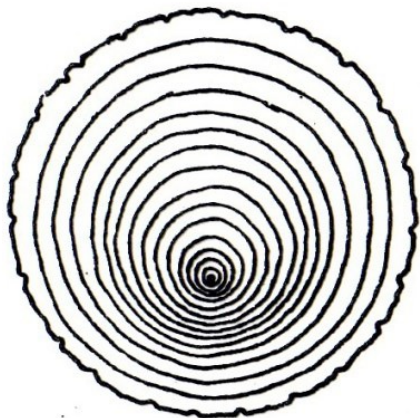
email: [ltakacs@epsz.bme.hu](mailto:ltakacs@epsz.bme.hu)



# FLOOR SLAB FAILURES



# TIMBER MISTAKES



excentricity



contortion



Inner knots/burls



drop out burls



cracks

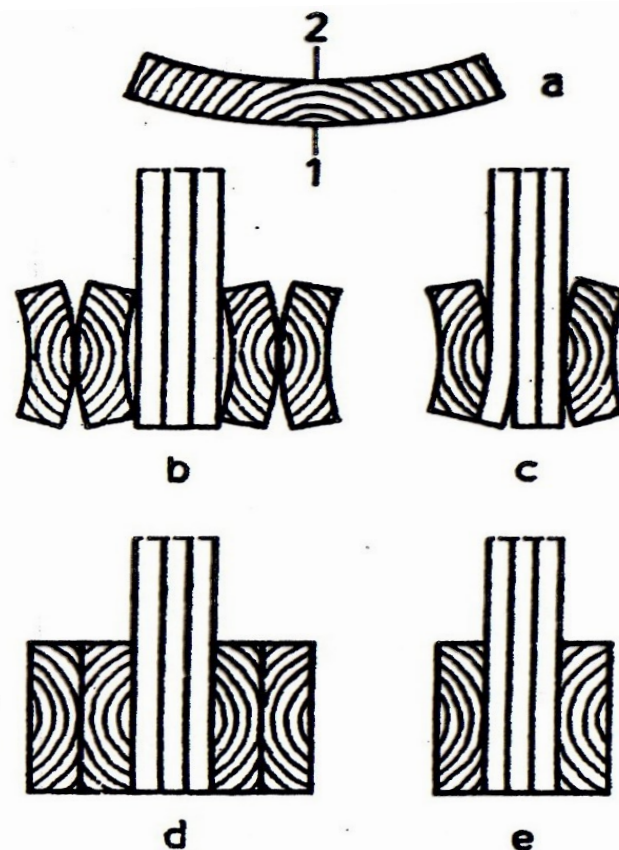


# TIMBER MISTAKES

Movements during drying – twisting, cracking - are not the mistake of the timber but the timber treatment.

Reasons are:

- Long ago, trees were cut in winter time when the moisture content is the lowest, nowadays trees are cut during the whole year
- Long ago, timber logs were dried for 2-3 years below well ventilated canopies before whipsawing – nowadays timber logs are whipsawed immediately after the cut



a: direction of the twisting during drying

Glueing of complex beams:

b, c: improper (can be delaminated)

d, e: proper



# BIOLOGICAL DETERIORATIONS: FUNGAL DECOMPOSITION



Spore of fungi can be found in the air so there should be only a given, continuous moisture content for the inhabitation – usual reasons are: water penetration, high moisture content  
Typical points are: eaves, chimney and other roof penetrations



# BIOLOGICAL DETERIORATIONS: INSECTS



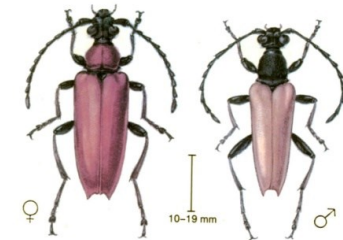
*Anobium punctatum* (De Geer, 1774)  
Holzwurm



*Rhyncolus culinaris* (Germar, 1824)  
Grubenholzkäfer



*Hylotrupes bajulus* (Linné, 1758)  
Hausbockkäfer



*Leptura rubra* (Linné, 1758)  
Rothsbock

The adult beetle form of wood boring insects lay eggs on timber surfaces usually in rough crevices especially in hidden areas. The eggs hatch out and the larvae are very small at this stage so entry bore holes that the larvae make are not readily visible. More insects deteriorate alburnum than core

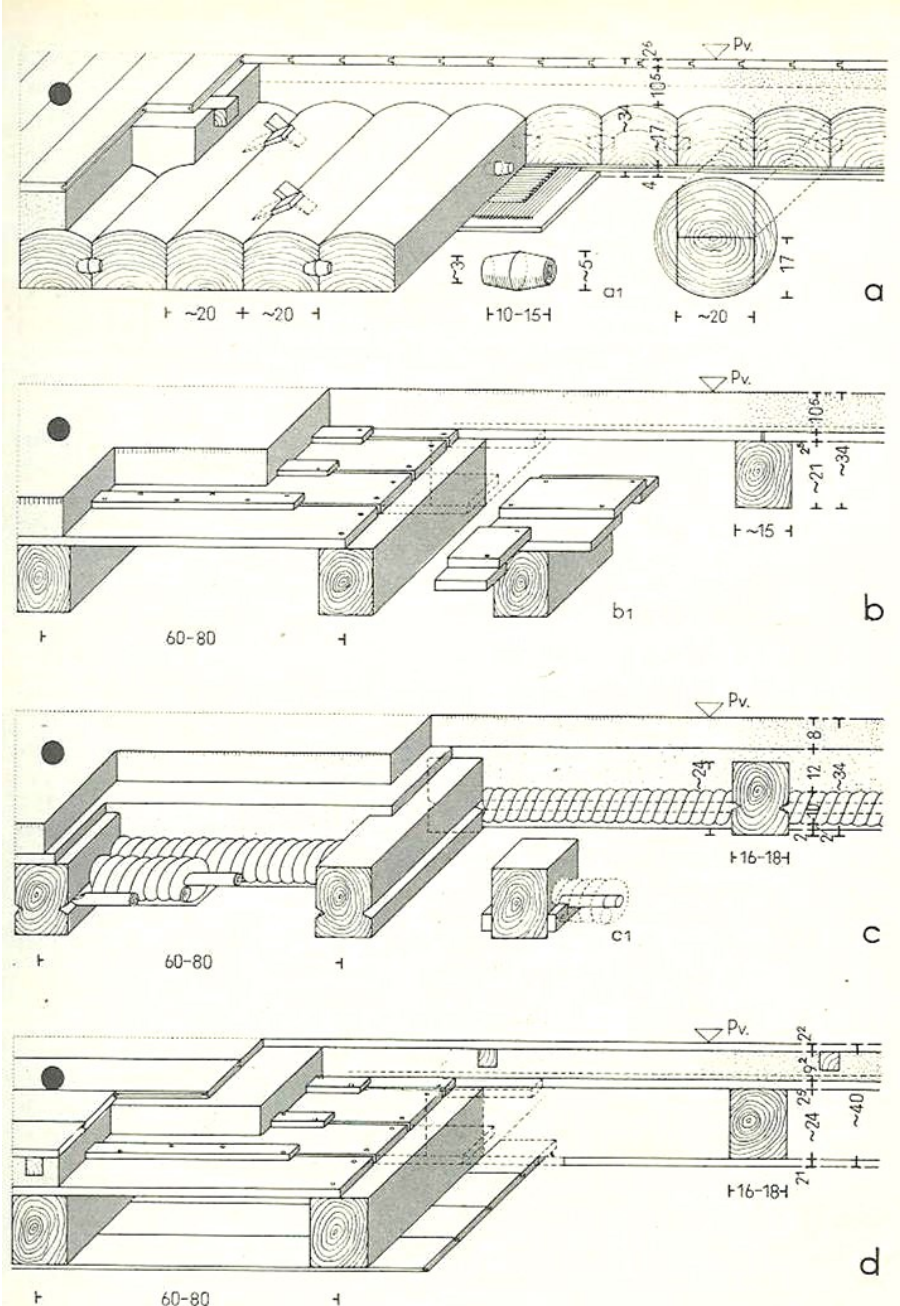


# TIMBER FLOOR SLABS

Dowelled beams

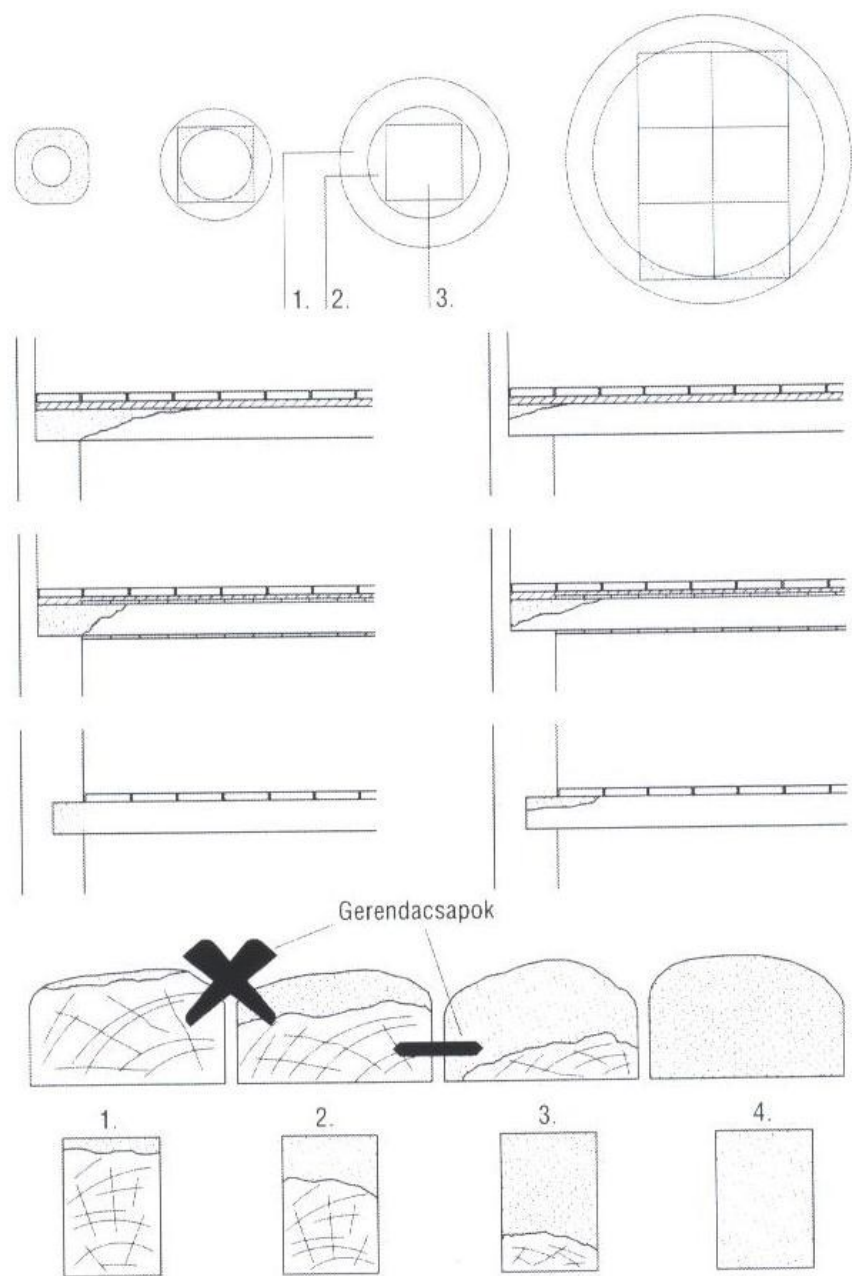
Suspended beams with boards (joints covered with timber battens)

Suspended beams with boards above and below (above: joints covered with timber battens, below: boards are plastered with straw net reinforcement)



# TIMBER FLOOR SLAB FAILURES

- Design and construction problems
- Inadequate loadbearing capacity (stress limit is decreasing with the ageing of the timber)
- Combustibility: reaction-to-fire is D-s2,d0 but the resistance-to-fire performance is better than unprotected steel
- Crack and twisting of the timber – reason: timber logs are usually sawn in wet condition – drying phase is 1-3 years long
- Biological deteriorations
  - Insects
  - Fungal infection: due to moisture exposure – in the middle of the floor slab or at the wall connection (due to condensation)



# BIOLOGICAL DETERIORATIONS - INSECTS



# BIOLOGICAL DETERIORATIONS DUE TO WATER LEAKAGE



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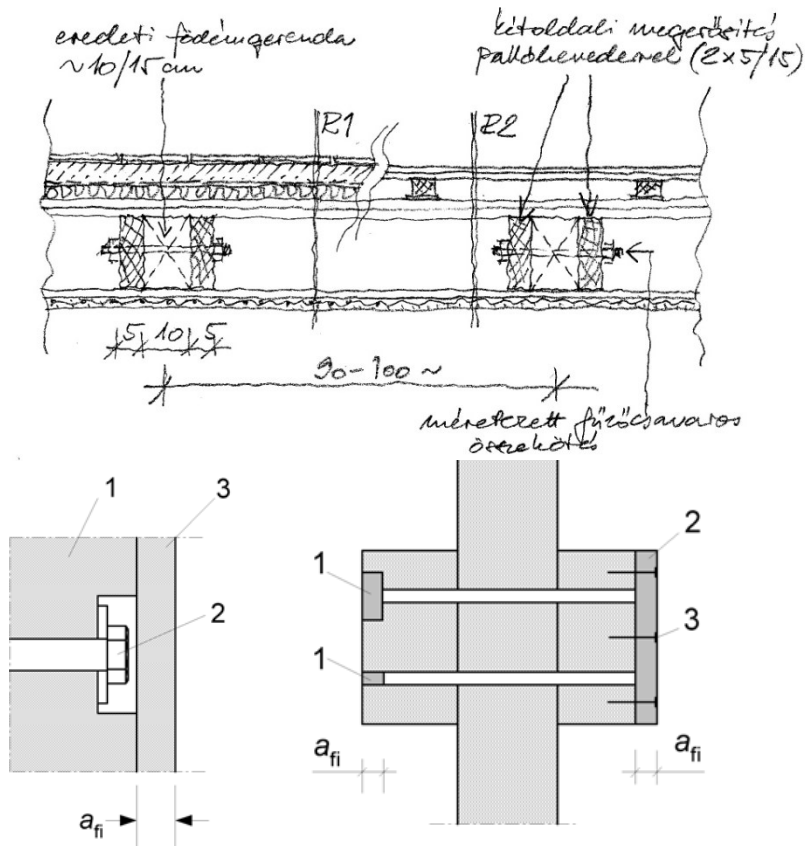


# BIOLOGICAL DETERIORATIONS DUE TO WATER LEAKAGE



# STRENGTHENING OF TIMBER FLOOR SLAB

Suspended timber floor slab: strenghtening with a pair of planks (fixed with threaded rods and nuts)



# NATURAL STONE STRUCTURES – STONE CORRIDORS, STAIRS

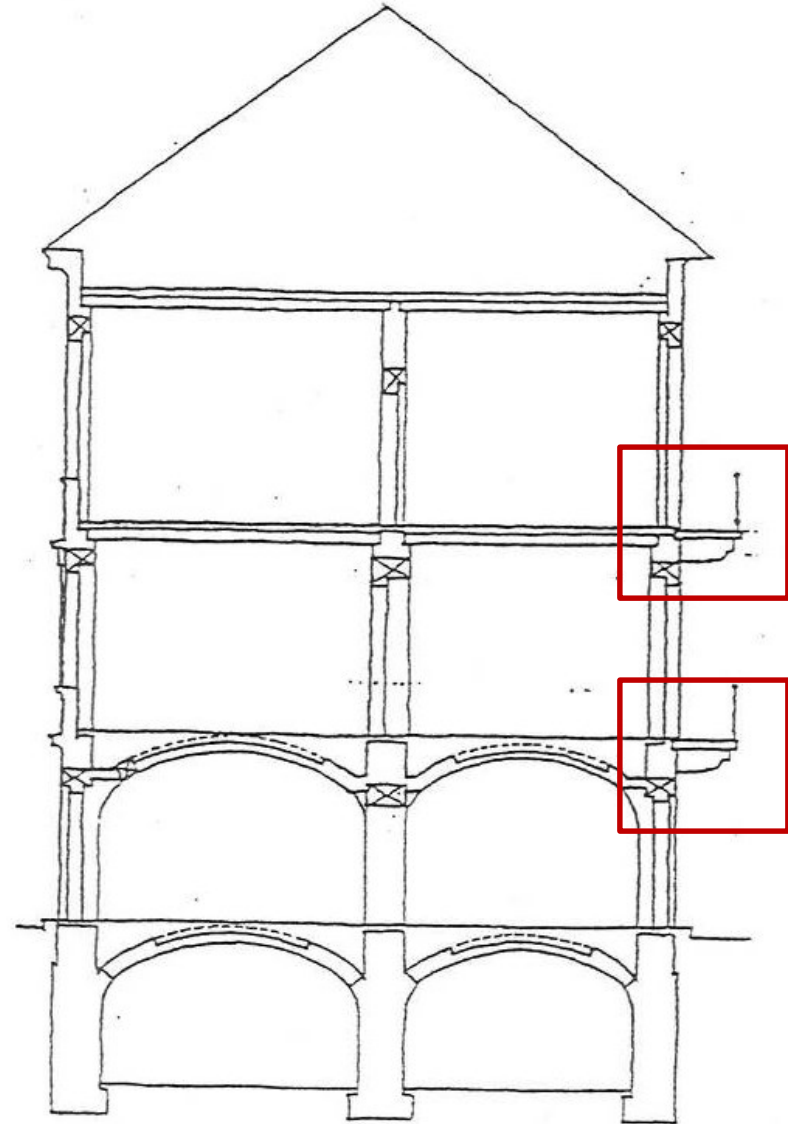
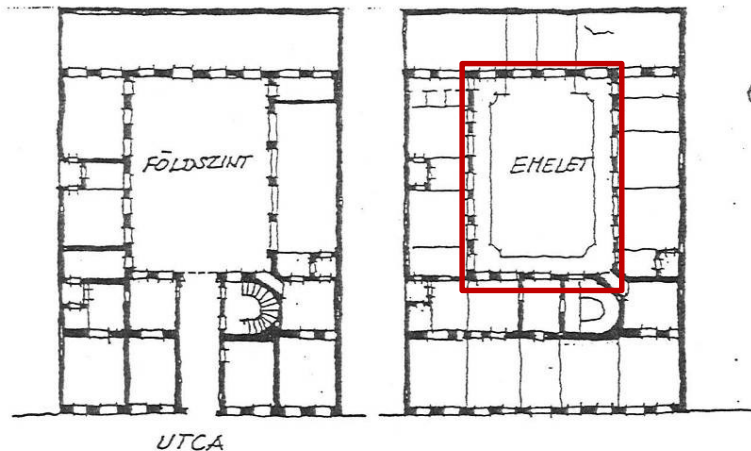
**Cracks:** overloading, dynamic load

**Wearing:** stairs

**Frost:** around handrail fixings (traditional way: cast lead, improper bracing: cement mortar – latter absorbs water)

**Structural stability problems** (lack of loading)

**Material damage** of exposed structures (acid rain, salty snow, soot accumulation, other chemicals)



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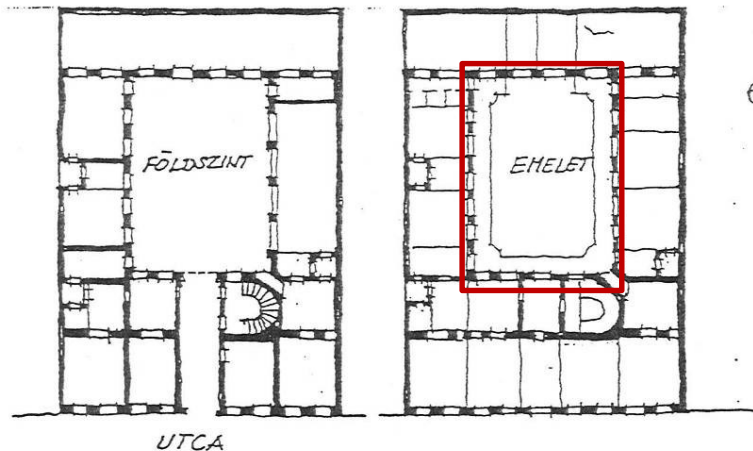
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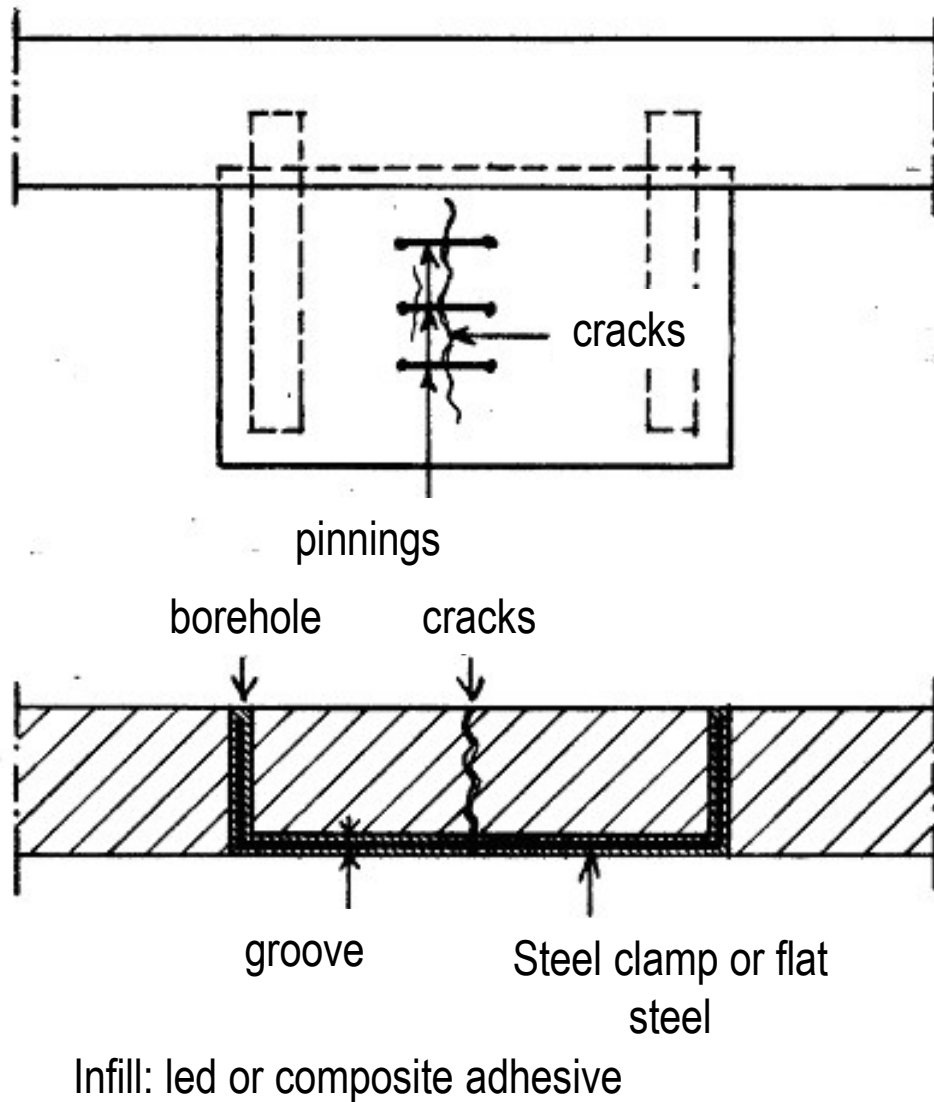
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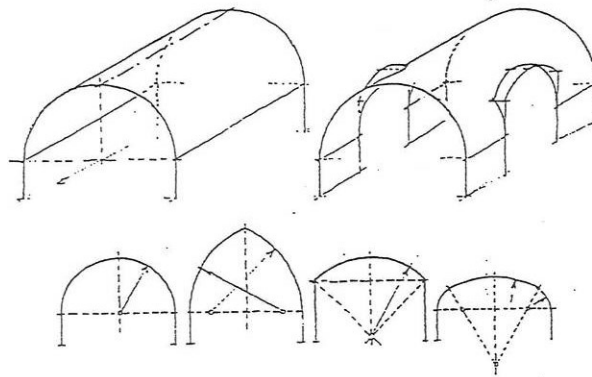
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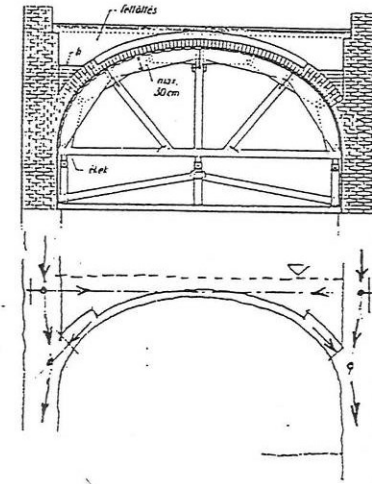
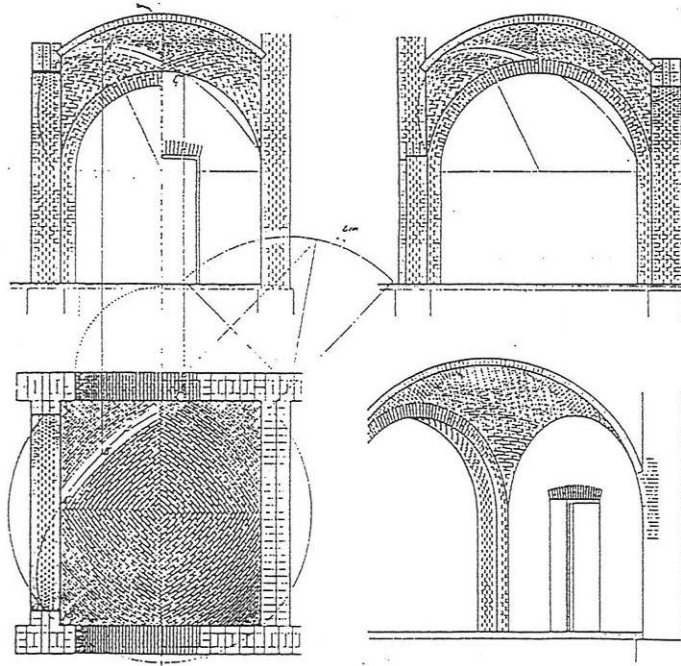
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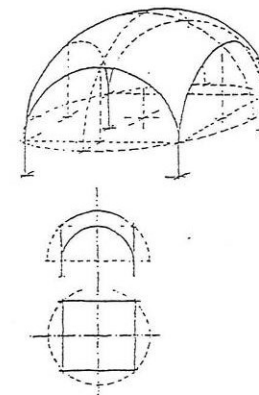
# VAULTED FLOORS



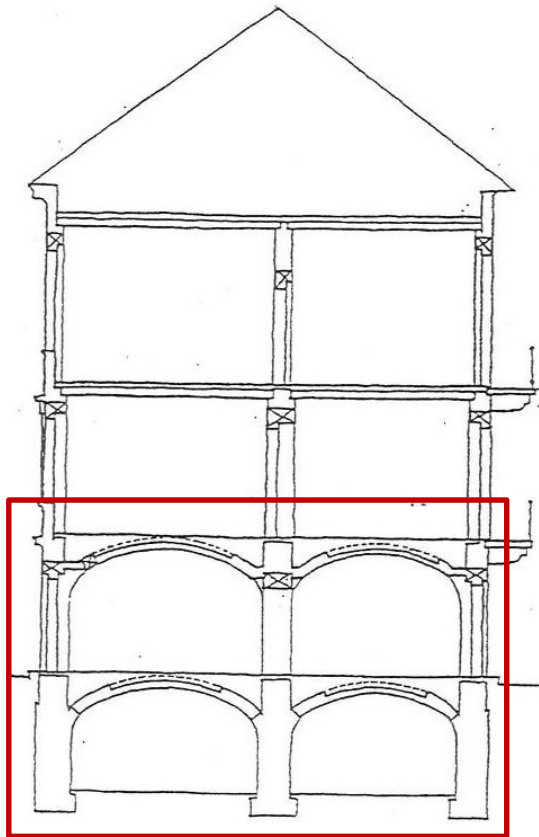
4.3.1. Donga és fiókos donga boltozat



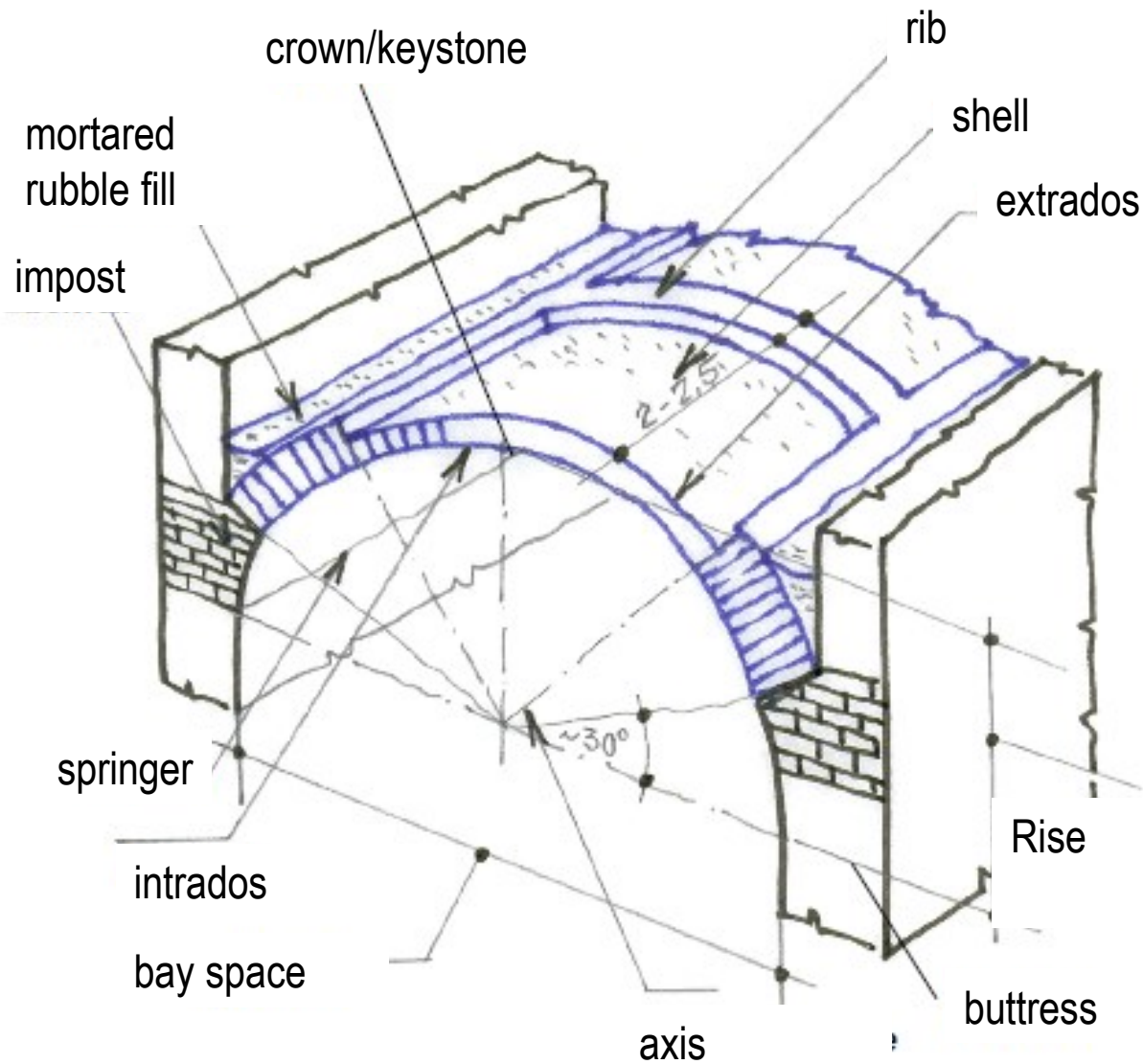
4.3.1. barrel vault



4.3.2. Cseh boltozat  
sémája és falazása



# VAULTED FLOORS – BARREL VAULT

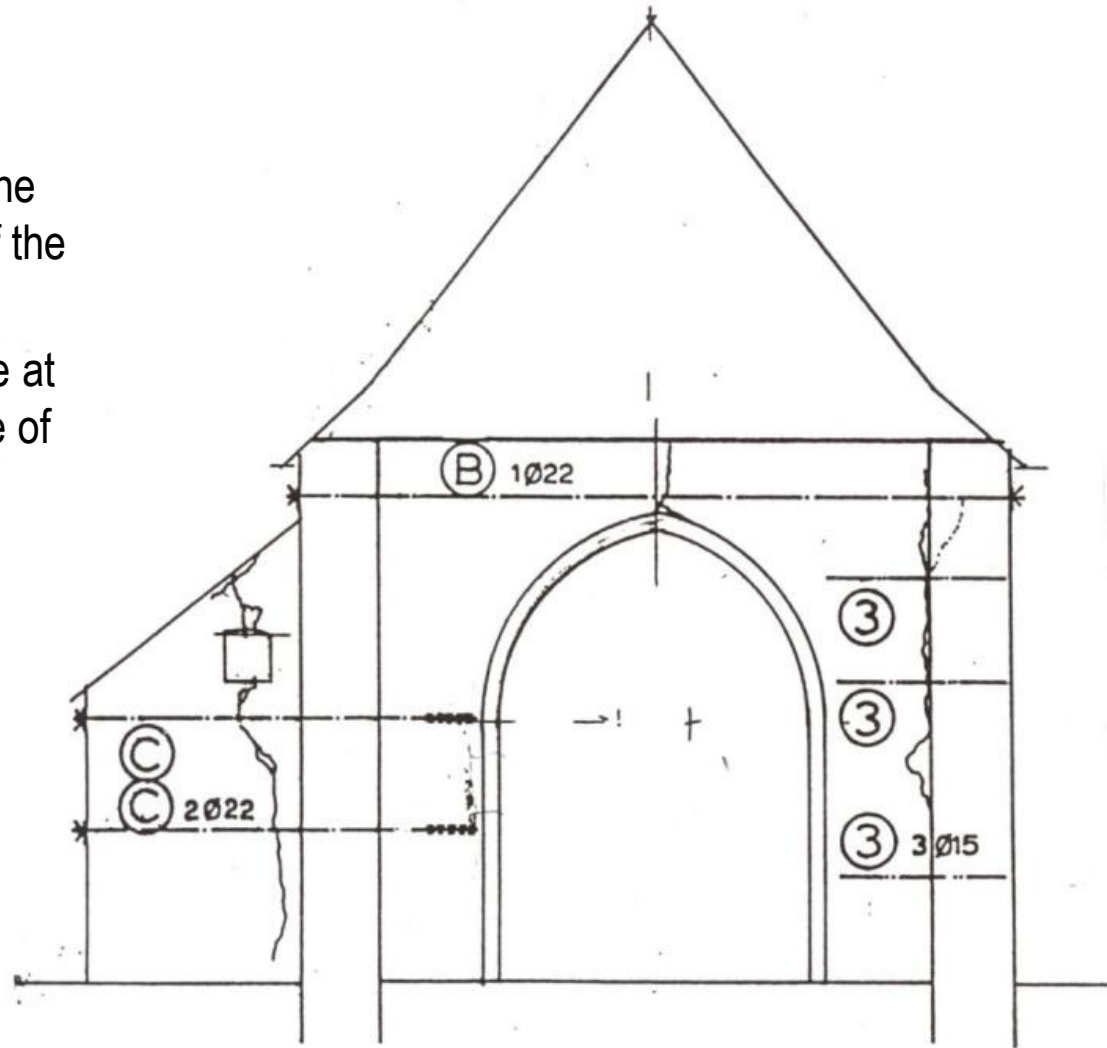


# VAULTED FLOOR FAILURES

Problems are usually caused by  
inequal foundation settlements or  
improper supports (piers, walls)

Overloading is not typical due to the  
enormous loadbearing capacity of the  
structures

Dynamic loads can cause damage at  
the crown (earthquake, fire, failure of  
other structure etc.)



# VAULTED FLOOR FAILURES



# VAULTED FLOOR FAILURES – NOTRE DAME, PARIS, 2019



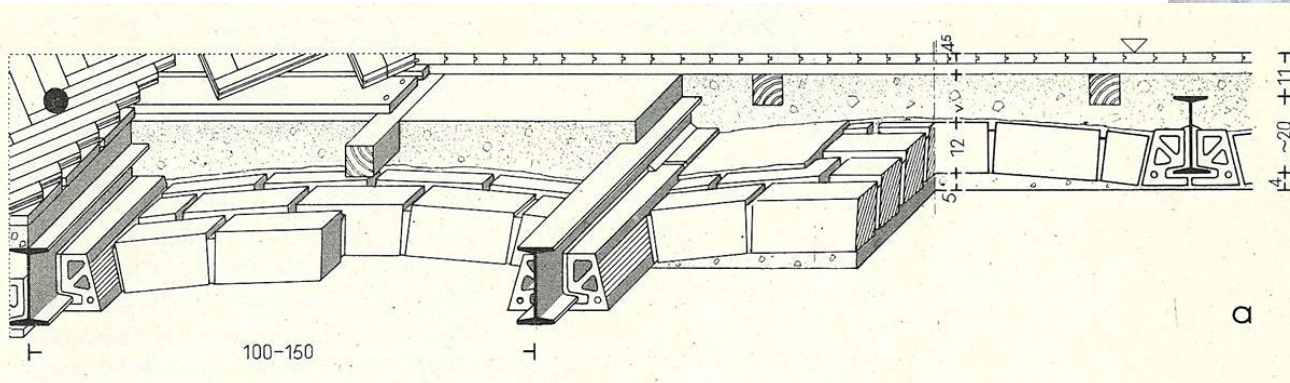
# VAULTED FLOOR FAILURES – NOTRE DAME, PARIS, 2019



# VAULTED FLOOR FAILURES – NOTRE DAME, PARIS, 2019



# FLOOR SLABS WITH STEEL BEAMS



Jack arch slab:  
hot rolled steel  
beams and flat  
brick arches  
(with or without  
abutment brick  
members)



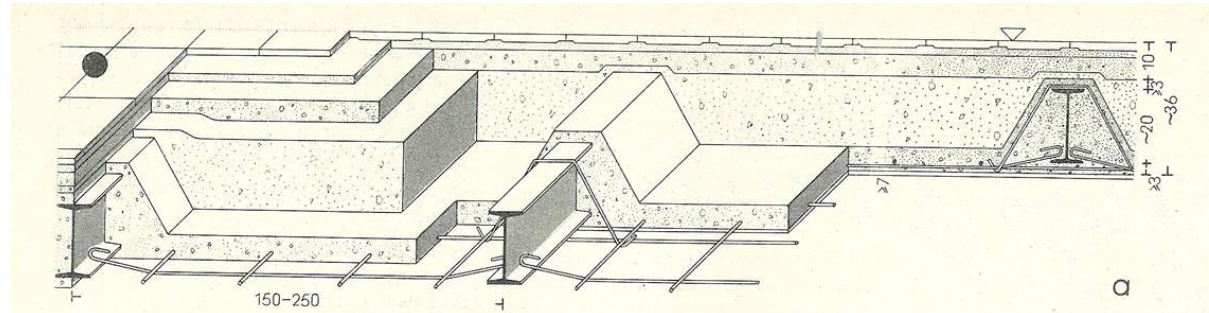
# FLOOR SLABS WITH STEEL BEAMS - FAILURES

- Improper loadbearing capacity, overloading
- Support failure
- Corrosion (water leakage, vapour condensation, or improper desing – it was forbidden to use over basement without waterproofing)

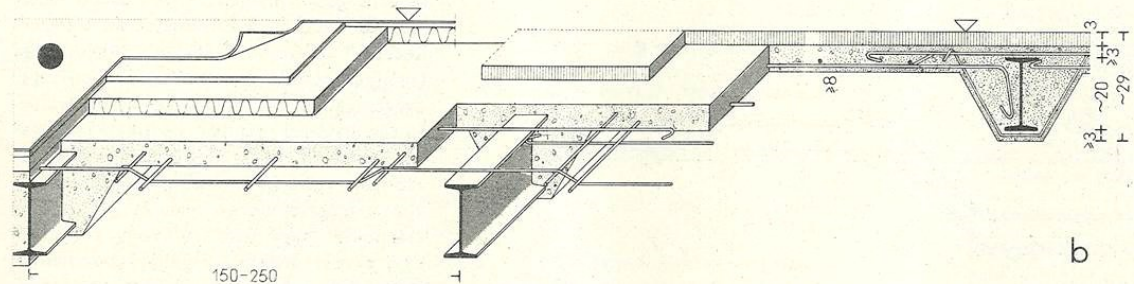


# FLOOR SLABS WITH STEEL BEAMS

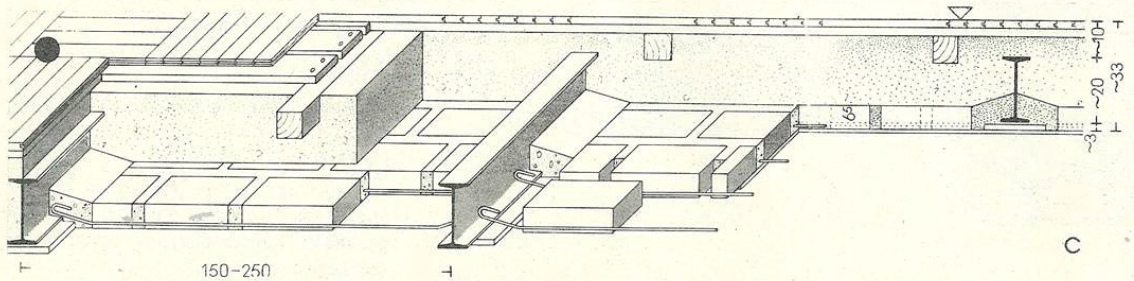
Upright steel beams with  
RC beams



Downstand steel beams  
with RC slabs

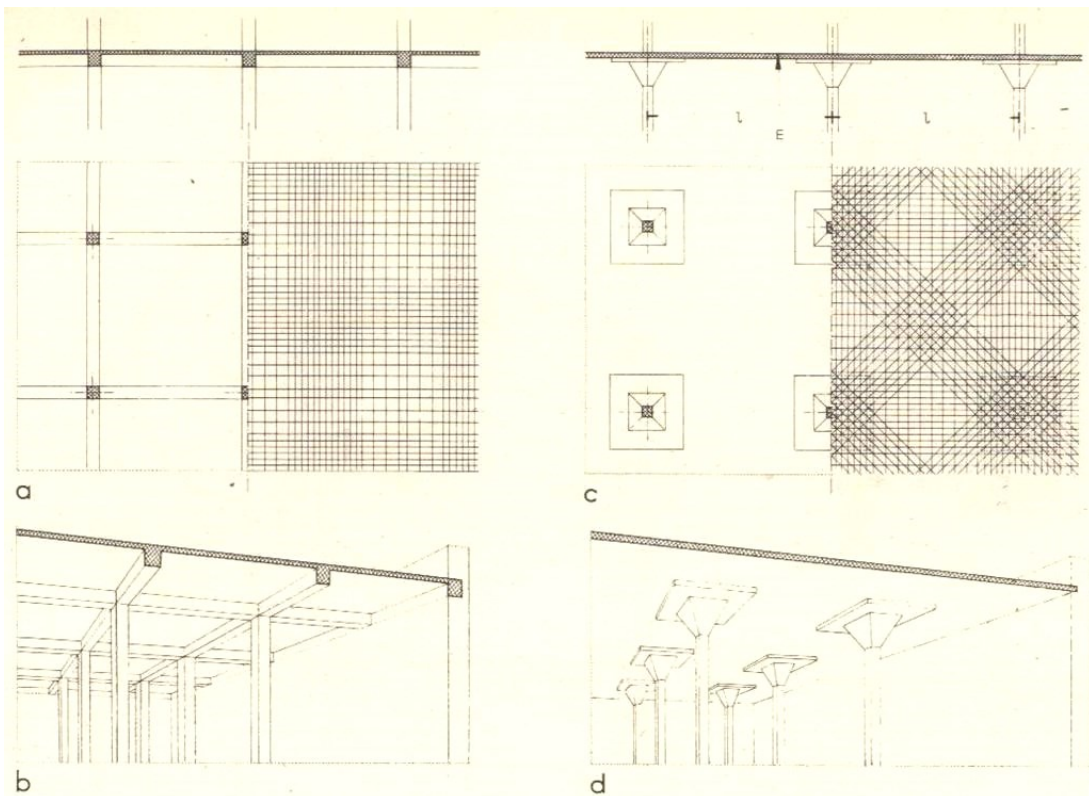


Upright hot rolled steel  
beams with RC brick infill

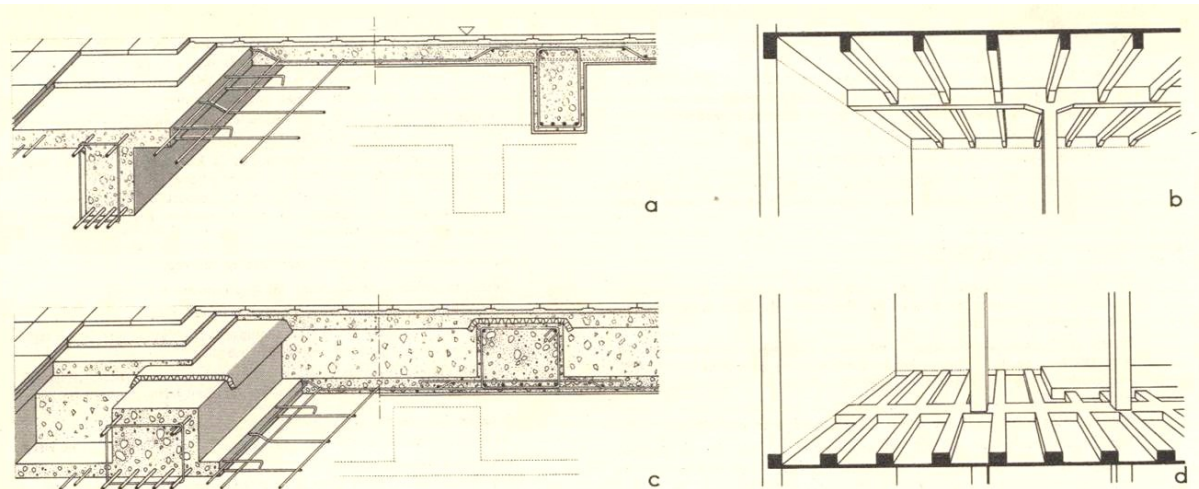


# MONOLITHIC RC FLOORS

Double downstand beams



Downstand beams



Upright beams



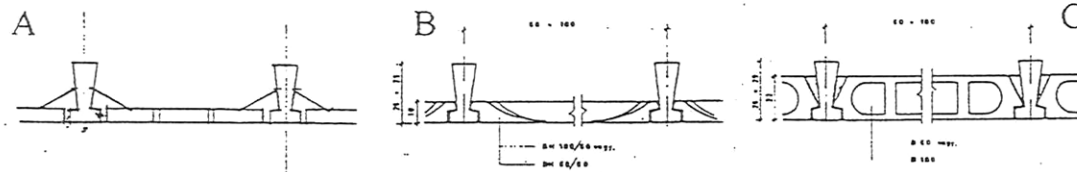
# MONOLITHIC RC FLOOR SLAB FAILURES

- Improper loadbearing capacity, overloading
- Support failure
- Corrosion (improper concrete cover – corrosion of the reinforcement, concrete corrosion)



# PREFABRICATED RC FLOORS

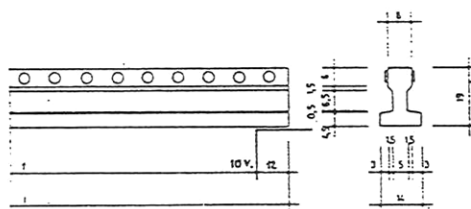
F, G type of beams (non stressed)



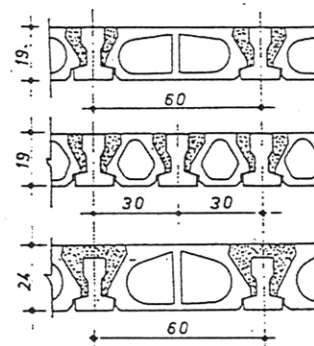
4.4.3. F, G gerendákkal épített födémek:

(A: Horcsik, B: BH-tálcás, C: B60 és B100 béléstestek)

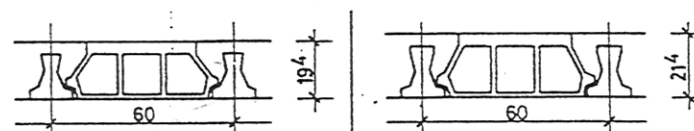
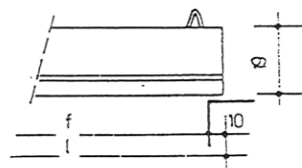
E type of beams  
(prestressed) with concrete  
infill elements



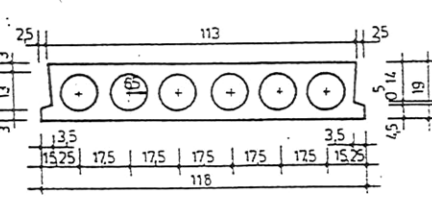
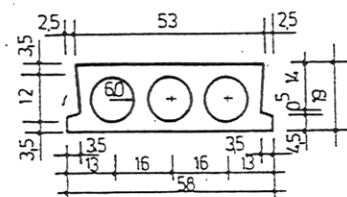
4.4.3. E-gerendás födémek



Prefabricated hollow floor  
slabs



4.4.3. PPB-födém



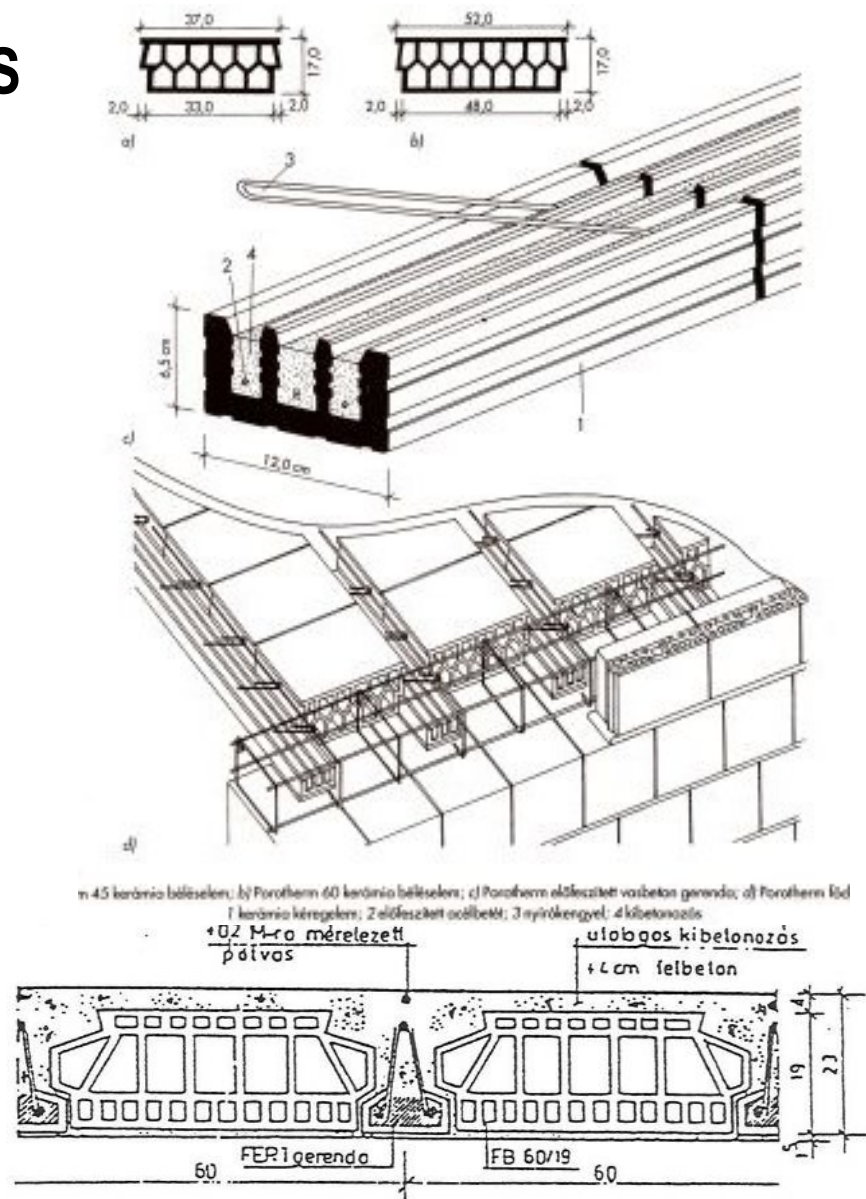
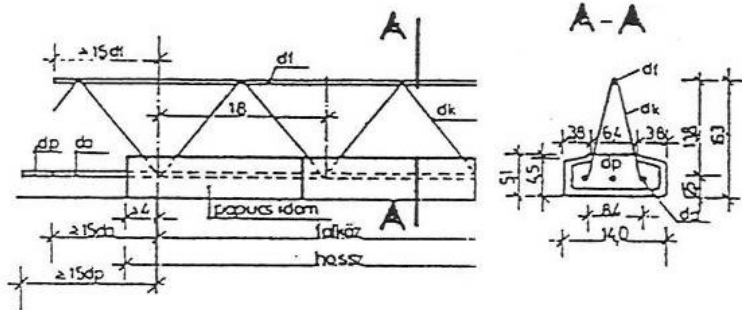
4.4.3. PK és PS-födémelemek



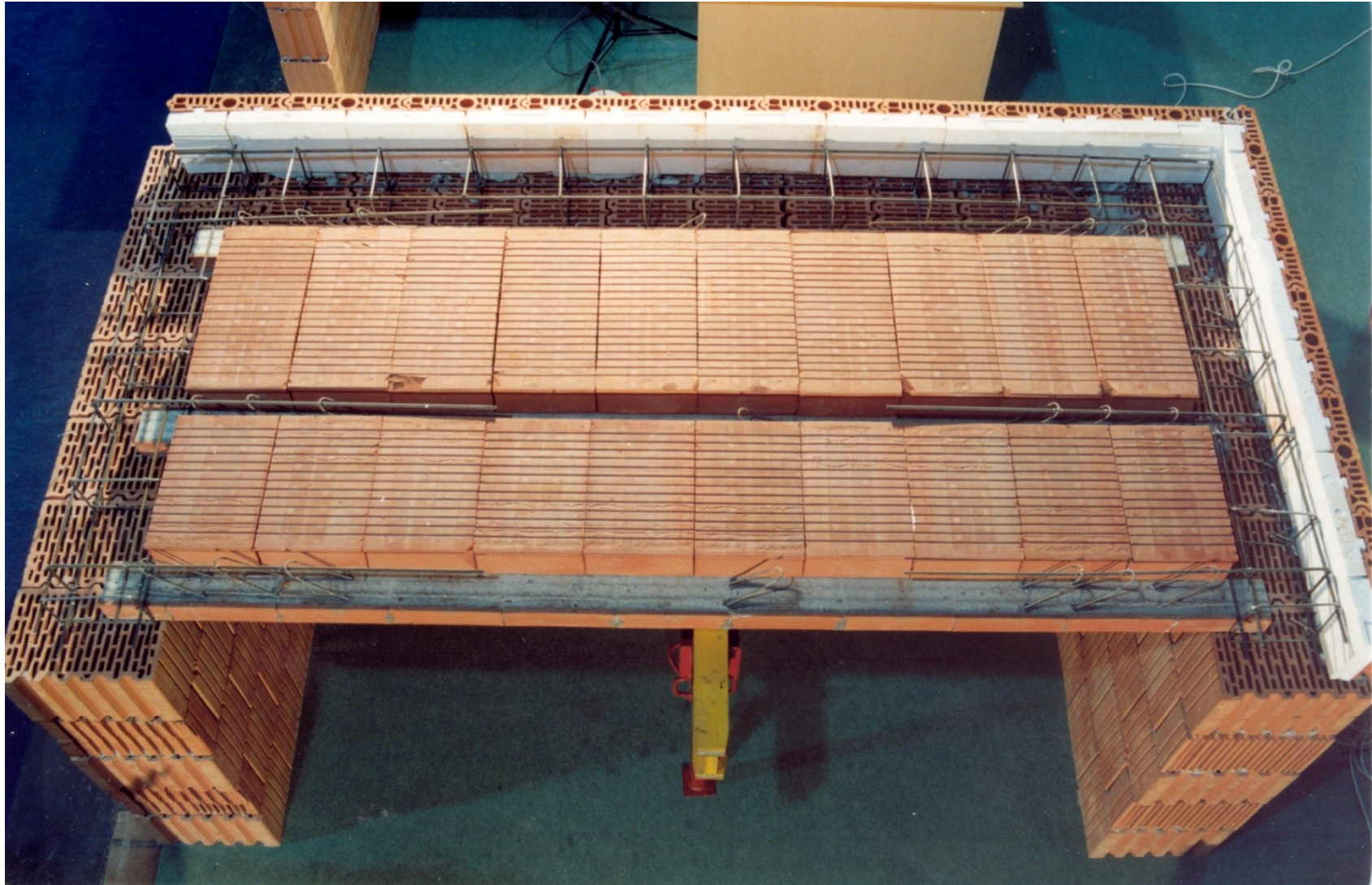
## SEMI-MONOLYTHIC RC FLOORS

Up-to-date floor (prestressed)

FERT floor (non-stressed)



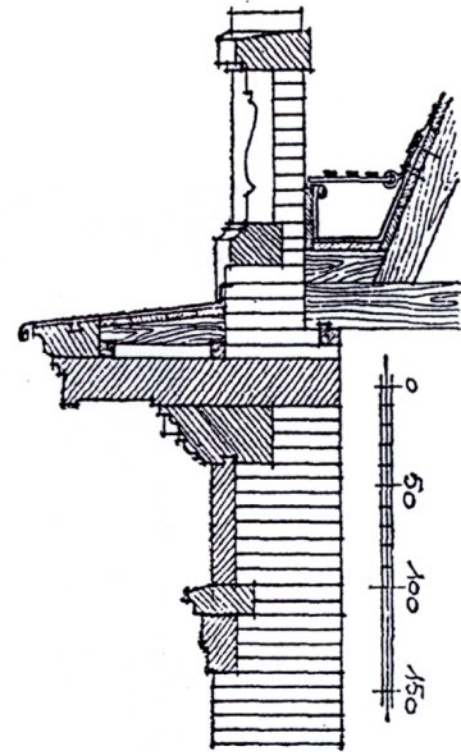
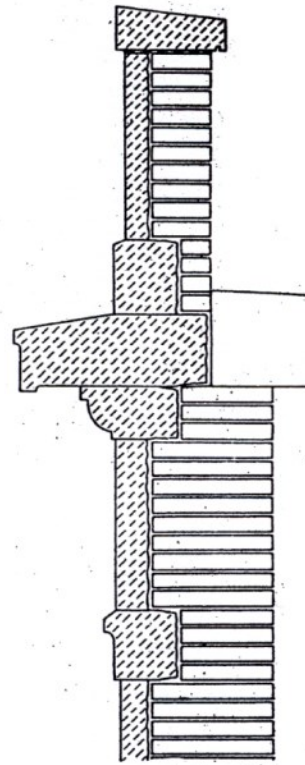
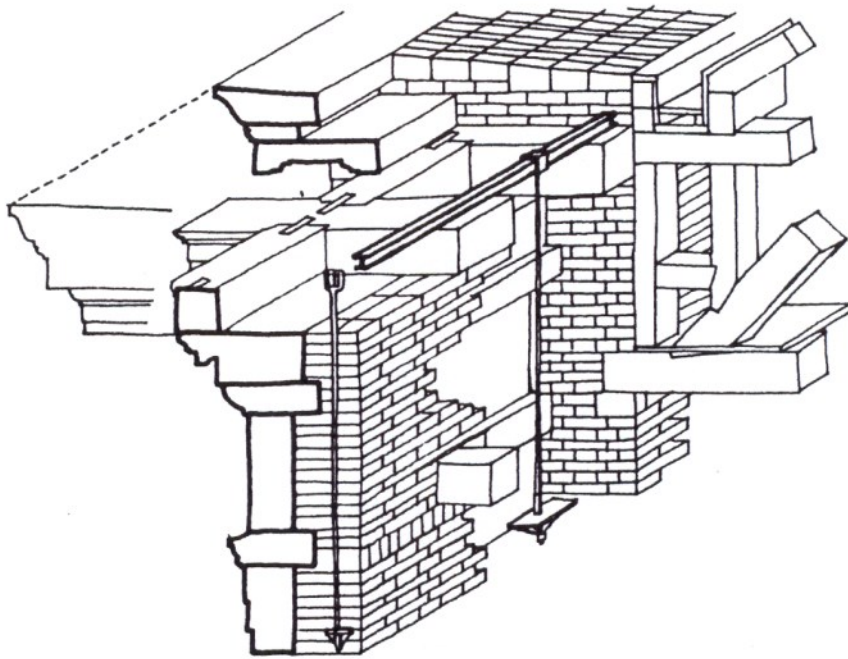
# SEMI-MONOLYTHIC RC FLOORS



# FROST DAMAGE OF PREFABRICATED RC BEAMS



# CORNICE PROBLEMS

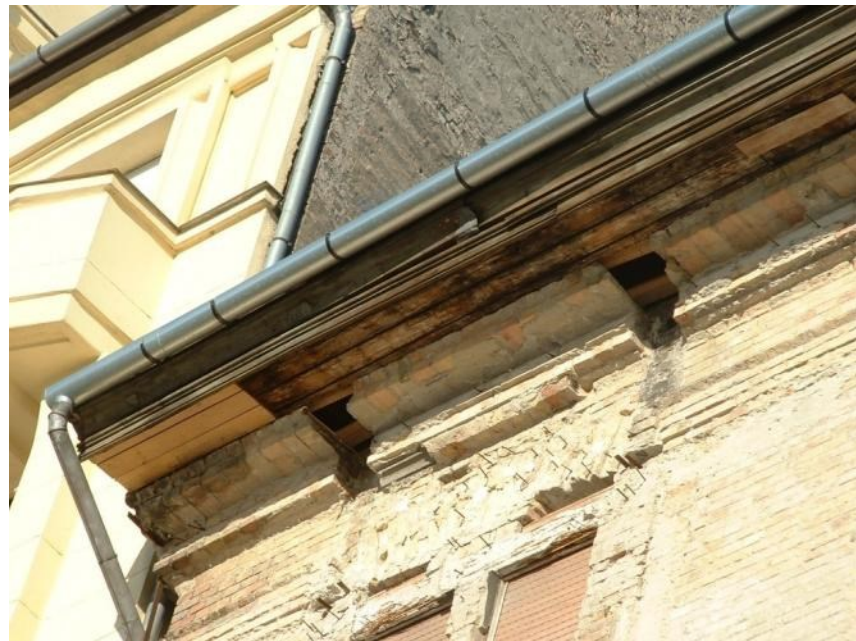


Structural stability: anchoring problems of the cantilevered members

- corrosion – water leakage, vapour condensation,
- fire,
- Improper reconstruction works



# CORNICE PROBLEMS



- Structural stability: anchoring problems of the cantilevered members (corrosion) – water leakage, vapour condensation
- Solution: first to repair the gutter and the flashings, then the cornice



# ROOF STRUCTURE FAILURES

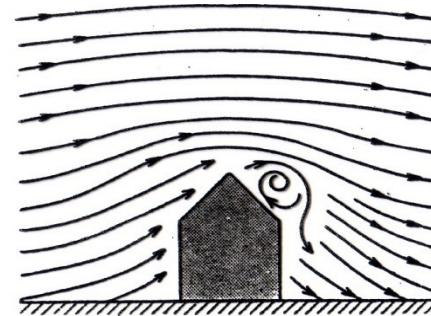


# SPECIAL EXPOSURES ON PITCHED ROOFS: WIND

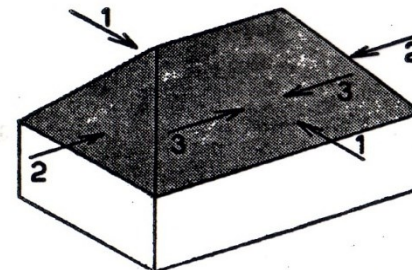


[www.langlovagok.hu](http://www.langlovagok.hu)

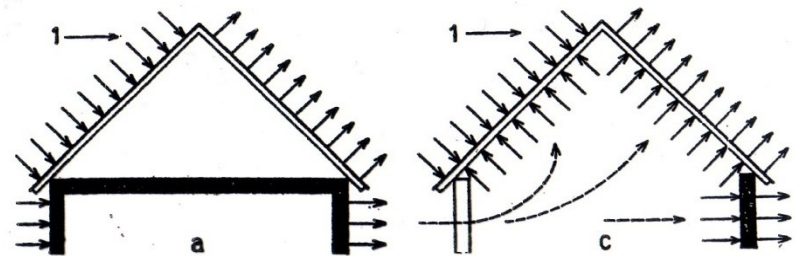
- Direction and the pressure is changing
- Dynamic effect



Wind pressure and -suction



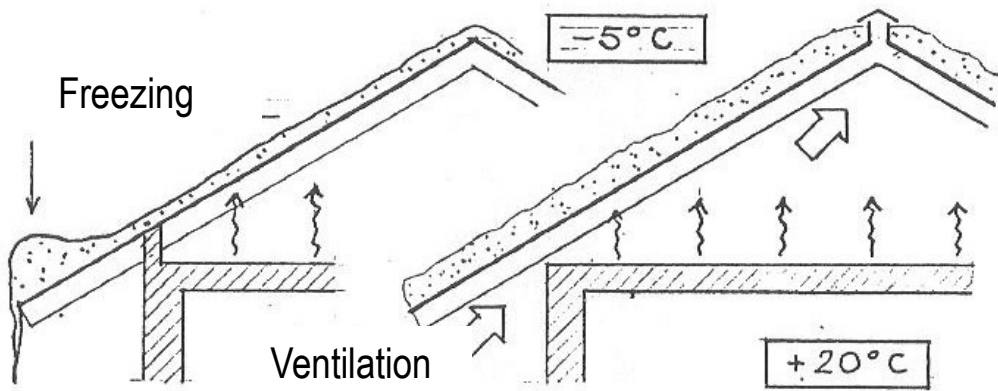
Direction of wind forces



# SPECIAL EXPOSURES ON PITCHED ROOFS: SNOW, ICICLES



- Due to the heat loss from inside, snow melts on the roof, but the molten snow freezes again around the eaves where there is no heat loss
- It may overload the eaves and can cause water backflow
- Solution: ventilating the roof, providing external temperature below the roof cladding



Snow, ice (extra loads in winter conditions)



# SPECIAL EXPOSURES ON PITCHED ROOFS: SNOW, ICICLES



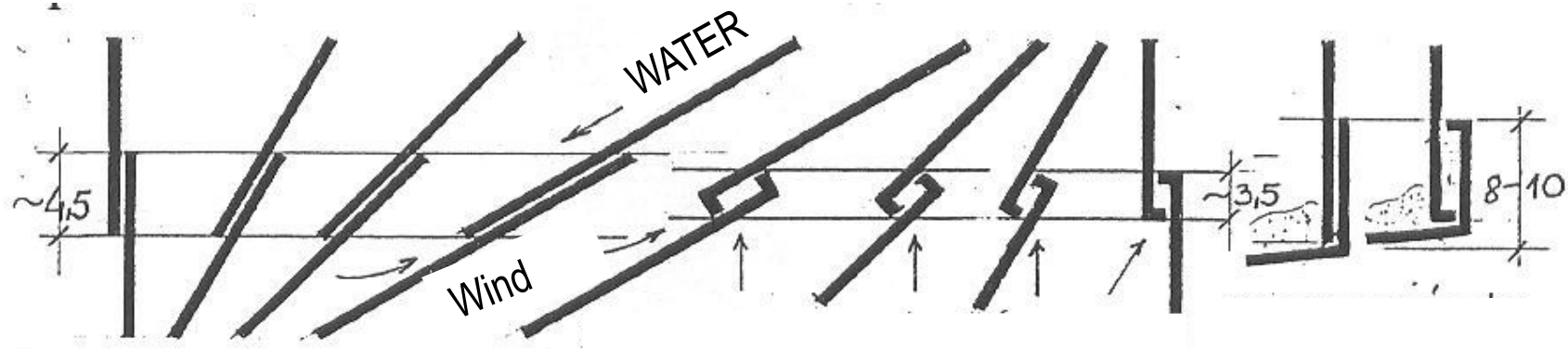
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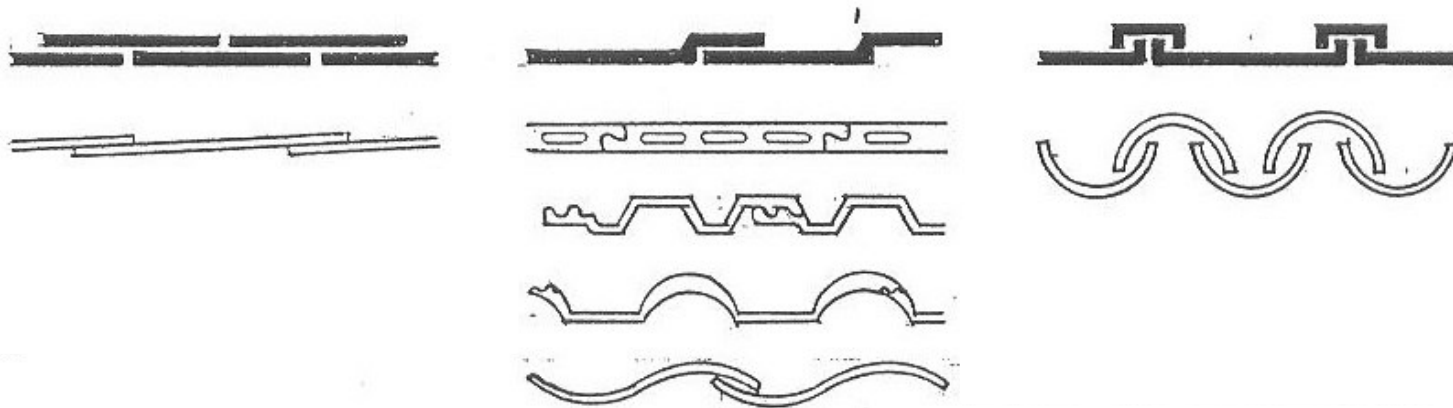
# RESULT OF A CLOUD-TO-GROUND DISCHARGE (LIGHTNING)



# OVERLAPPING AND JOINTS OF THE ROOF COVERING ELEMENTS



Overlapping of the roof covering elements – decompression gap



Single and double layer plain covering – interlocking roof covering – tegula-imbrex covering



# ALLOWED PITCH RANGE OF ROOF COVERINGS

cladding types	roof pitch angle																			
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	
Burn clay roof tiles:																				
- beaver-tail shape																				
- extruded																				
- compression-molded																				
- Dutch																				
Concrete roof tiles:																				
-Dutch-like																				
- beaver-tail like																				
-ETERNIT artificial slate claddings:																				
- scale-like																				
- corrugated sheet																				
Metal shingles																				
Bituminous shingles																				
Bituminous membrane																				



# PITCHED ROOF STRUCTURE AND ROOF COVERING FAILURES

- Timber mistakes (cracks, twisting etc.) – usually minor problems
- Water penetrations (mainly at the eaves and at the penetrations like chimney, dormer windows, skylight windows etc.)
- Biological deteriorations (fungal infection, insects)
- Frost damages

## Test methods:

- Visual inspection – at daylight, from inside out
- Water test (leakage)



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# ROOF COVERING FAILURES - FROST



# ROOF COVERING FAILURES – IMPROPER ROOF PITCH ANGLE



# BITUMINOUS SHINGLE FAILURES – WEARING



# BITUMINOUS SHINGLE FAILURES – WEARING



# RAINWATER SYSTEM FAILURES



- Improper inclination
- Frost – icicles (mechanical damage and/or overload of the gutter)
- Snow – avalanche
- Lack of maintenance (cleaning – twice a year)



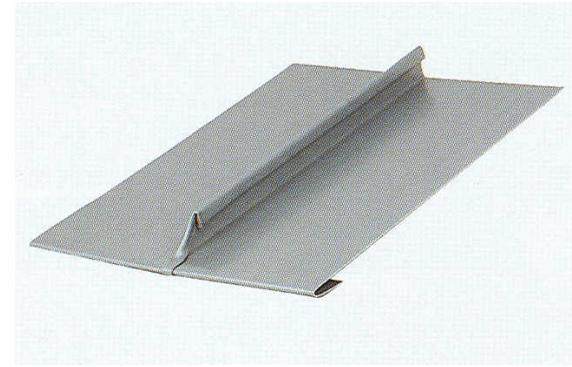
# MATERIALS OF METAL ROOF CLADDINGS

**Materials (thickness: 0,5 – 1,0 mm):**

- **aluminium** surface - anodic oxidation - or surface treated)  
corrugation pattern: trapezoid, wavy or composite profile  
panels, planks, strips
- **steel** (galvanised or coated) trapezoid, wavy or composite  
profile panels,
- **Copper** (seamed roofing or profile panels).
- **titanium zink** – modular roof covering (soldered roof  
coverings will be introduced separately)

**Contact corrosion** has to be considered when different kind of metals have physical connection or connection via rainwater or dewatering:

- water drained away from copper surfaces may not make  
contact with any other metal;
- a separating layer must be built in between incompatible  
components;
- the majority of timber conservation substances attack  
metals;
- concrete and plastered surfaces release calcium - hidroxide  
that destroys aluminium and zinc.



Copper



Coated steel



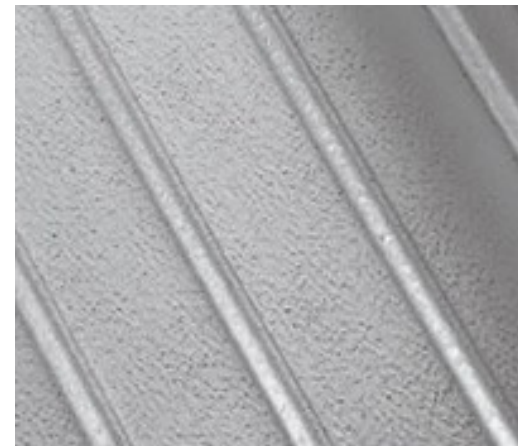
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Pre-weathered aluminium

Titanium zink: bright-  
rolled, natural and pre-  
weathered



# MATERIALS OF METAL ROOF CLADDINGS



# METAL ROOF CLADDINGS – PROPER EXAMPLES



# METAL ROOF CLADDINGS – PROPER EXAMPLES



# METAL ROOF CLADDINGS – PROPER EXAMPLES



# METAL ROOF CLADDINGS – IMPROPER EXAMPLES



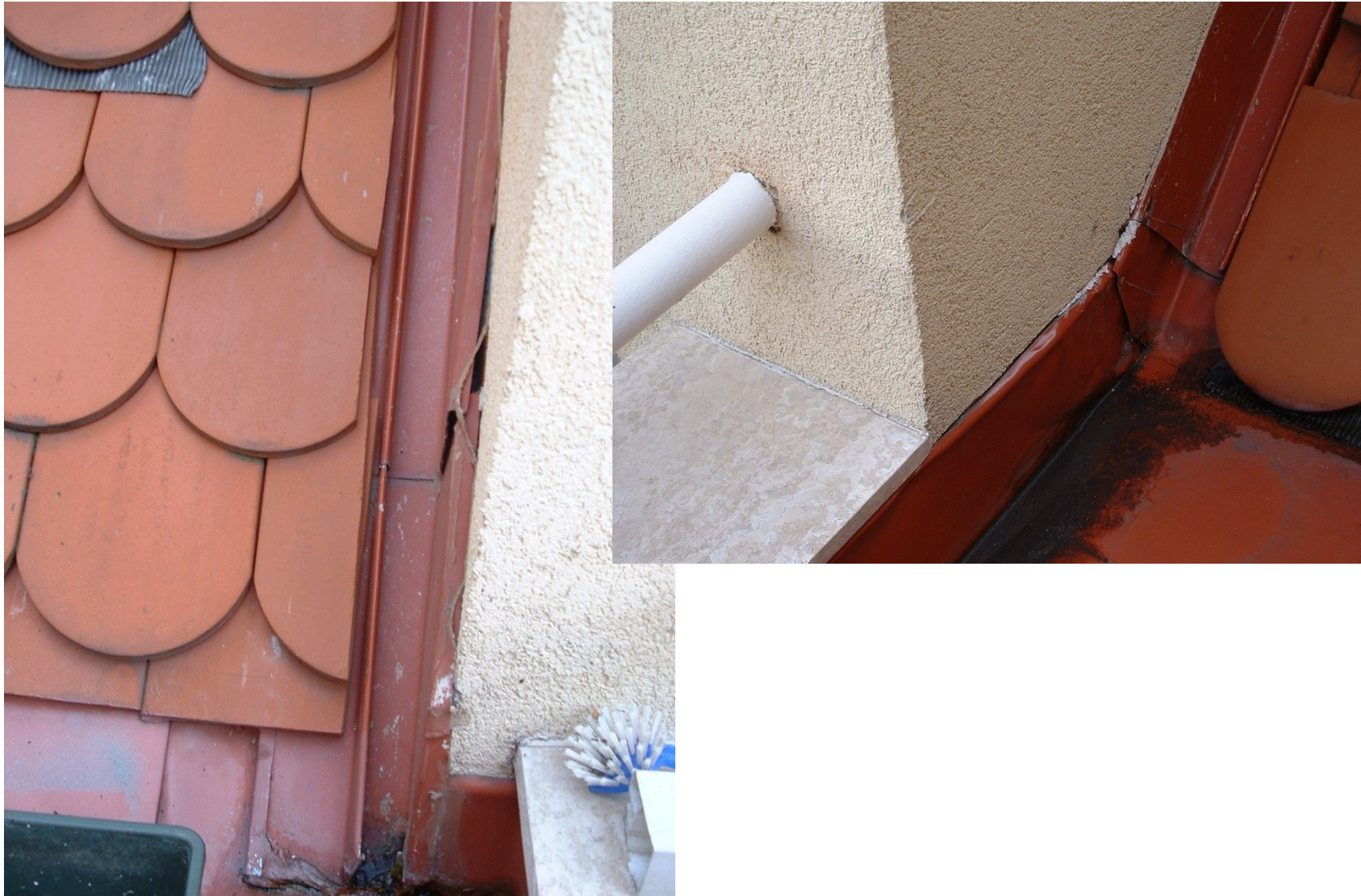
# METAL ROOF CLADDINGS – IMPROPER EXAMPLES



# METAL ROOF CLADDINGS – IMPROPER EXAMPLES



# METAL FLASHINGS – CONNECTION FAILURES



# METAL FLASHINGS – CONNECTION FAILURES

