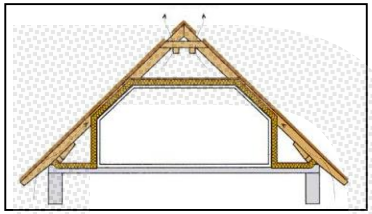
Budapest University of Technology and Economics
Faculty of Architecture Engineering
Department of Building Constructions

FLAT ROOFS

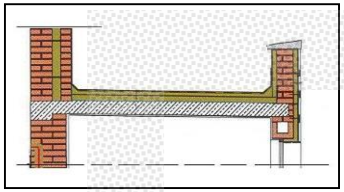
GUIDELINES
GENERAL REQUIREMENTS

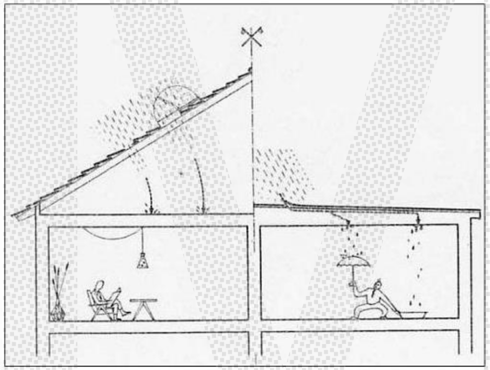
Horváth Sándor - Fülöp Zsuzsanna Ph.D

Budapest 2017.



ROOF THERMINOLOGY





PITCHED ROOF

FLAT ROOF

low pitch roof

roof with pitch between 6 and 30 degree

middle pitch roof

roof with pitch between 30 and 45 degree

high pitch roof

roof with pitch between 45 and 60 degree

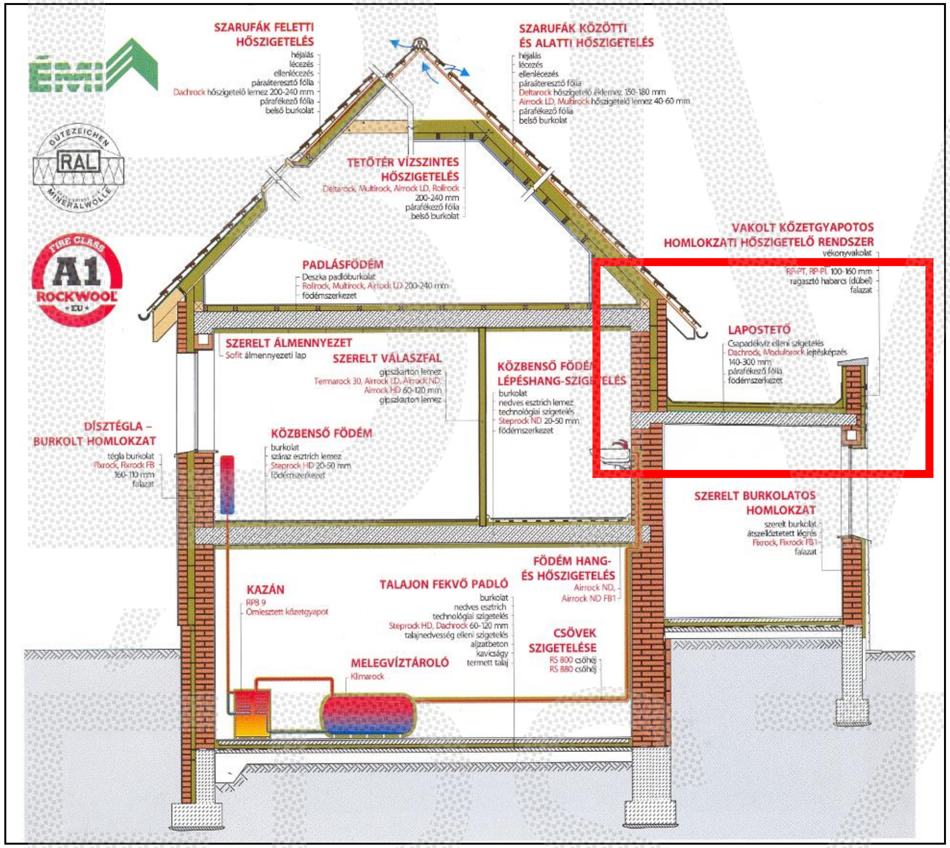
very high pitch roof

roof with pitch of over 60 degree

slope

2 % - 8 % (6°)

ROOF THERMINOLOGY



FLAT ROOFS

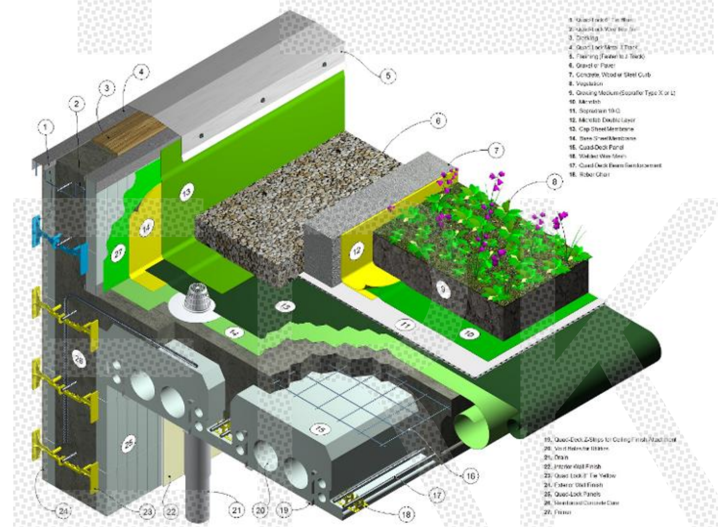
EVALUATION IN THE CONTEXT OF THE WHOLE BUILDING

CLASSIFICATION OF FLAT ROOFS

Non Exploited -
(Non Trafficked) flat roof

walking on the roof
surface only for maintenance;

Exploited (Trafficked) flat roofs

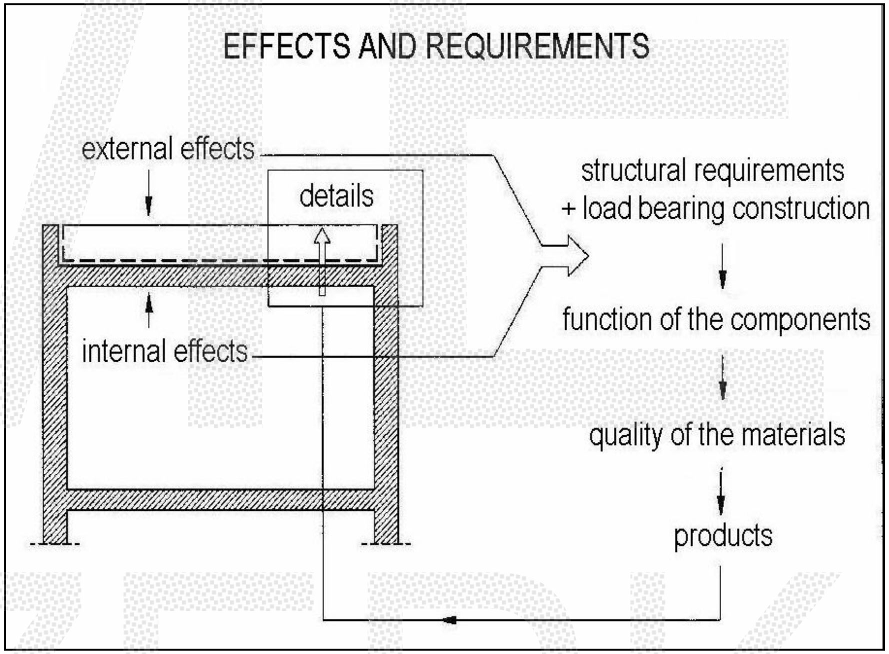


terraces
green roofs
roads, parking areas.

REQUIREMENTS OF NON EXPLOITED FLAT ROOFS

Requirements
according to the **impacts**

loads given from structures, wind, snow,
SUPPORTING, FIXING
UV radiation
UV PROTECTION
rain
WATERPROOFING, DRAIN SYSTEM
Internal - external temperature
THERMAL INSULATION
Internal – external vapour pressure
VAPOUR PROTECTION
chemical, mechanical etc. interaction
SEPARATION
noise
SOUND INSULATION
fire
FIRE RESISTANCE



NON EXPLOITED FLAT ROOFS

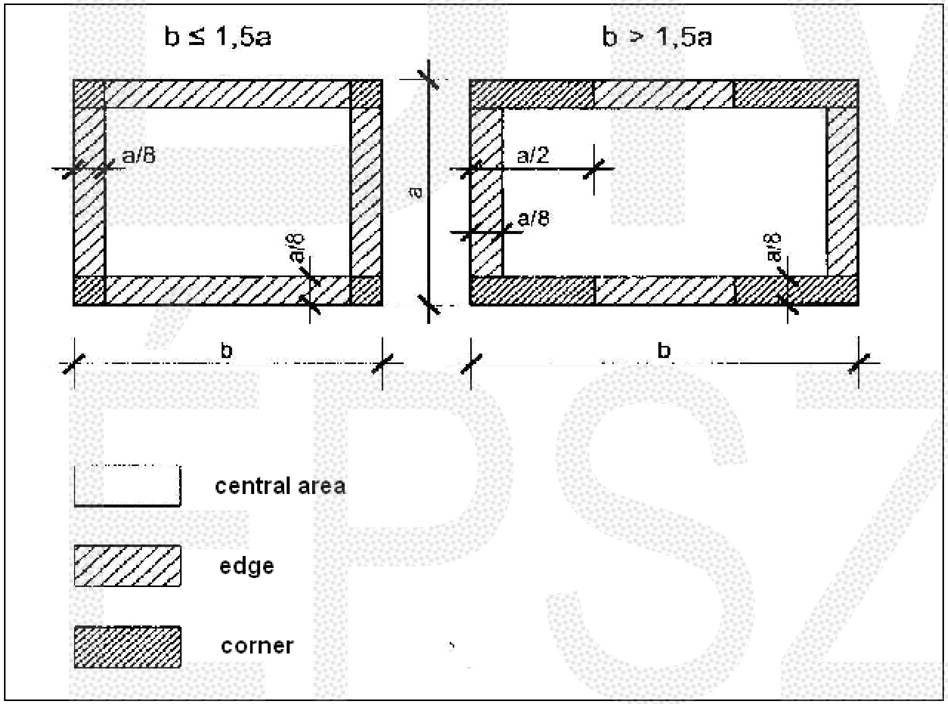
LAYERS

1. Loadbearing slab	r.c. / trapezoid metal sheet
2. Fixing method	glued or ballasted or mechanically fixed
3. Drain system	internal (gully) - external (gutter)
4. Waterproofing (DPC)	plastic or bitumen membranes
5. Slope of DPC	loadbearing structure / concrete / thermal insulation
6. UV protection	chemical or mechanical
7. Thermal insulation	plastic foam / mineral wool
8. Vapour barrier	plastic or bitumen membranes
9. Separation layer	glass or plastic fleece

WIND LOADS - FASTENING

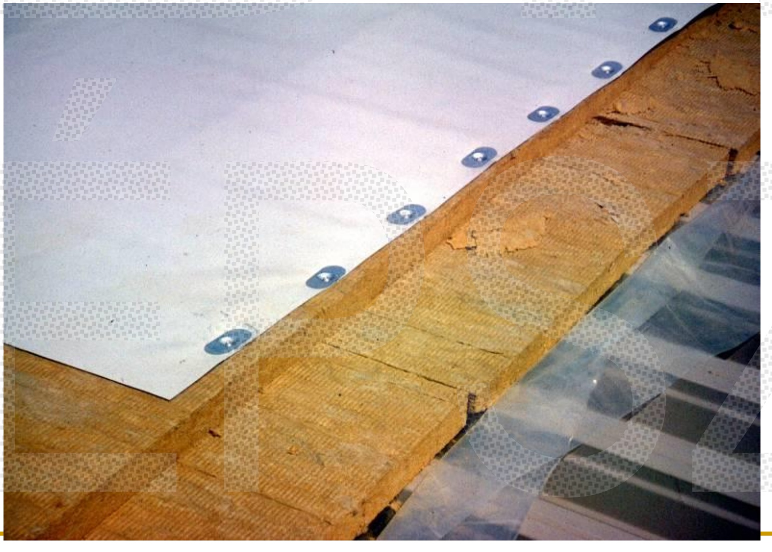
Windpressure (kg/m2)

Hight of the roof	Situation on roof surface		
	corner	edge	central area
≤ 0-8 m	225	168	34
8-20 m	360	210	42



Lightweight or small elements must be fixed on the roof surface. Wind loads are classified and measured by standards.

WIND LOADS - FASTENING

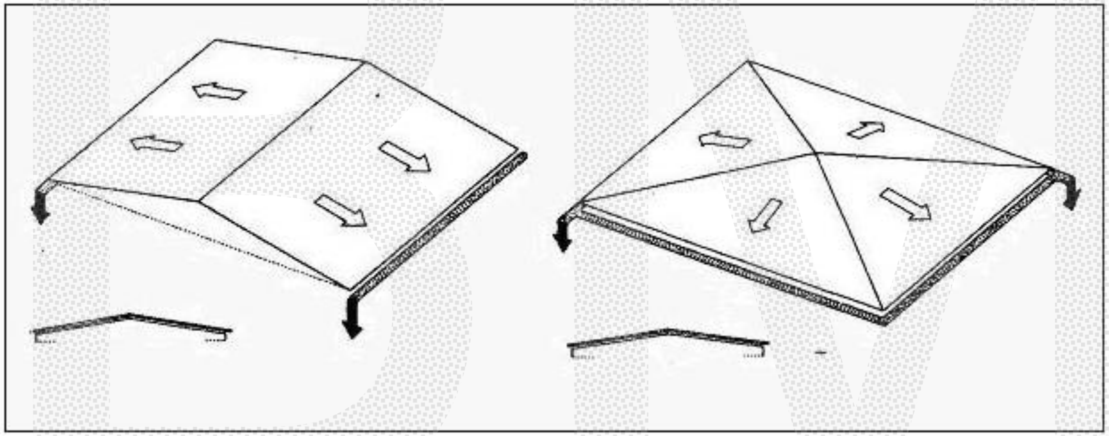


FASTENING SYSTEMS

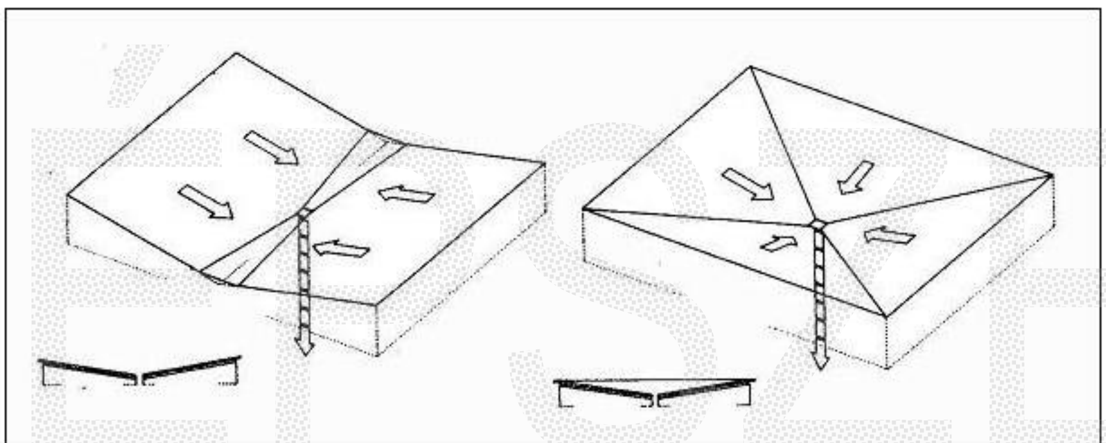
- ballasted
- glued
- mechanically fixed
- „compound”

EACH LIGHTWEIGHT ROOFING LAYER MUST BE FIXED!

FLAT ROOFS RAINWATER DRAIN SYSTEM



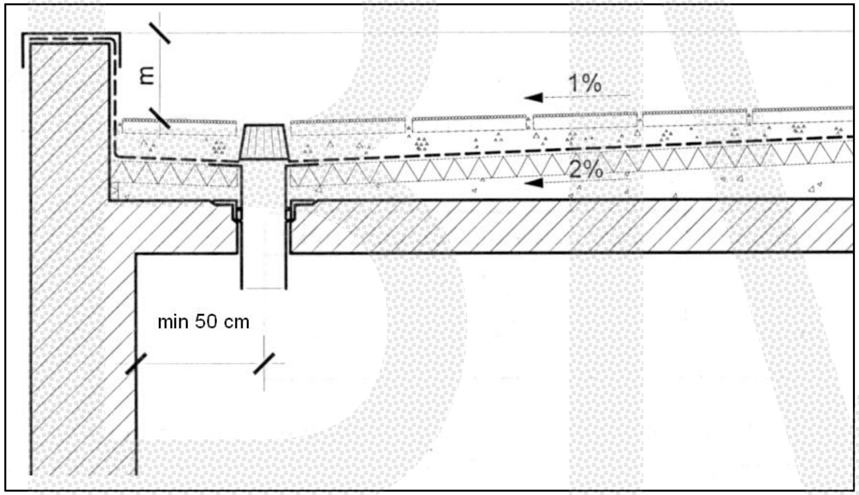
External:
gutter



Internal:
gully

Dr Gábor László

INTERNAL DRAIN SYSTEM
Gully



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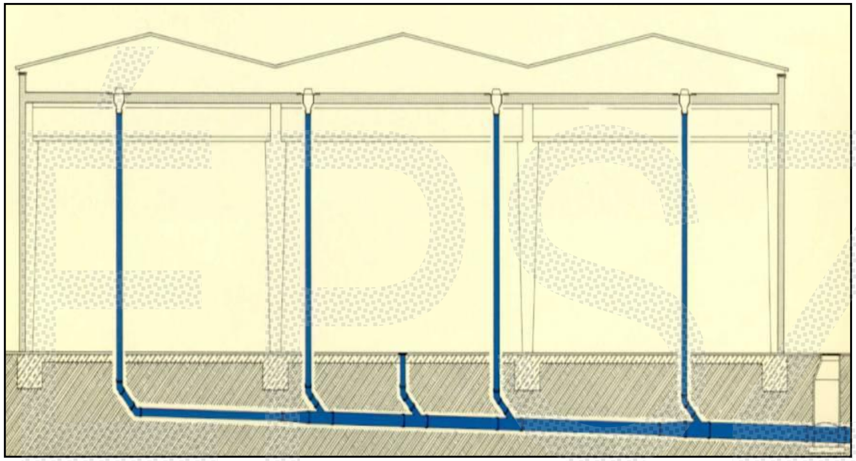
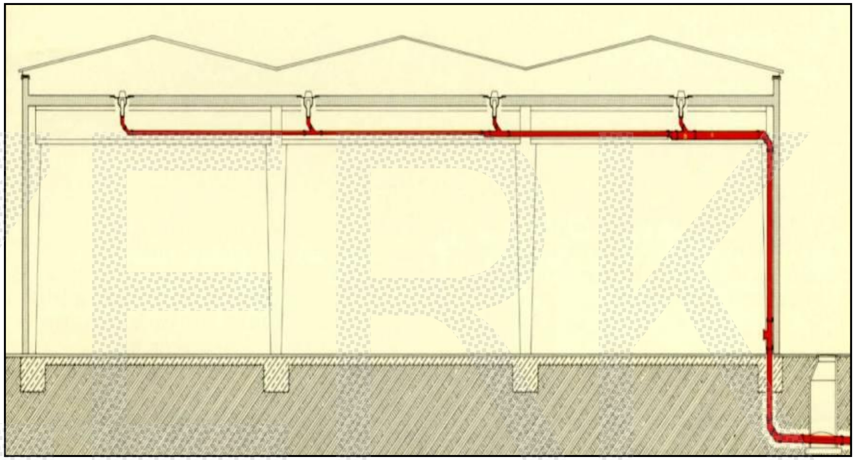
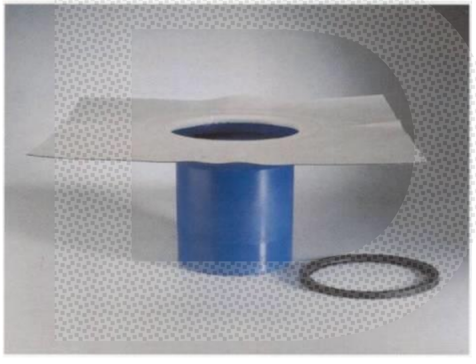


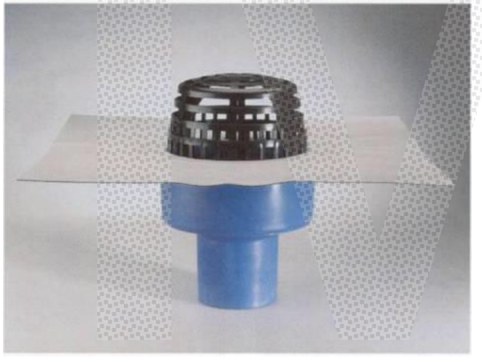


INTERNAL DRAIN SYSTEM

Gully

Gravity roof drainage	Siphoned roof drainage





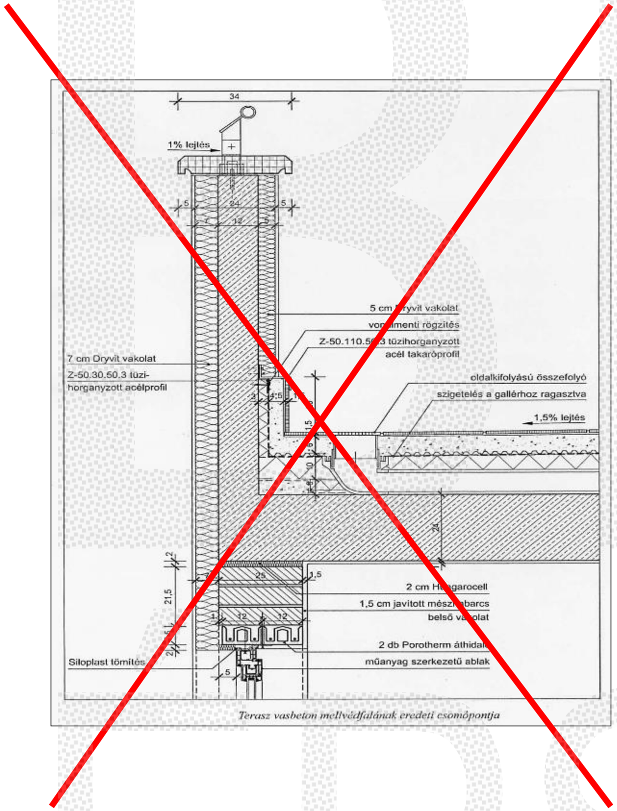
diameter of pipe: calculated
1 m^2 roof ⇨ 1 cm^2 pipe
1 piece / 150 m2 roof

Collecting pipes
in slope: approx. 1 %

diameter of pipe: 50mm
1 piece / 300-400 m^2 roof

horizontally (no slope)

INTERNAL DRAIN SYSTEM
Gully

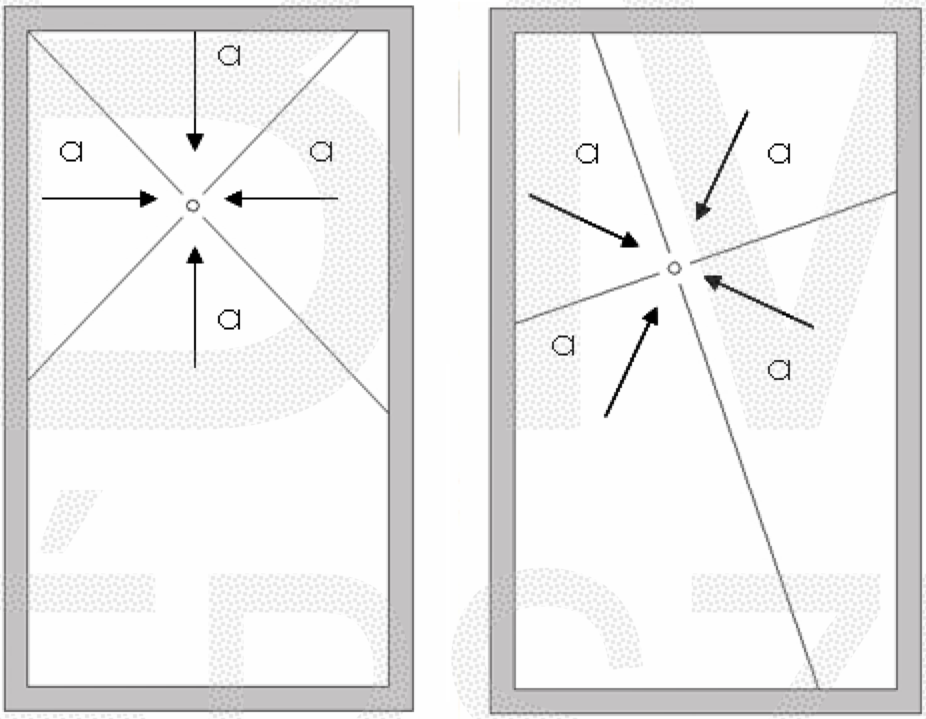


DO NOT LAY THE RAINWATER PIPE INSIDE ROOF INSULATION LAYERS

INTERNAL DRAIN SYSTEM

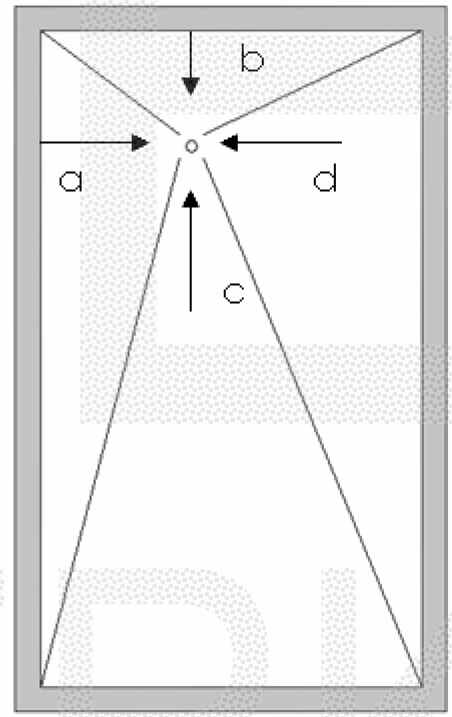
PERPENDICULAR VALLEYS

Same slope on surfaces



CORNERS VALLEYS

Different slopes on surfaces



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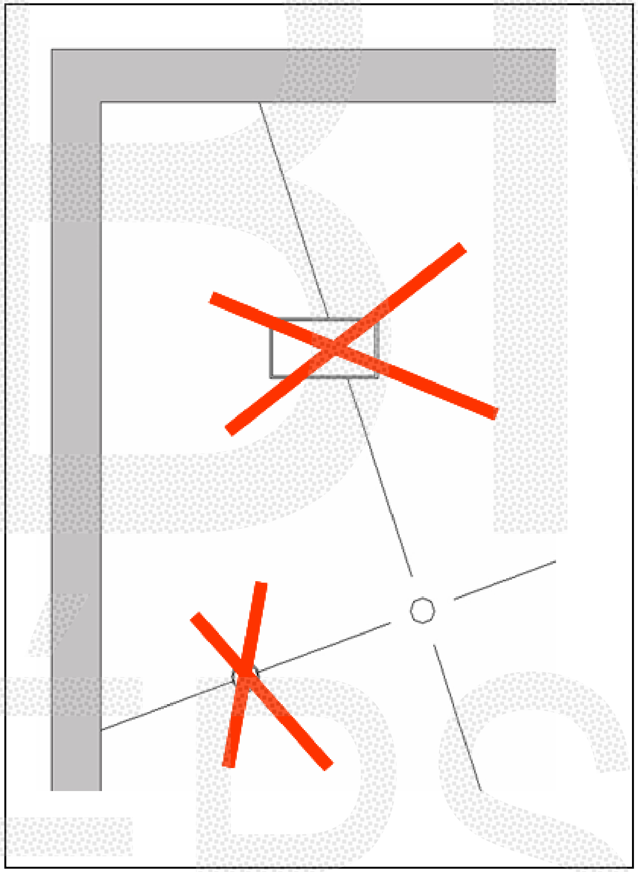
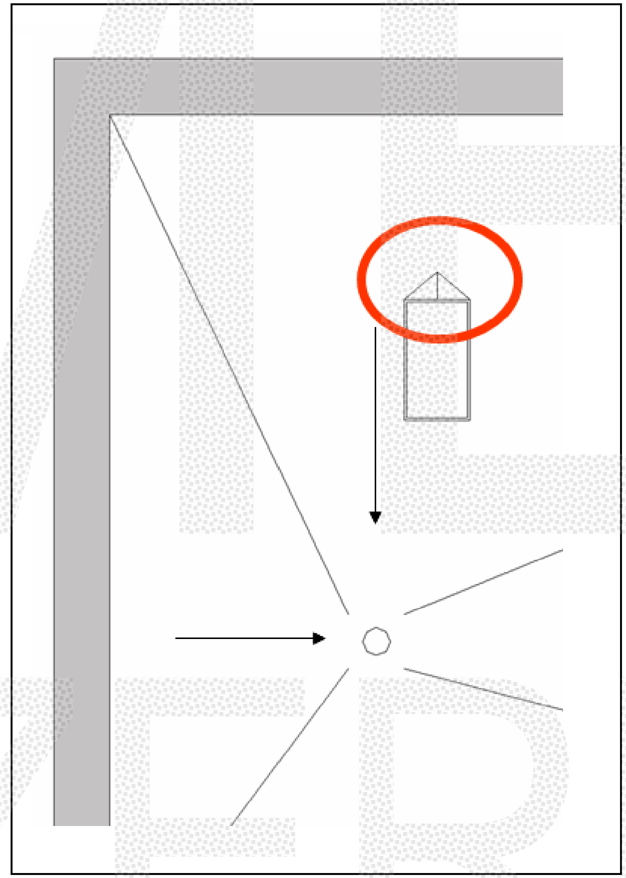
Minimum slope:

- on general surface: min **2 %** (substructure)
- In valleys: min **1 %**

INTERNAL DRAIN SYSTEM





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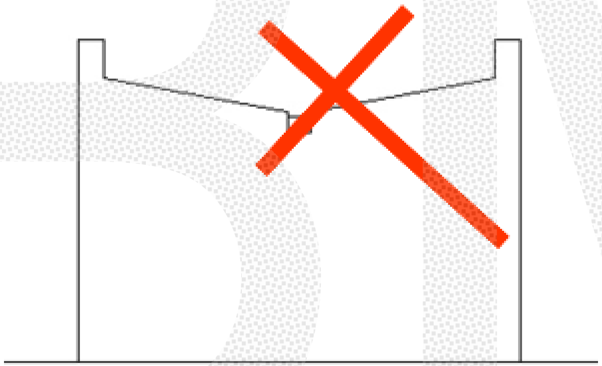
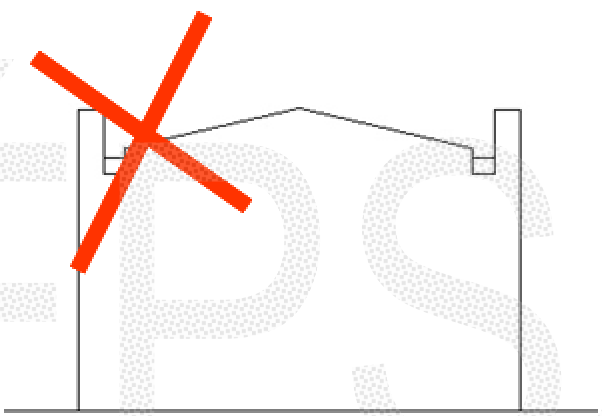
REQUIRED SLOPE MUST BE PROVIDED ON EACH PARTOF THE ROOF SURFACE

INTERNAL DRAIN SYSTEM



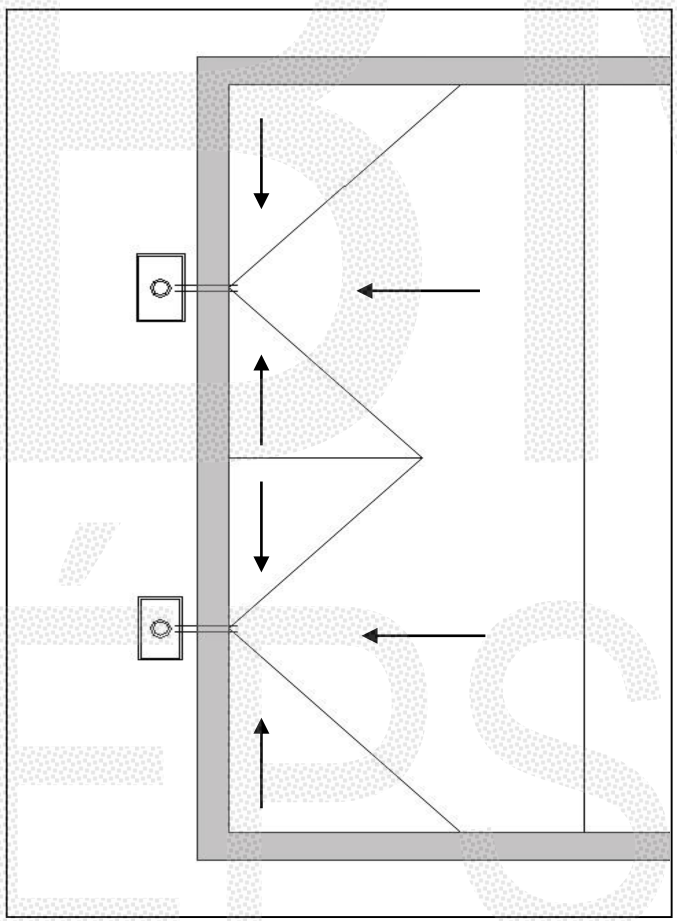
Don't create internal channel on non-exploited flat roofs!



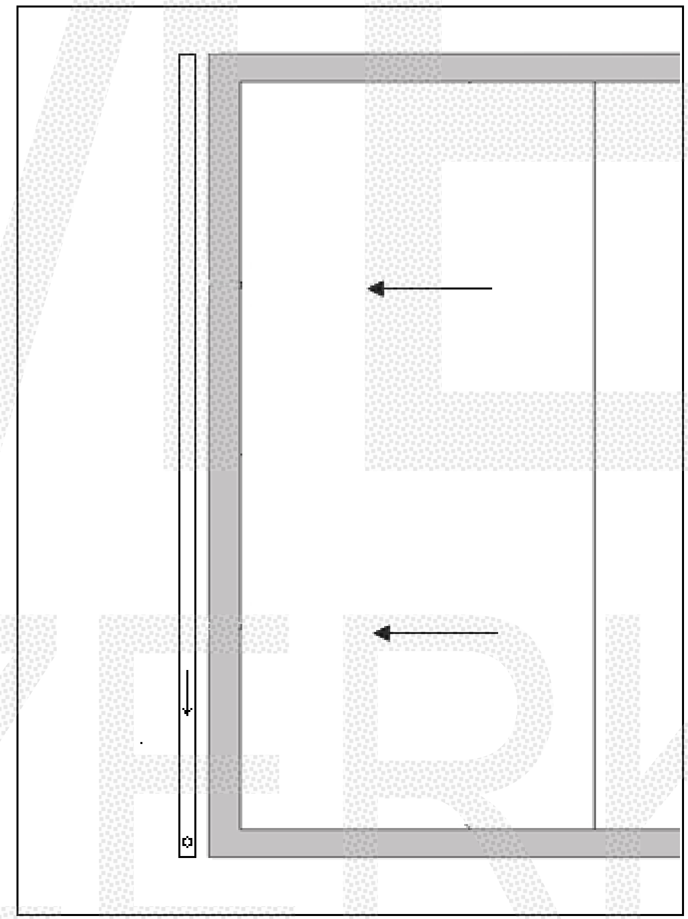
- slope,
- flashing,
- collection snow, waste

EXTERNAL DRAIN SYSTEM

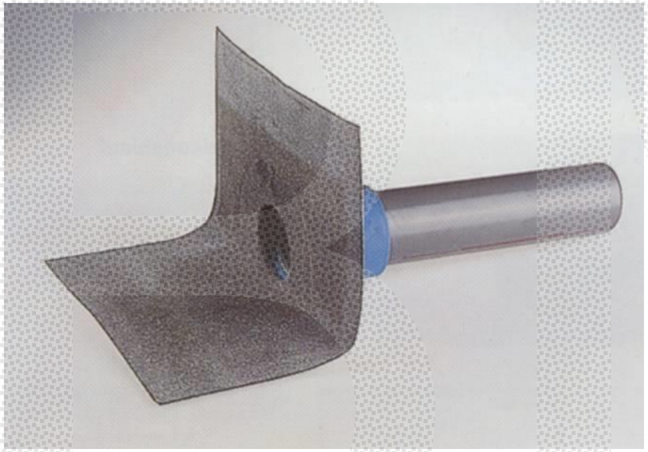
POINT WISE DRAIN SYSTEM



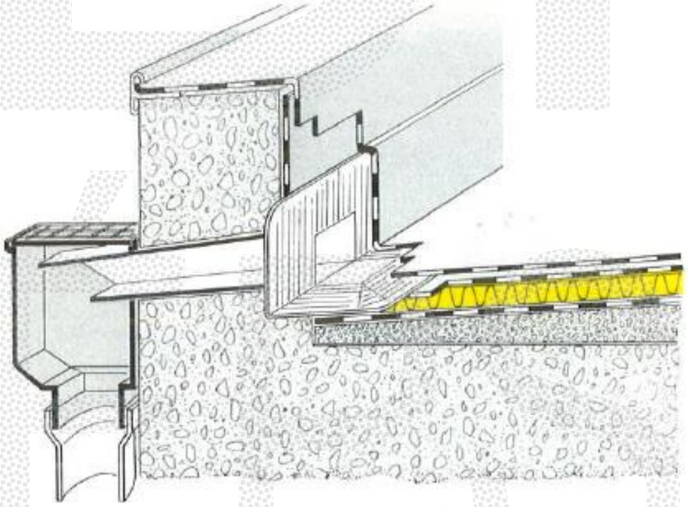
LINEAR DRAIN SYSTEM



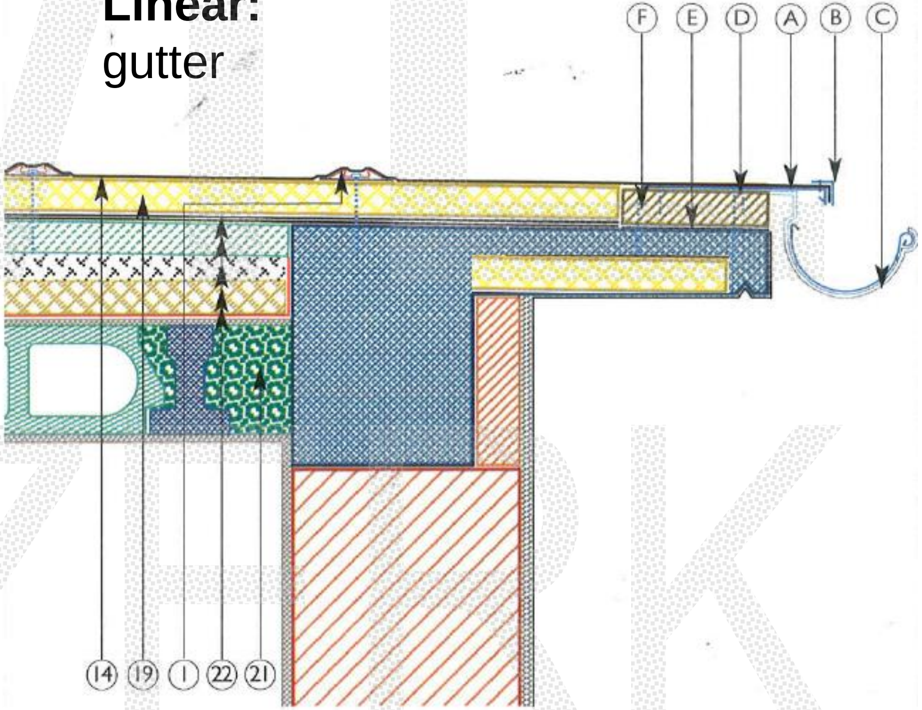
EXTERNAL DRAIN SYSTEM



Point wise:
outlet



Linear:
gutter



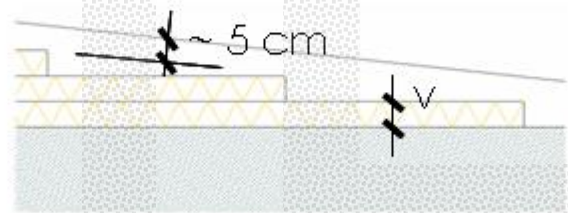
INCLINATION OF WATERPROOFING

BY SCREED

- CONCRETE

1 cm – 0,22 kN/m^2

- CONCRETE +
  THERMAL INSULATION



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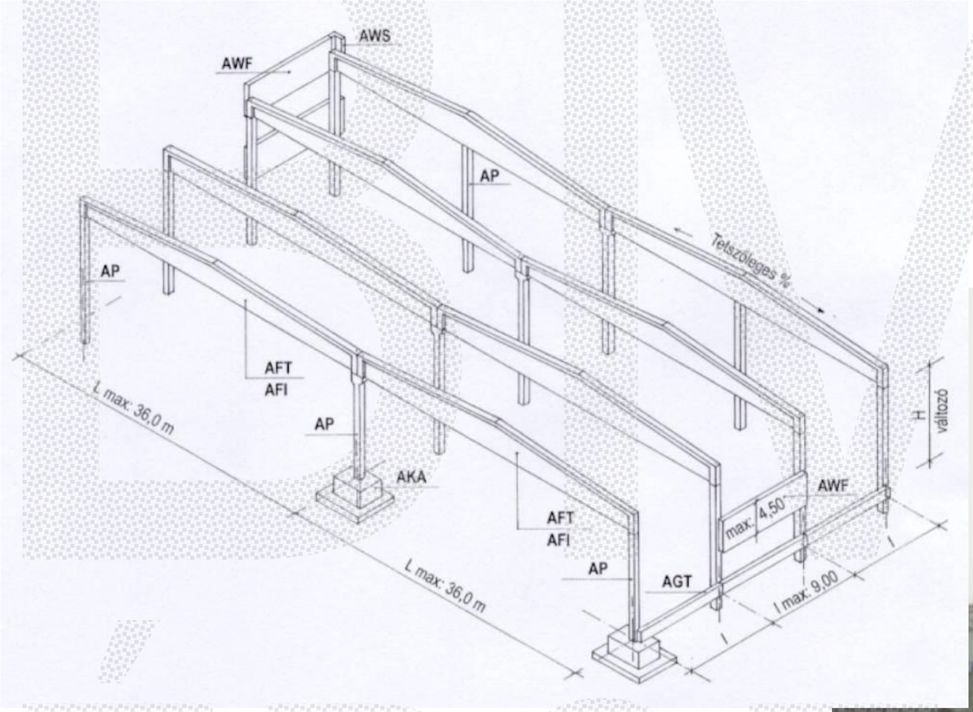
- LIGHTWEIGHT CONCRETE

1 cm – 0,04 kN/m^2

Minimum slope: on screed: 2,0 %

INCLINATION OF WATERPROOFING



BY LOADBEARING SLAB

Minimum slope:

- on boarding: 4,0 %
- on big span or metal slabs: 3,0 %

INCLINATION OF WATERPROOFING

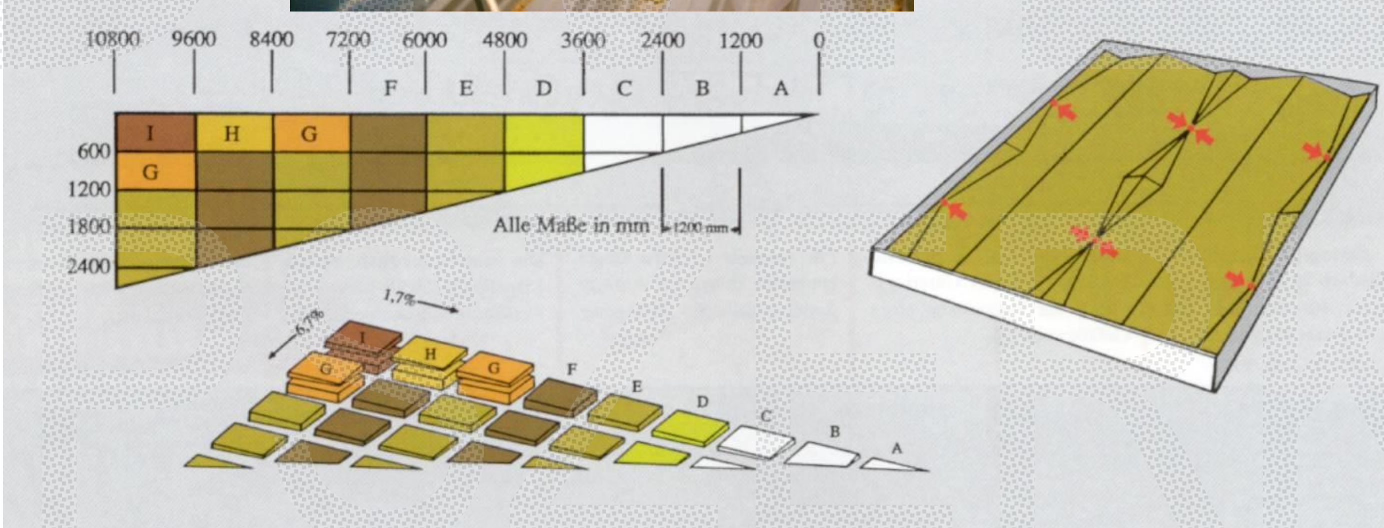
BY THERMAL INSULATION

MATERIALS

- PS FOAM
- PU FOAM
- **ROCKWOOL**
- FOAMGLASS

Minimum slope:

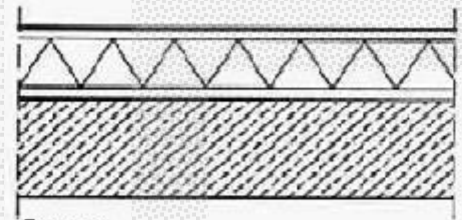
on thermal insulation: 2,5 %



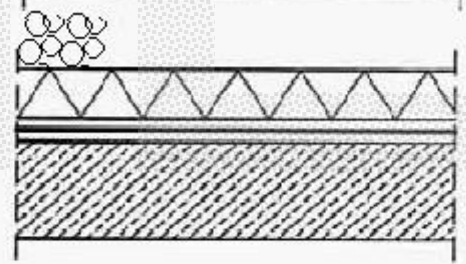
LAYER ARRANGEMENTS - NON EXPLOITED FLAT ROOFS

Non ventilated :
there is no ventilation layer

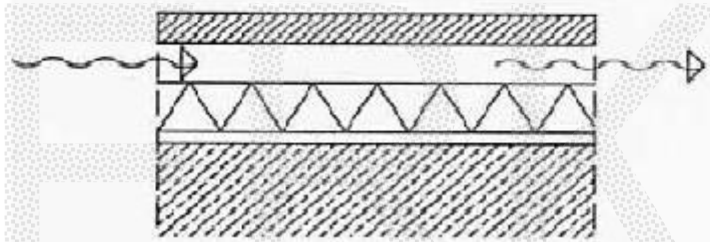
Normal (Conventional) :
waterproofing is above thermal insulation



Inverted: waterproofing is under thermal insulation



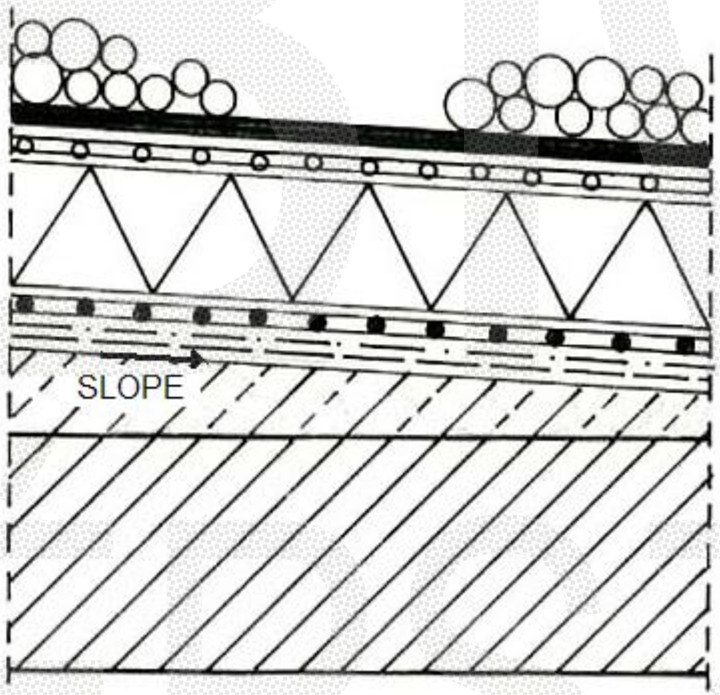
Ventilated:
Ventilation layer is between waterproofing and thermal insulation



MATERIALS DEPEND ON THE SYSTEM!

NON EXPLOITED FLAT ROOFS

normal, non ventilated 1.



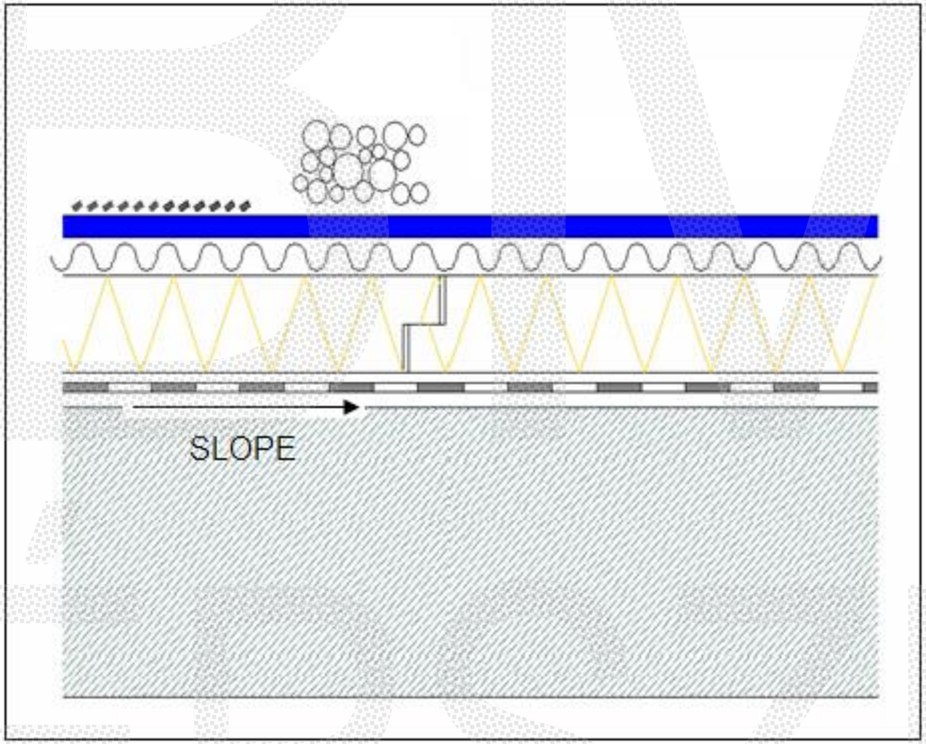
layers

- UV protection or/and (ballasting)
- waterproofing
- (separation)
- thermal insulation
- vapour barrier
- (separation)
- (priming)
- smoothing
- Screed in slope
- load bearing slab

MATERIALS DEPEND ON THE SYSTEM!

NON EXPLOITED FLAT ROOFS

normal, non ventilated roof 2.



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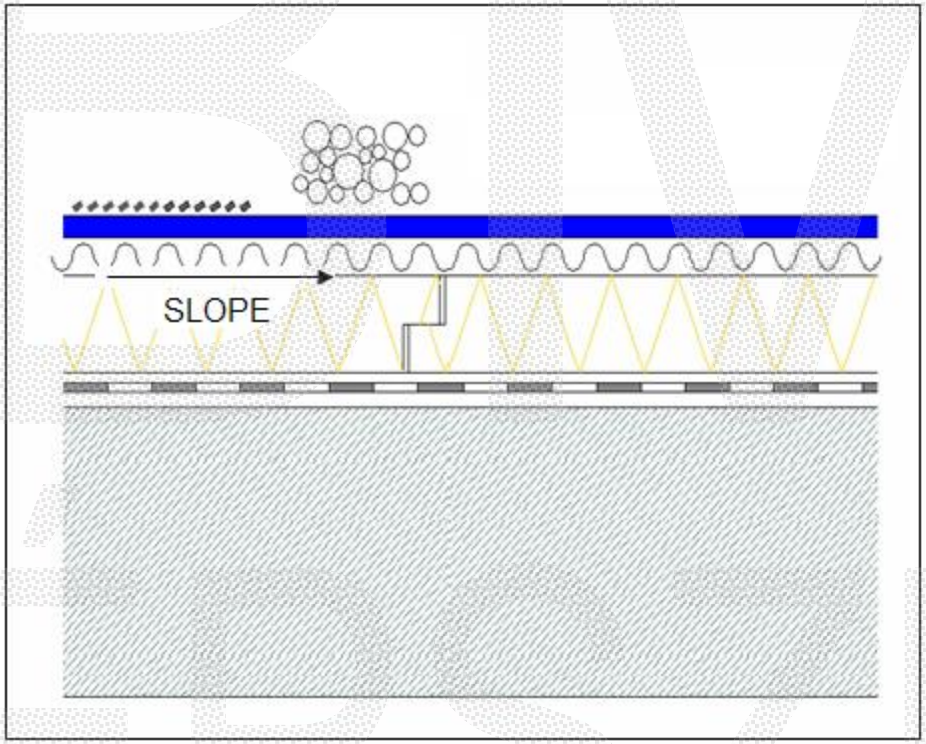
LAYERS

UV protection
Waterproofing (+ fixing)
Separation
Thermal insulation
Vapour barrier
Load bearing slab in slope

NON EXPLOITED FLAT ROOFS

normal, non ventilated roof 3.



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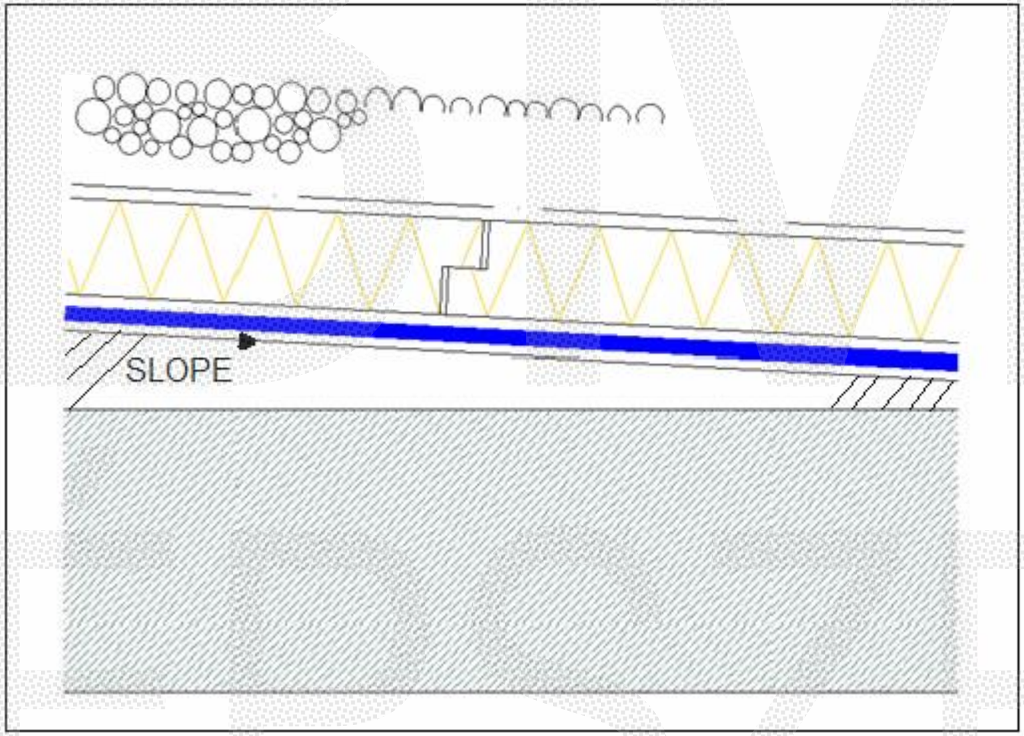
LAYERS

UV protection
Waterproofing (+ fixing)
Separation
Thermal insulation in slope
Vapour barrier
Load bearing slab

NON EXPLOITED FLAT ROOFS

inverted, non ventilated roof



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LAYERS

Ballasting (e.g. gravel)
Separation
Thermal insulation
Waterproofing
Screed
Load bearing slab
(min 20 cm r.c. slab)

FLAT ROOFS

WATERPROOFING LAYER

Purposes

Protection structures and internal spaces from rain

Materials of waterproofing

- Bituminous membranes
- Plastic membranes
- Liquid waterproofing

THERMAL INSULATION LAYER

PURPOSES

Energy saving: reduce heat loss

Internal comfort: temperature

Protection of structures:

heat gain on and in the supporting construction

prevent the vapour condensation

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THERMAL INSULATION

HEAT TRANSFER

Thermal conductivity (α) is defined as the quantity of energy, transferred between the surfaces in unit time.

Heat transmission coefficient : U (k) (W/m²K) - constructions

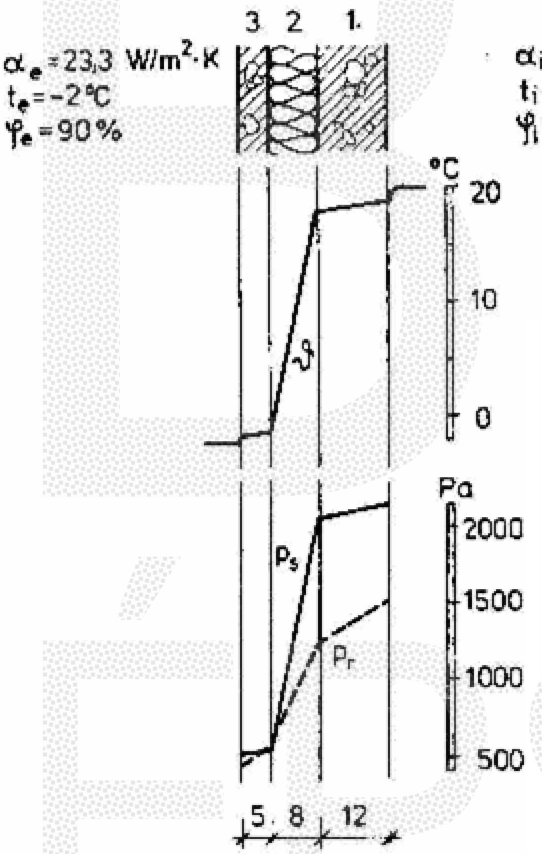
$$k = \frac{1}{\frac{1}{\alpha_i} + \sum \frac{d}{\lambda} + \frac{1}{\alpha_e}} \quad \Rightarrow \quad U = \frac{1}{\frac{1}{h_i} + \Sigma R_j + \frac{1}{h_o}}$$

Thermal conductivity: λ (W/m K) - materials

h = surface conductance

$$R = \frac{d}{\lambda}$$

HEAT AND VAPOUR FLOW



Jel	Layers	Alapadatok d (m)	λ (W/mK)	δ (g/msPa x 10⁻⁶)	Heatflow (t_e = −2) $R=\frac{1}{\alpha_i};\frac{d}{\lambda}$ (m²K/W)	ϑ = Rq (°C)	ϑ (°C)	Vapourflow p_s (Pa)	$R_v=\frac{d}{\delta}$ (m²sPa/g x10⁶)	Δp = gR_v (Pa)	p_r (Pa)
	Inside α_i = 8,1				0,123	1,24	+20,00				
1	r.c.	0,12	1,55	0,008	0,077	0,77	+18,76	2156	15	260	1519
2	ps foam	0,08	0,042	0,002	1,905	19,26	+17,99	2063	40	692	1259
3	r.c.	0,05	1,55	0,008	0,032	0,31	−1,27	549	6	103	567
	Outside α_e = 23,3				0,043	0,42	−1,58 −2,00	534			464
	Összesen:	0,25			2,180	22,00			61	1055	

$U=\frac{1}{2{,}18}=0{,}46$ W/m²·k $q=k\Delta t=0{,}46\cdot 22=10{,}1$ W/m² $g=\frac{\Delta p}{R_v}=\frac{1055}{6{,}1\cdot 10^6}=17{,}3\cdot 10^{-6}$ g/m²·s

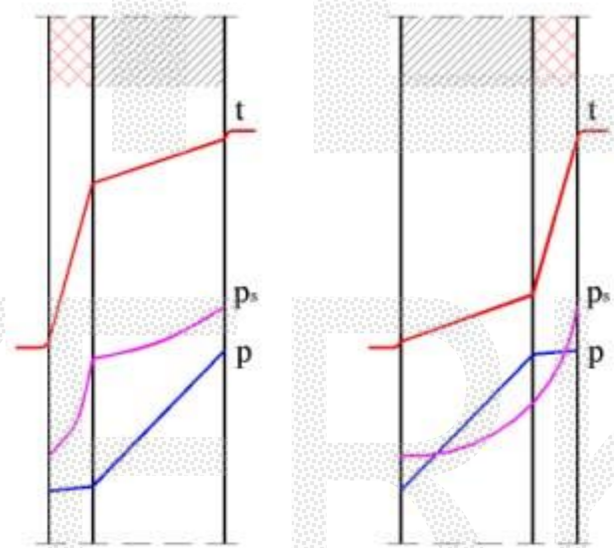
ϑ temperature p_s max vapour pressure p_r partial vapour pressure

HEAT AND VAPOUR FLOW

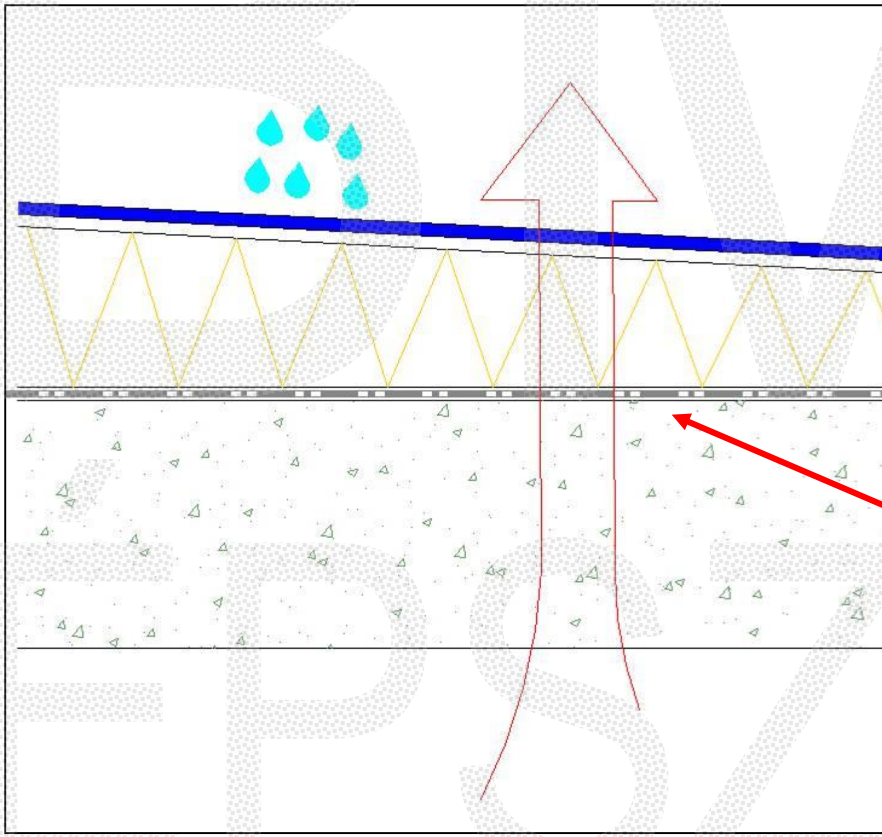
Design considerations

The risk of condensation is the highest in the outside half of the thermal insulation layers. Thermal insulation materials have high resistance against heat flow (->big temperature drop), but their resistance against vapour flow is usually small. The opposite relates to the materials of load-bearing and outside surface coatings layers. This is, why calculated partial pressure is near to the saturation value in the outside half of the thermal insulation layer: the temperature is low, the partial pressure is high.

E.g. condensation occurs when warm moist air meets a cold surface.



HEAT AND VAPOUR FLOW



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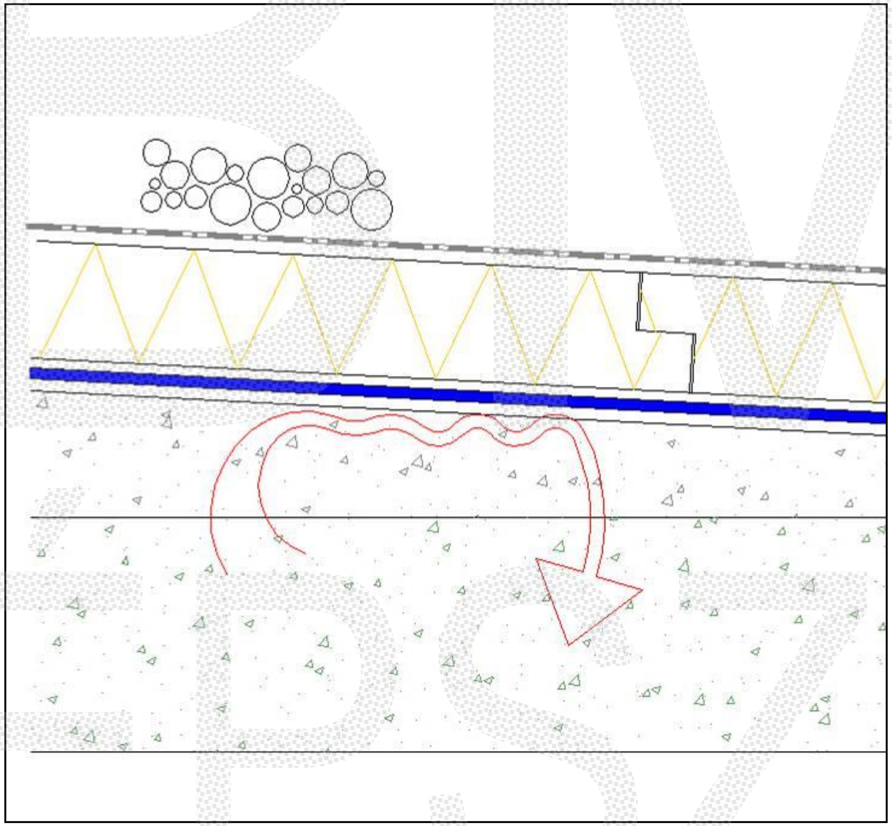
Normal roof

The vapour resistance of layers must decreases from inside to outside

Vapour barrier layer is under the thermal insulation

HEAT AND VAPOUR FLOW



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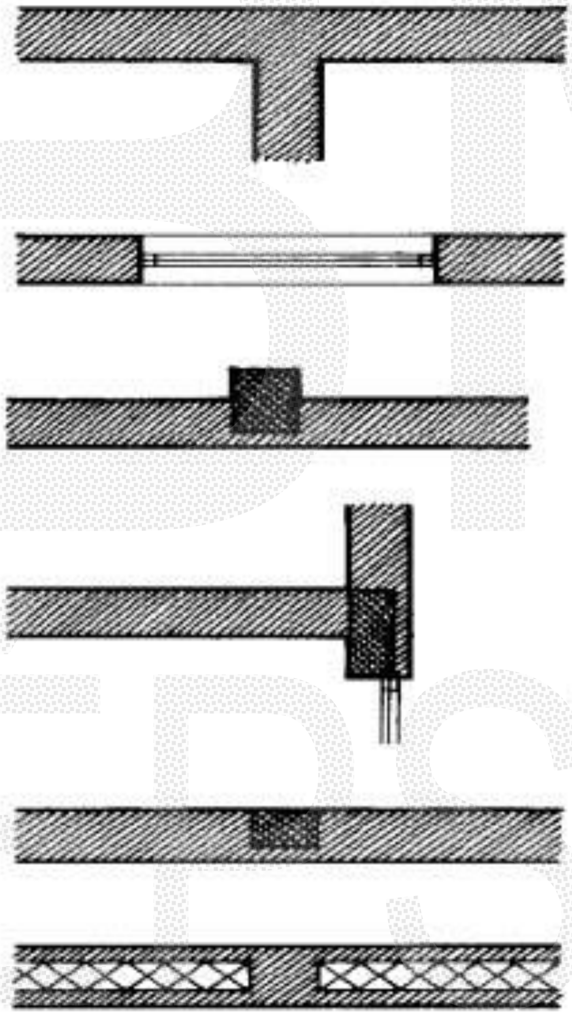
Inverted roof

Waterproofing layer
= Vapour barrier layer

Requirement:
$2{,}5\ kN/m^2$
$R = 15\ m^2 sPa/g \times 10^6$
under waterproofing

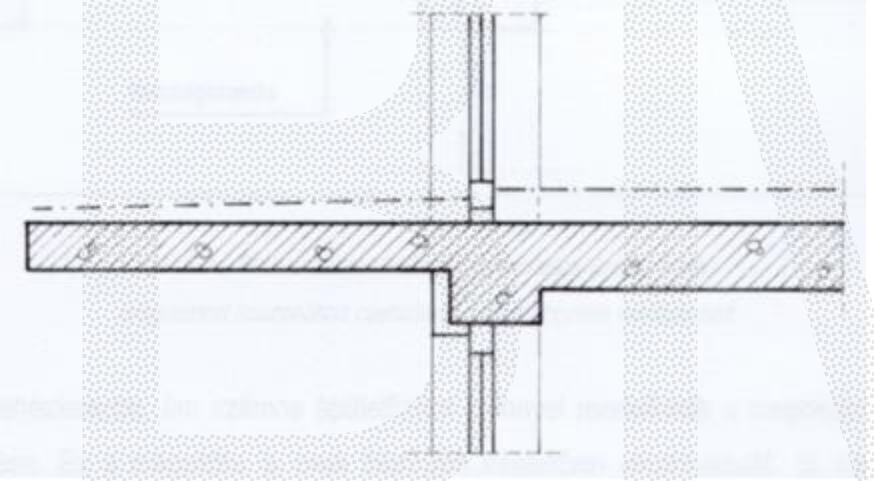
Multidimensional steady state heat flow: thermal bridges

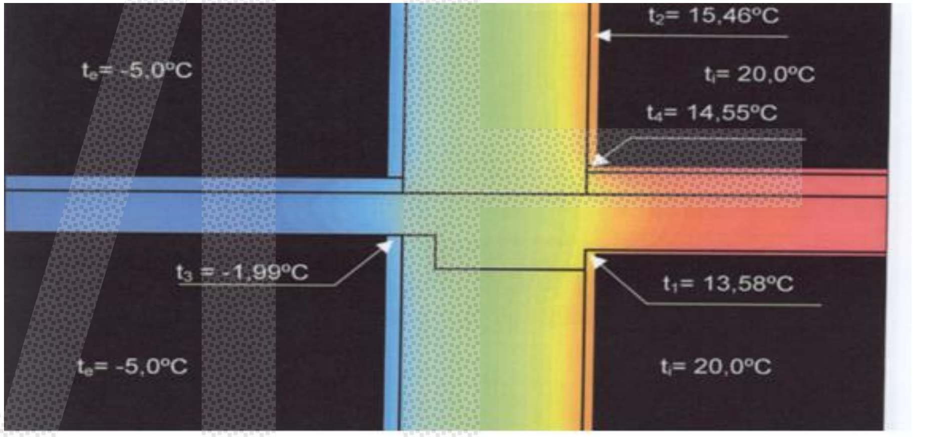


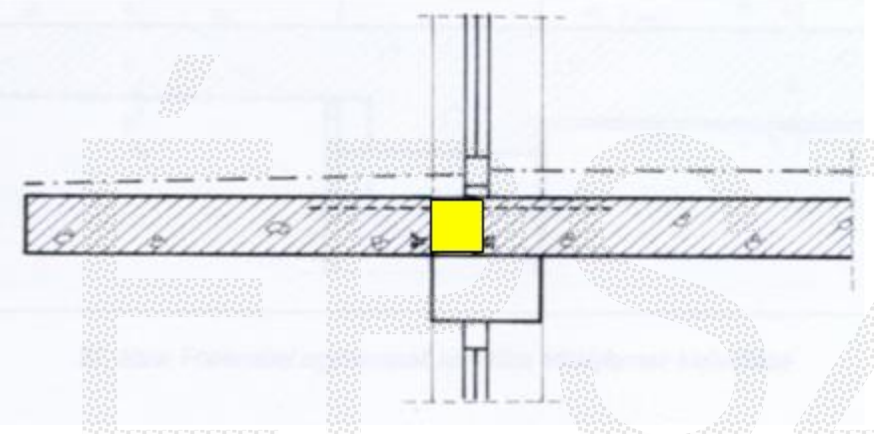
In real building elements the criteria of the one dimensional heat flow are often not fulfilled. Everywhere when the border differs from the plan parallel planes, two or three–dimensional heat flows develop. These special parts are called thermal bridges.

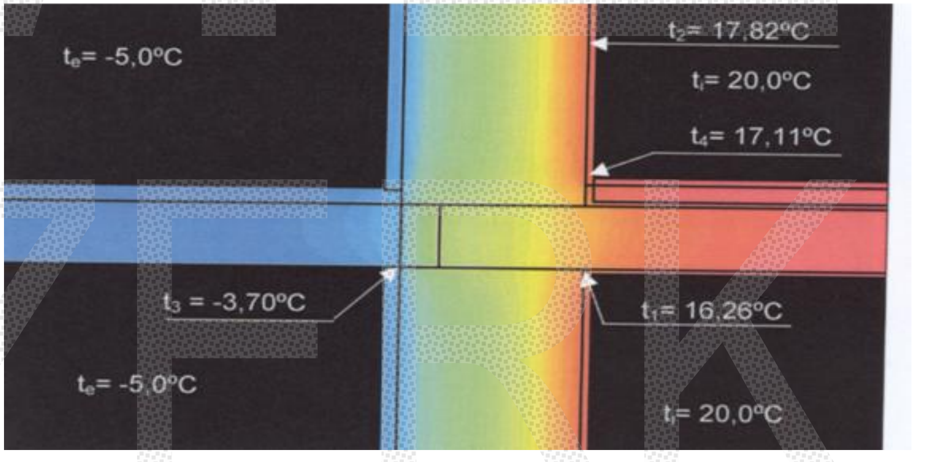
Thermal bridges are the consequences of the geometric form, the combination of materials of different conductivities, or both.

THERMAL BRIDGES



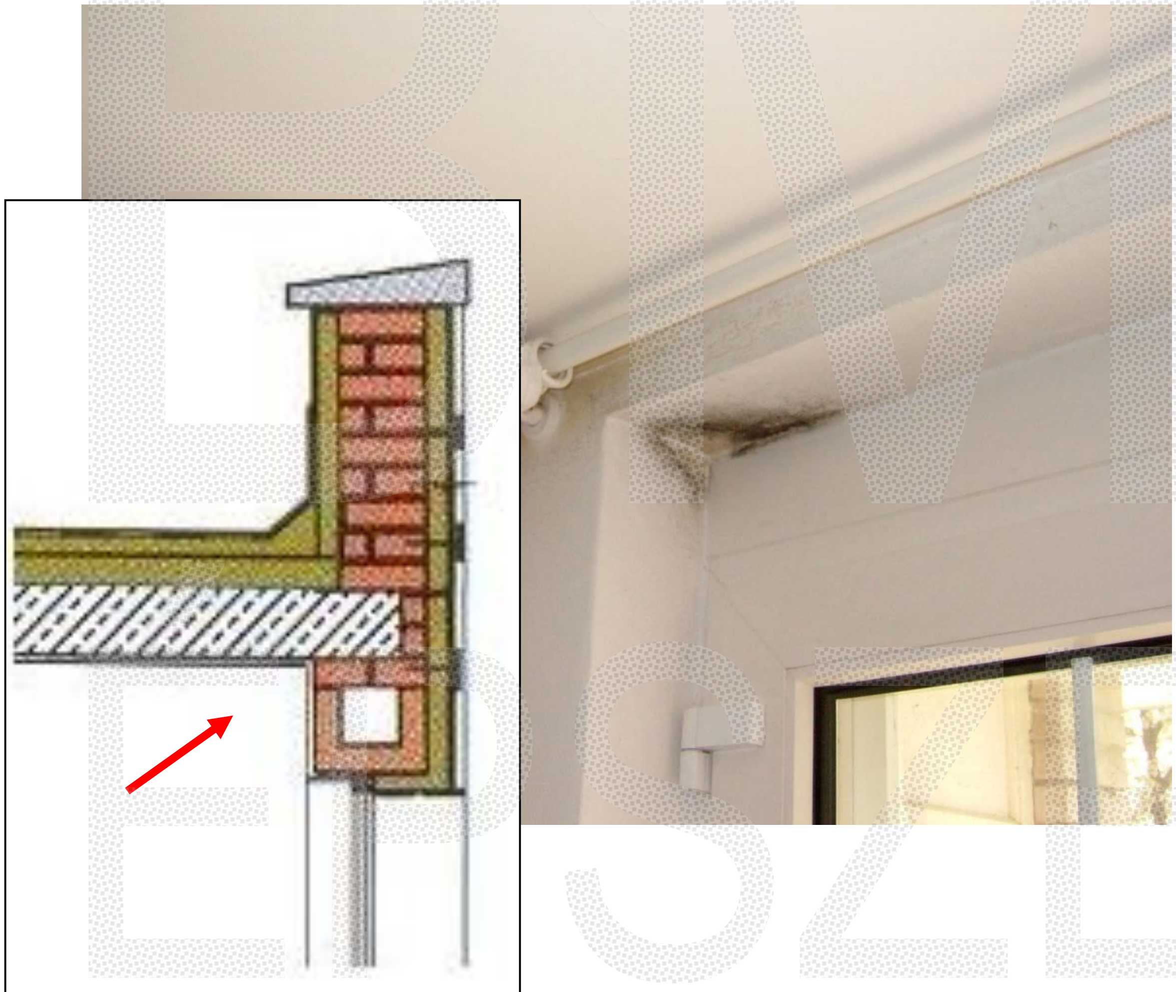






THERMAL BRIDGES

Multidimensional steady state heat flow: thermal bridges



They are the consequences of the geometric form, the combination of materials of different conductivities, or both.

A serious ongoing dampness problem due to condensation has been established mould fungus, a parasite freely available in the air, can developed on walls, ceilings.

Mould growth requires an atmospheric relative humidity level in excess 85 % sustained for periods up to 12 hours per day.

THANK YOU FOR YOUR ATTENTION!

NON EXPLOITED FLAT ROOFS

LAYERS

1. Loadbearing slab	r.c. — trapezoid metal sheet
2. Fixing method	glued or ballasted or mechanically fixed
3. Drain system	internal (gully) - external (gutter)
4. Waterproofing (DPC)	plastic or bitumen membranes
5. Slope of DPC	loadbearing structure — concrete — thermal insulation
6. UV protection	chemical or mechanical
7. Thermal insulation	plastic foam — mineral wool
8. Vapour barrier	plastic or bitumen membranes
9. Separation layer	glass or plastic fleece