

RADIANT SYSTEMS

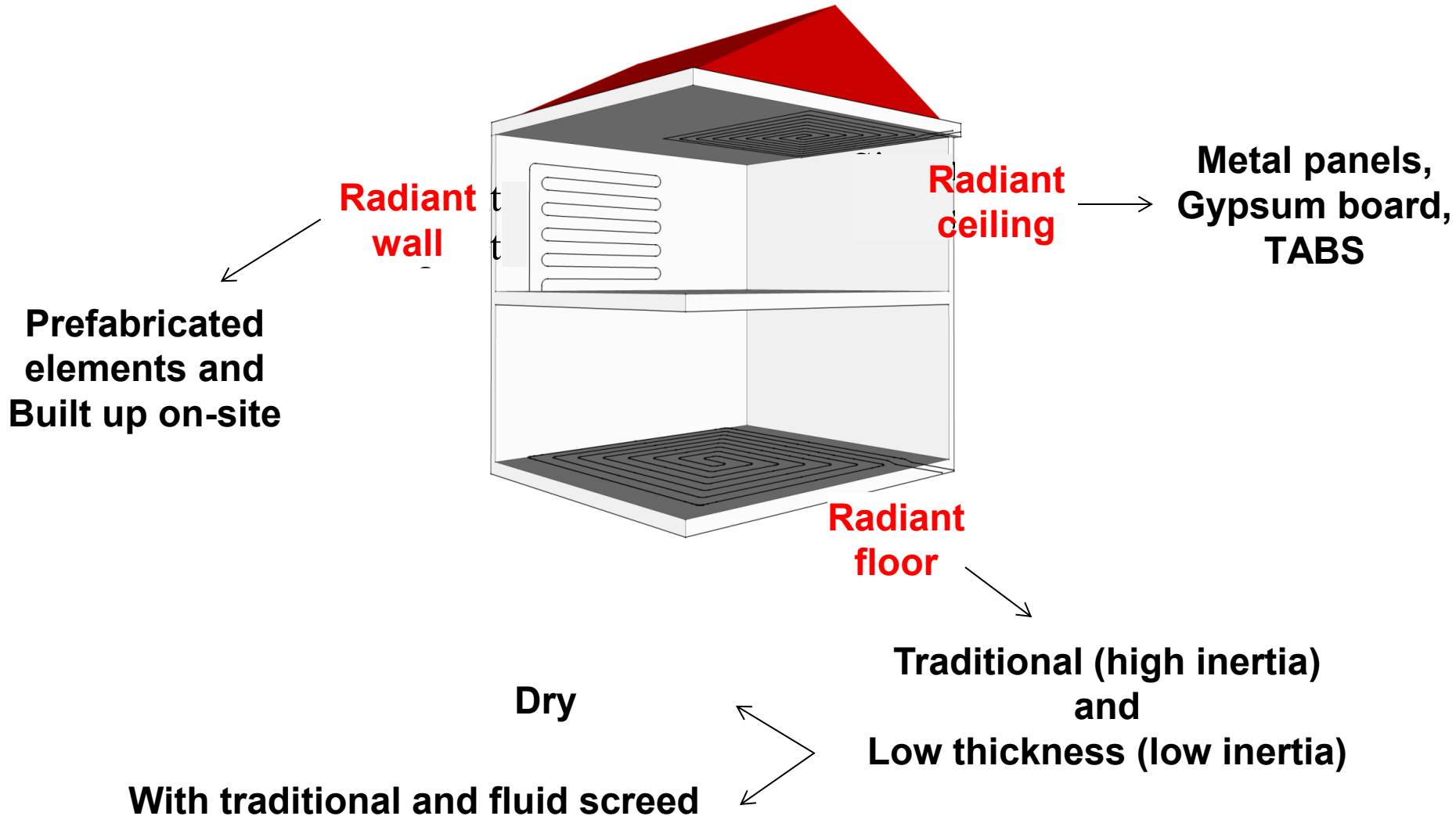
Radiant systems

- 1. Type of radiant systems**
- 2. Heat transfer phenomena**
- 3. Sizing radiant systems**

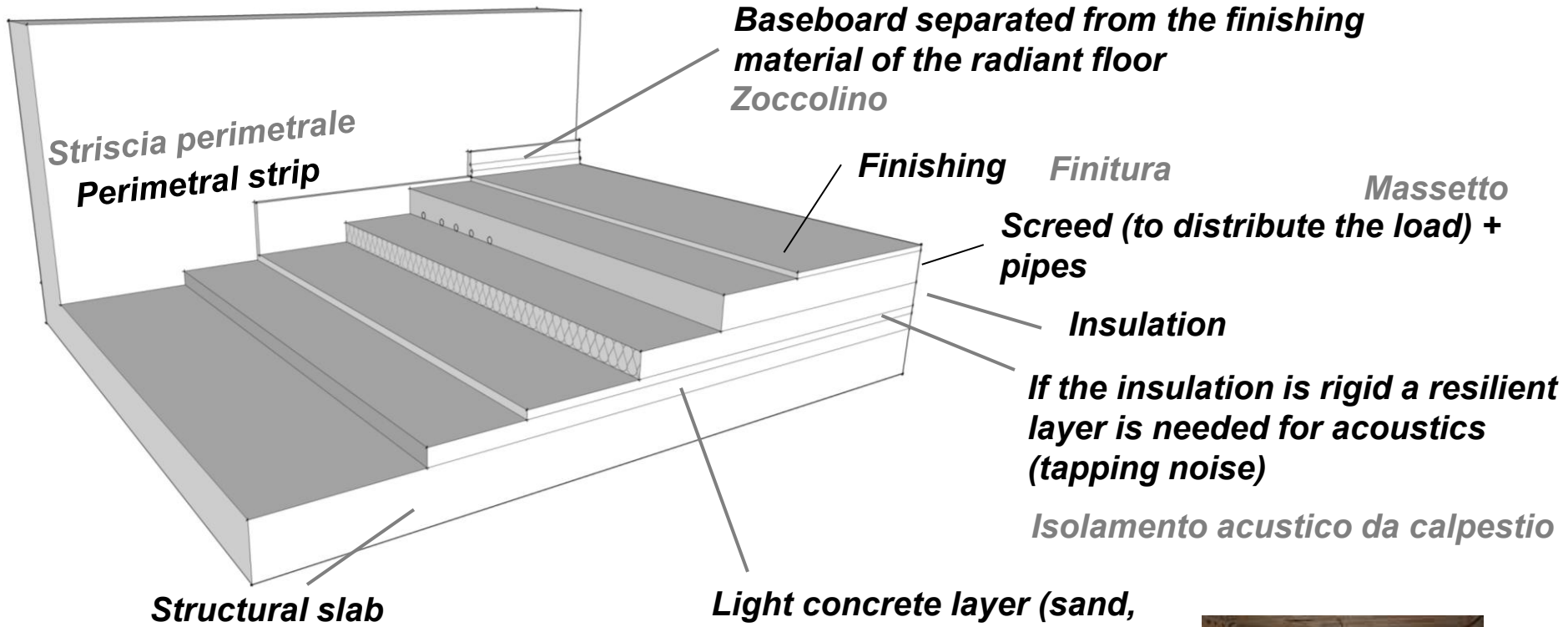
1. Types of radiant systems

Types of radiant systems

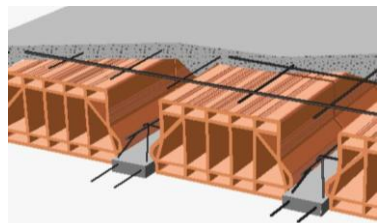
Screed: massetto
Gypsum board: cartongesso



Components of a radiant floor



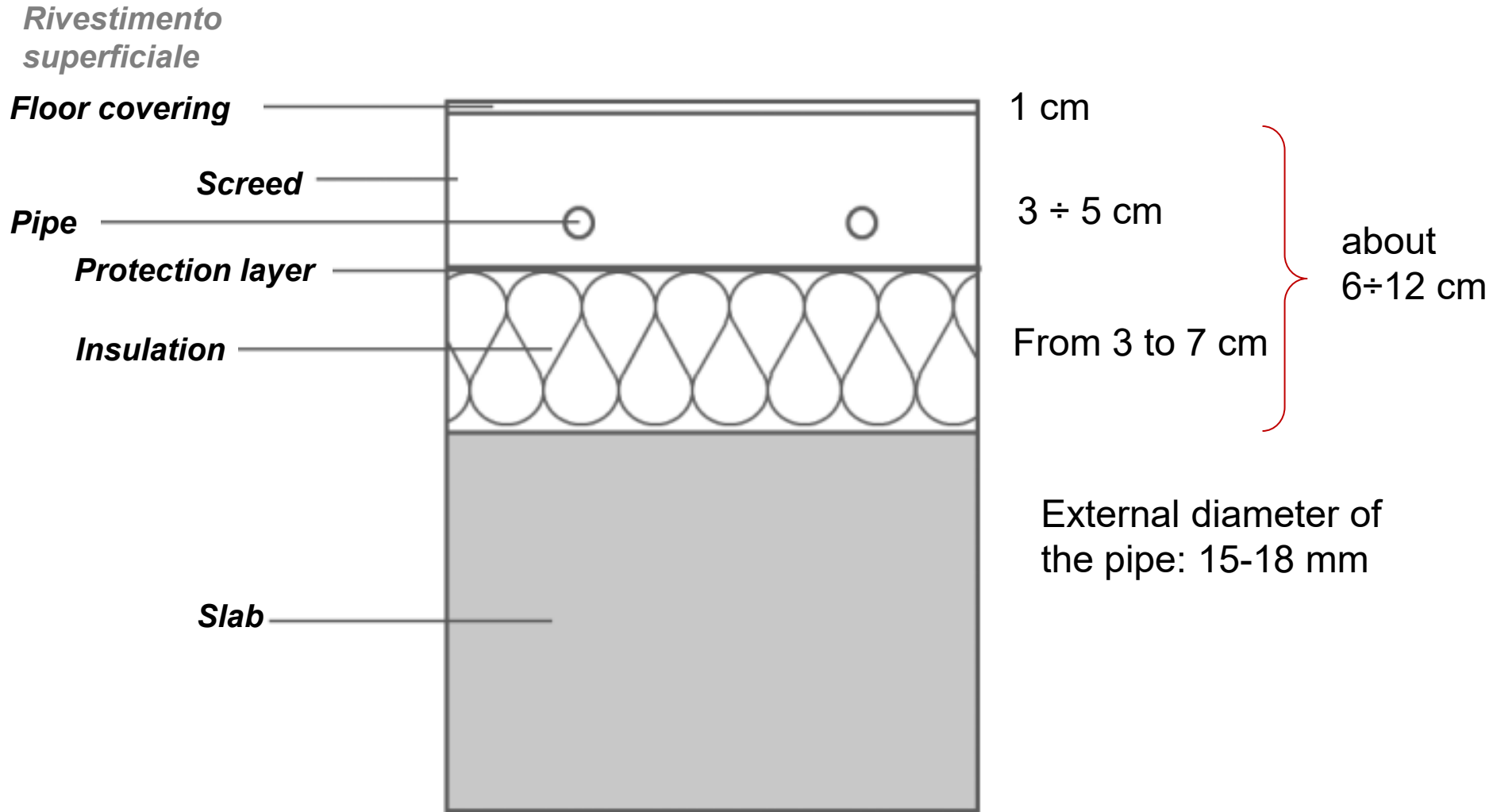
Light concrete layer (sand, cement and other light filling).
Used to cover the MEP
Magrone alleggerito



Solaio strutturale portante



Classic radiant floor (high inertia)



Standard EN 1264: Type A

Classic radiant systems

Use: residential buildings and offices

Fixing systems for the pipes with clips



Velcro tape

Wire mesh & clips



Clip su rete metallica

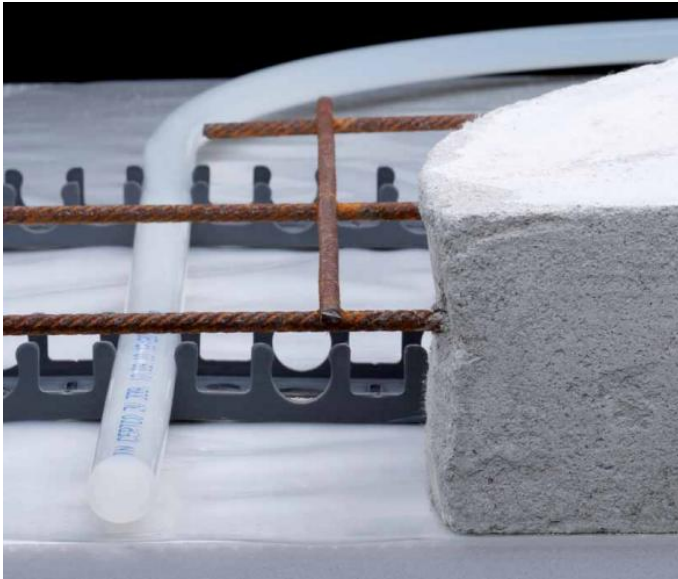


Rustricated
insulating panel

Isolamento con lastra bugnata

Industrial floor radiant system

Pipes fixed on welded mesh





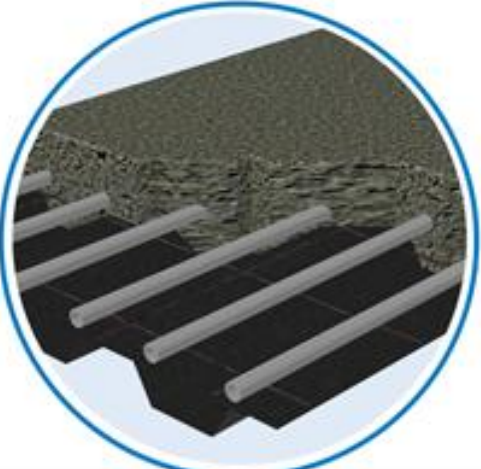
External diameter
of the pipe: 25 mm

*rete elettrosaldata
e traliccio di armatura*

Pipes fixed on welded mesh and pylons
armature

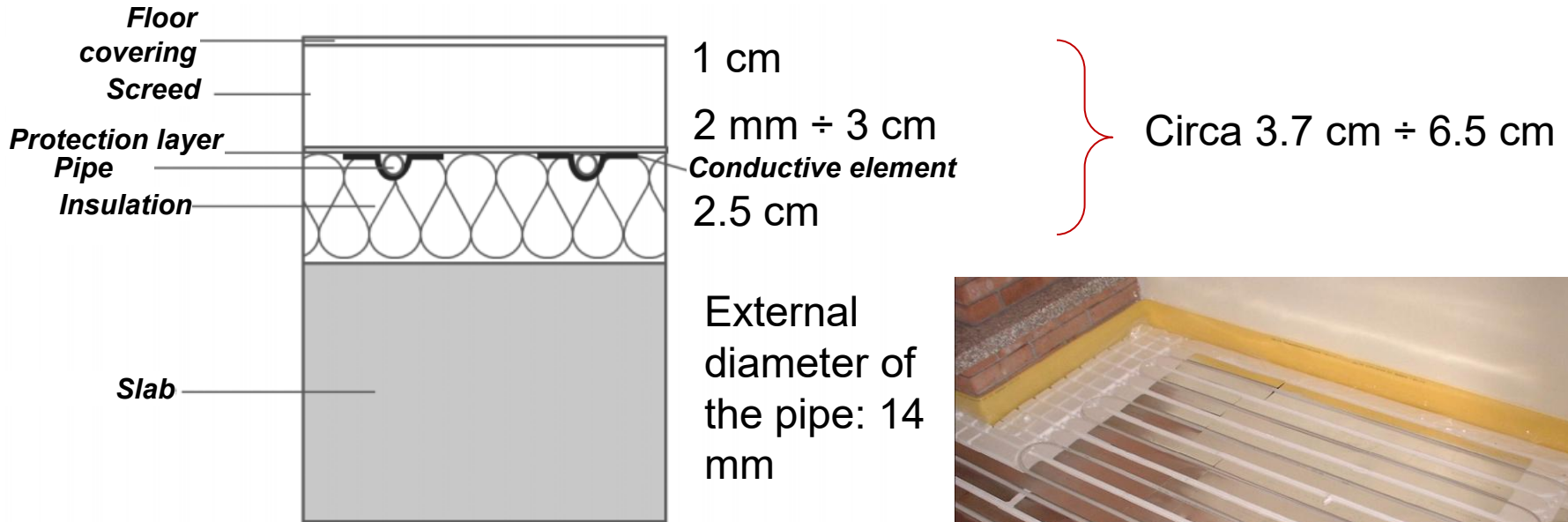


TABS: Thermo-Active Building systems

TABS	Application	
System with prefabricated welded mesh	Office buildings and industrial buildings	 A 3D perspective rendering of a TABS system. It shows a grey concrete slab with a grid of metal reinforcement bars (welded mesh) embedded within it. Several red and white pipes are laid out across the surface of the slab, supported by small spacers. The floor below is shown in a yellow color.
Light filling materials in structural slabs	Office Buildings	 A photograph of a construction site. It shows a concrete slab under construction, supported by a complex network of steel scaffolding. The slab is filled with a light-colored material, likely insulation or a lightweight aggregate. Several pipes are visible, running across the slab. The scene is set outdoors with a blue sky and some construction equipment visible in the background.
Corrugated sheet	Office Buildings	 A circular inset image showing a close-up of a corrugated sheet. The sheet is dark in color and has a wavy, corrugated surface. Several grey pipes are embedded within the sheet, running parallel to each other. The image is framed by a blue circular border.

Low thickness radiant floor

Use: residential buildings and tertiary buildings



Pipes embedded in the insulation

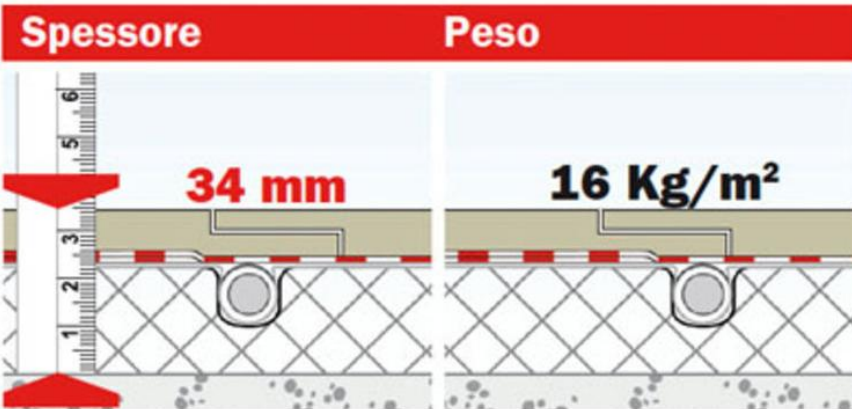


Dry systems – Thickness: circa 25 mm

Steel sheet – Thickness: 1 mm

Self-levelling screed (with additives - 30 mm)

Low thickness Radiant systems 1/3



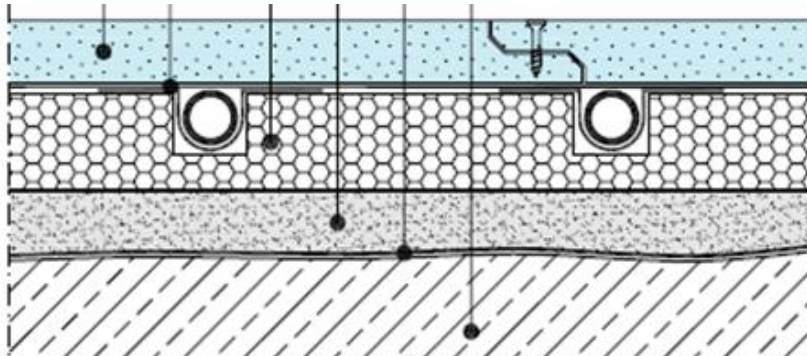
Calciosilicato

Calciumsilicate sheet
thickness: 9 mm

Therma conductivity: 0.35 W/(m K)

Usual size of the boards: 1.2 m x 1.2 m

Fibrogesso



Plaster fibre sheet

thickness: da 18 a 25 mm

Thermal conductivity : 0.28–0.32 W/(m K)

Limit temperature: 45°C



Lastra in acciaio

Steel sheet

Limited thickness (2 mm)

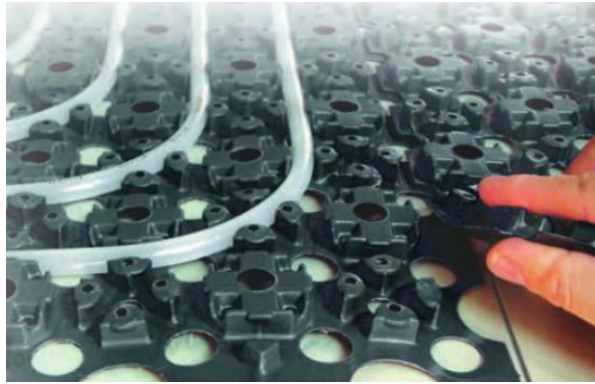
High conductivity

Quick installation

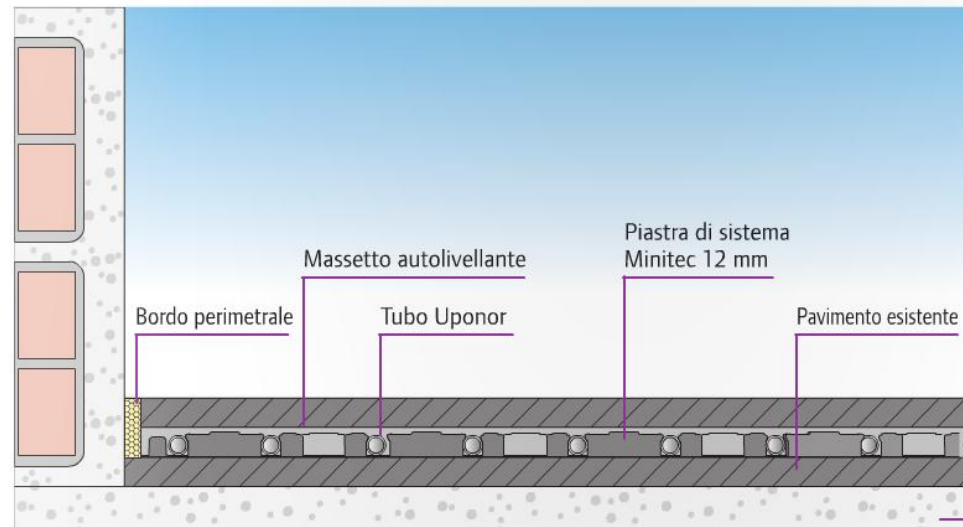
Relevant costs

Low thickness Radiant systems 2/3

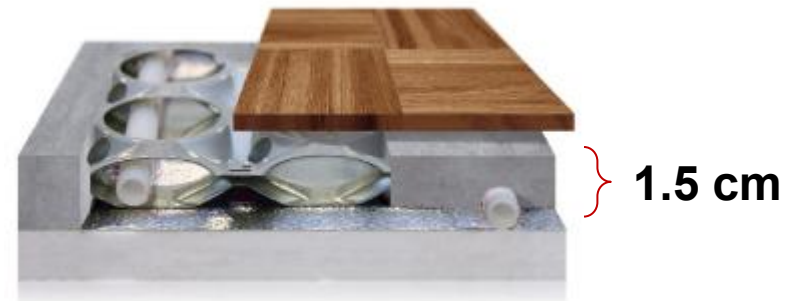
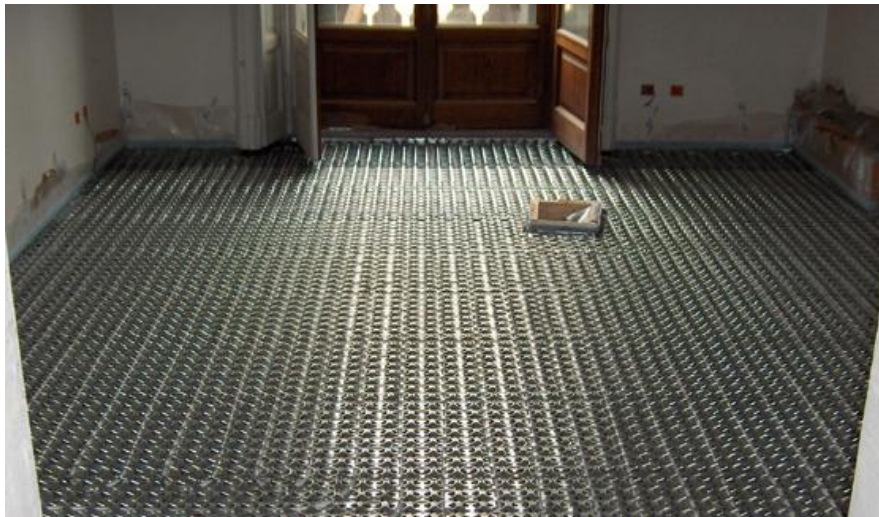
Pipes inserted in prefabricated panels



Pipes diameter:
9.9 x 1 mm



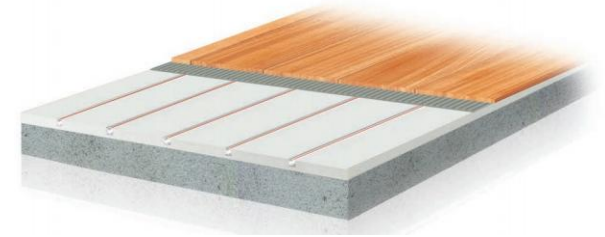
Pipes inserted in prefabricated metal structures



Low thickness Radiant systems 3/3

Tubazioni inserite in un supporto fresato

Pipes inserted in milled in support layer



s = 0 mm

Modular systems for raised floors

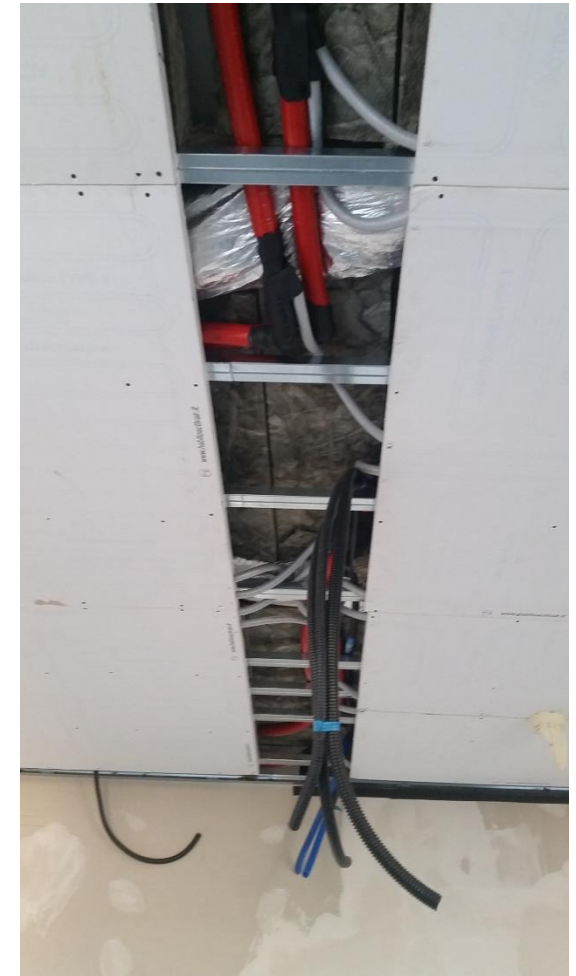
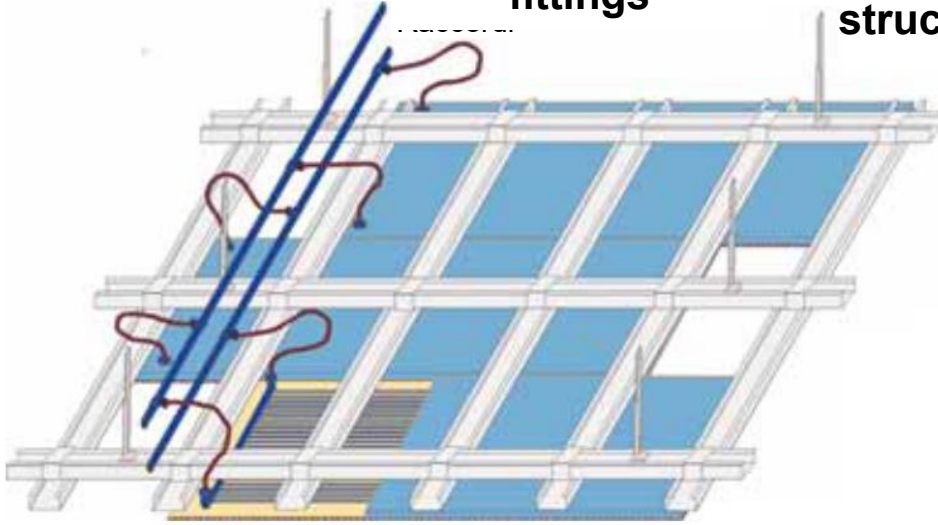


Sistemi radianti modulari per pavimenti flottanti

Ceiling radiant systems 1/2

Connectors/
fittings

Metal support
structure



Ceiling radiant systems 2/2

Gypsum board, insulation and pipes. Prefabricated solution

Pipes embedded in the milled gypsum board



Residential and office buildings

Pipes embedded in the insulation with conductive metal sheets and planar gypsum boards

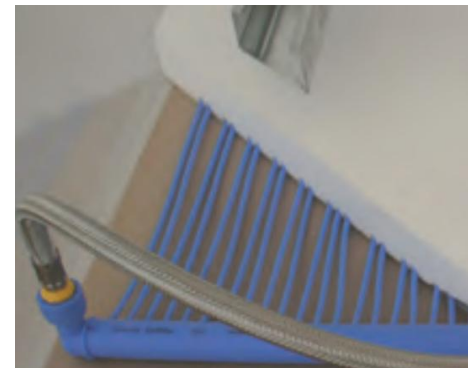


Metal elements (usually hollowed metal sheets) with plastic and metal pipes



Office buildings

Capillary pipes in radiant ceiling systems



Radiant ceiling Vs. floor

Smaller pipe diameters in the ceiling than in radiant floors (6 ÷ 10 mm external diameter).

In ceiling shorter water circuits than floor radiant systems.

Lower water velocity in ceiling radiant systems than in floor radiant systems.

Temperature difference:

	Heating	Cooling
Floor	3÷7	2÷3
Ceiling	2÷3	3÷4

In both systems the perimetral strip has to be installed.

As an alternative the radiant ceiling has to be finished above the wall.

The ceiling can have sound-absorbing characteristics: acoustic comfort possibility combined with the hollow structure.



With radiant floor the screed has to be decoupled acoustically for tapping noise.

Perimetral strip

The perimetral strip allows the expansion of the support layer embedding the pipes



The standard EN 1264 declares that the minimum thickness of the perimetral strip has to allow at least 5 mm expansion. Usually the thickness varies from 5 to 8 mm.



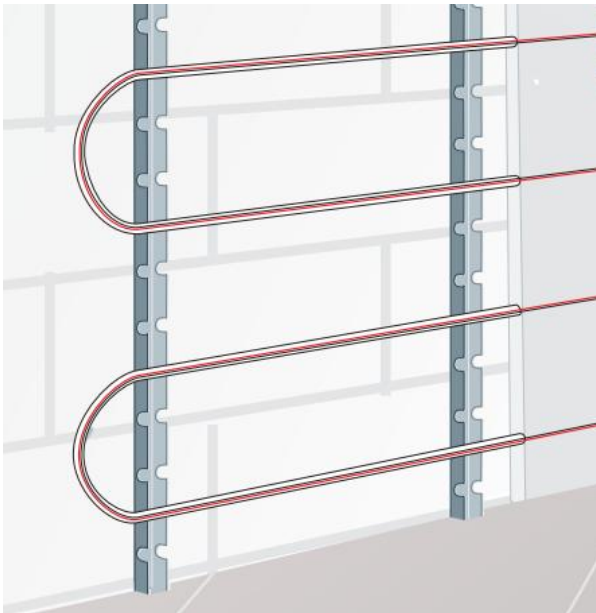
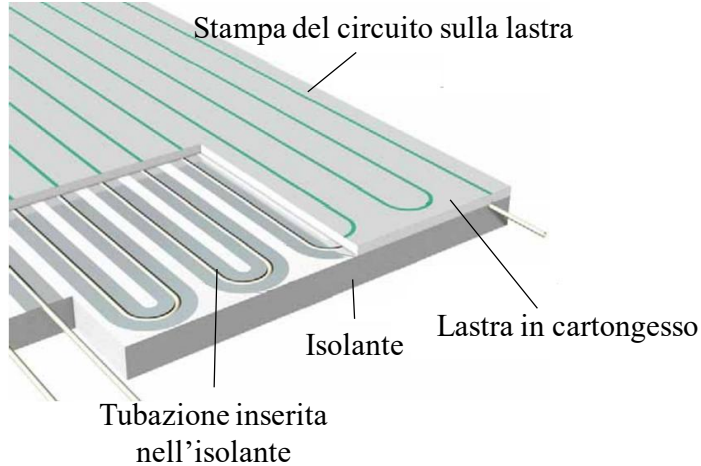
**Important:
surround
pillars and
stairs, if any**

Walls radiant systems 1/2



Walls radiant systems 2/2

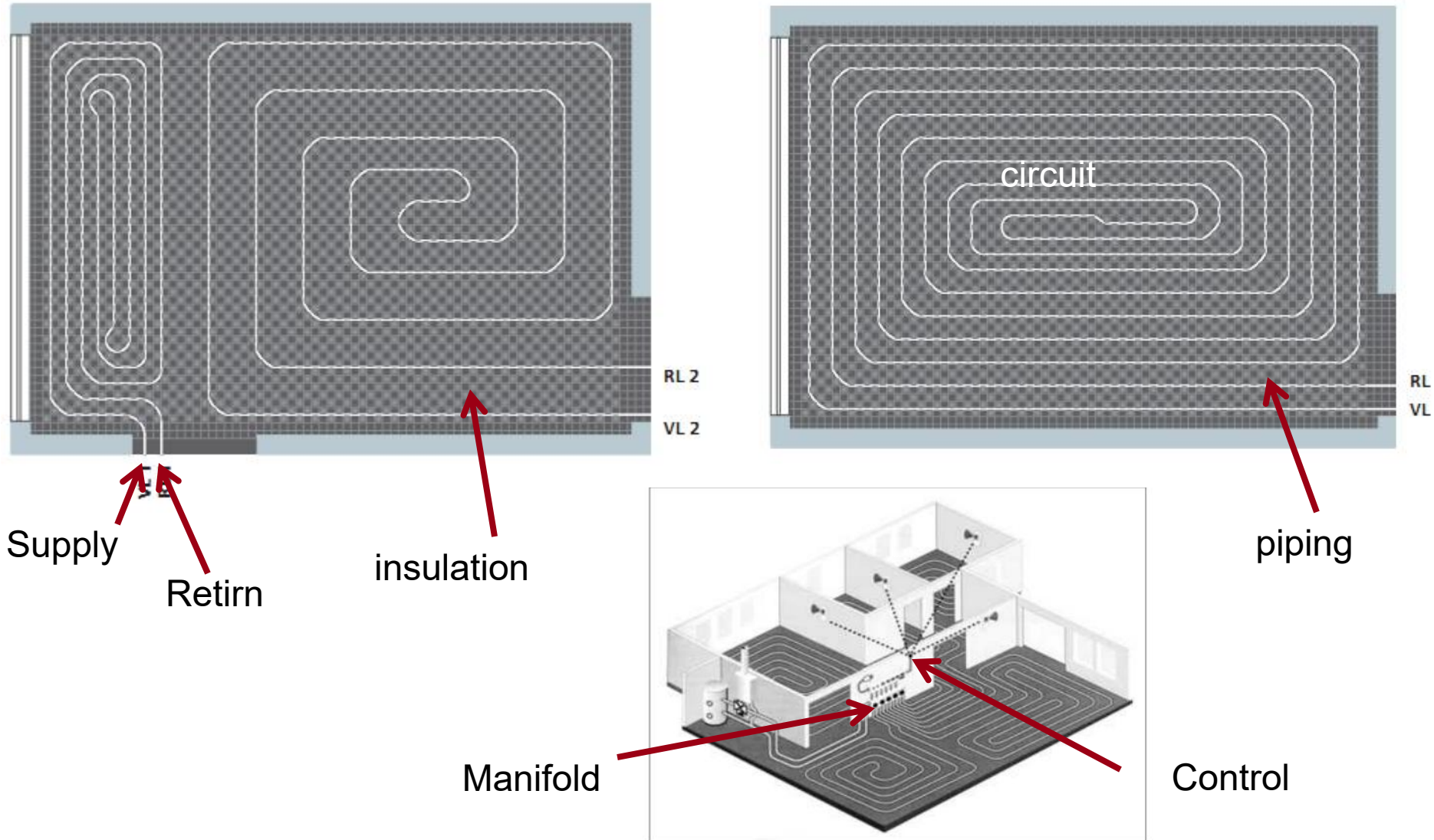
Pipes embedded in prefabricated panels (similar to radiant floors)



Pipes coupled to fixing elements on the wall

**Walls radiant systems are not frequent (limits in the furniture, pictures, ecc.).
Interesting as integrated systems in the retrofit of buildings when internal insulation is foreseen.**

Components of a radiant system



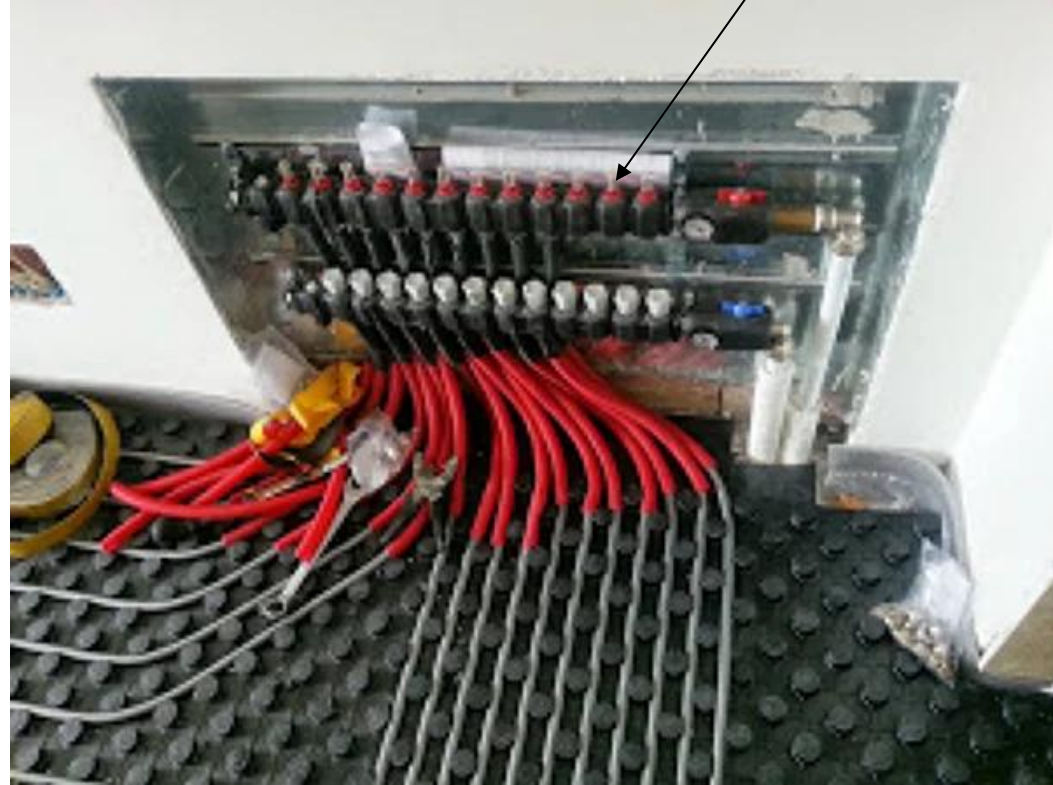
Manifold

Metal



Automatic venting: it is installed at the highest point of the hydronic circuit

Flussimetro
Flowmeter



Plastic

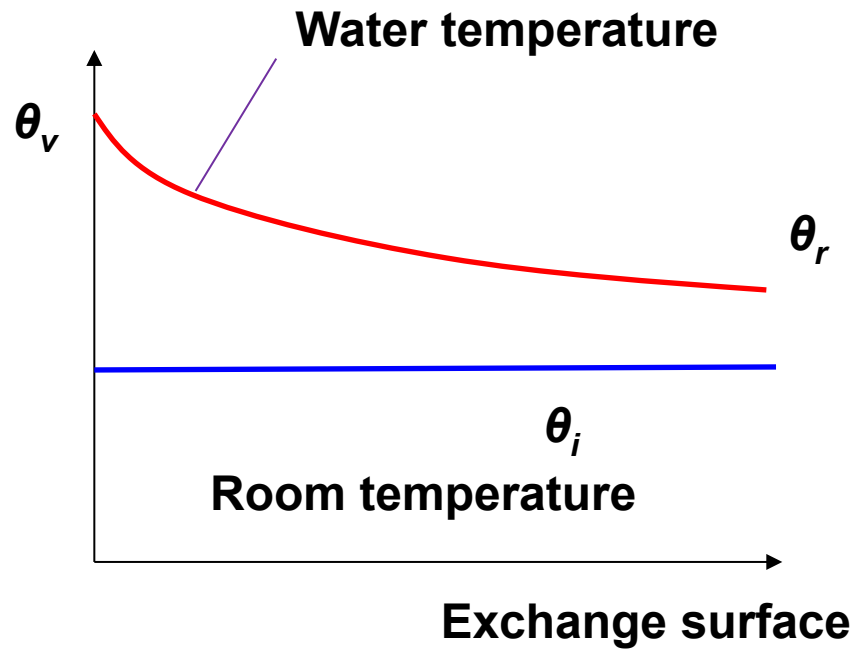
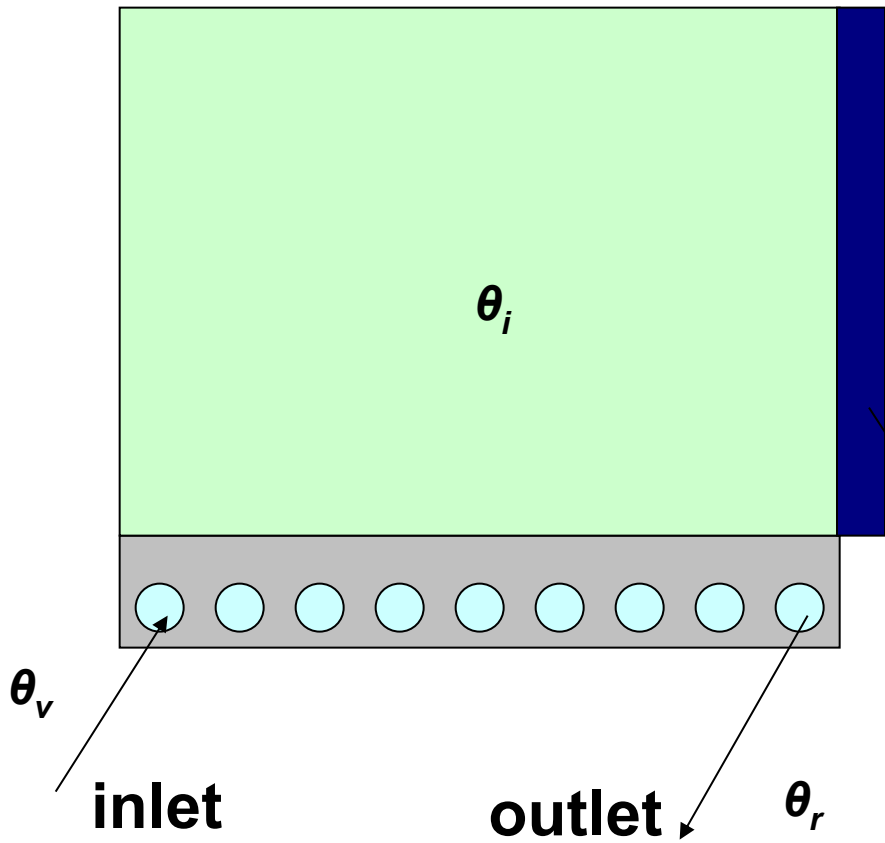
Usual screed



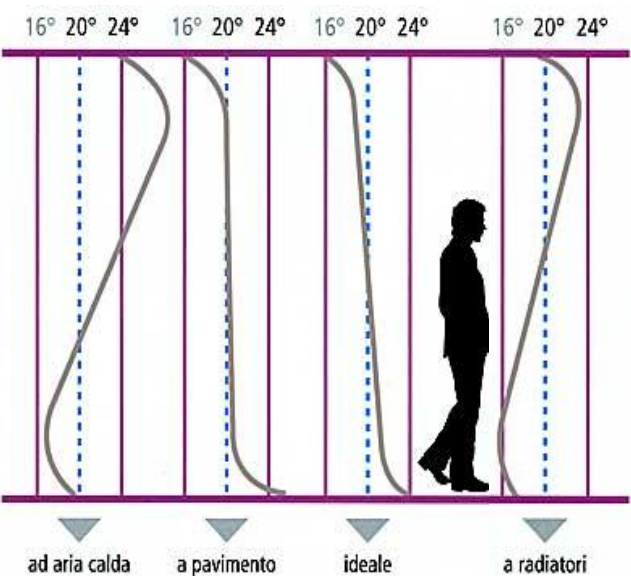
Self-levelling screed



2. Heat transfer phenomena

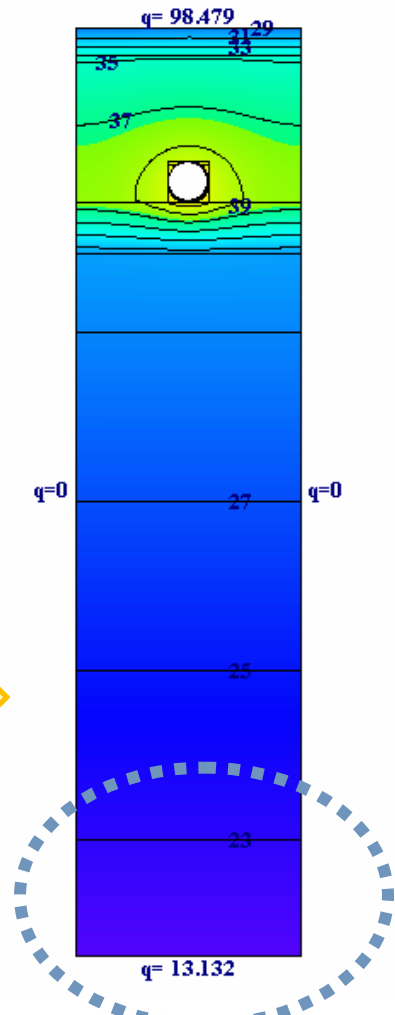
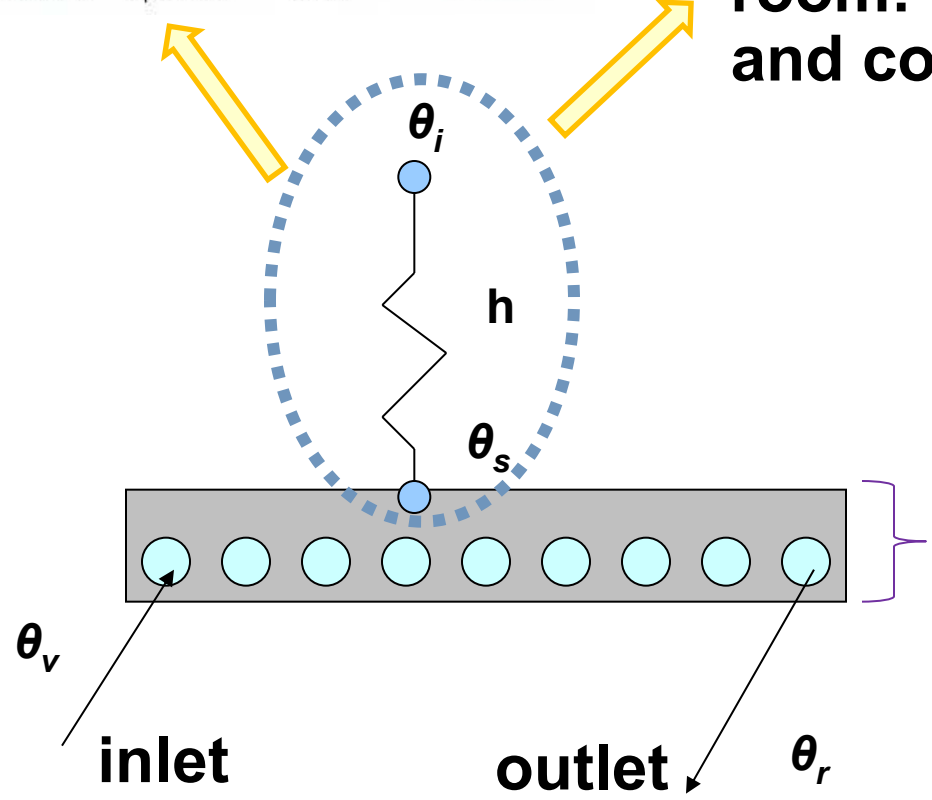


External Wall



Stratification: negligible

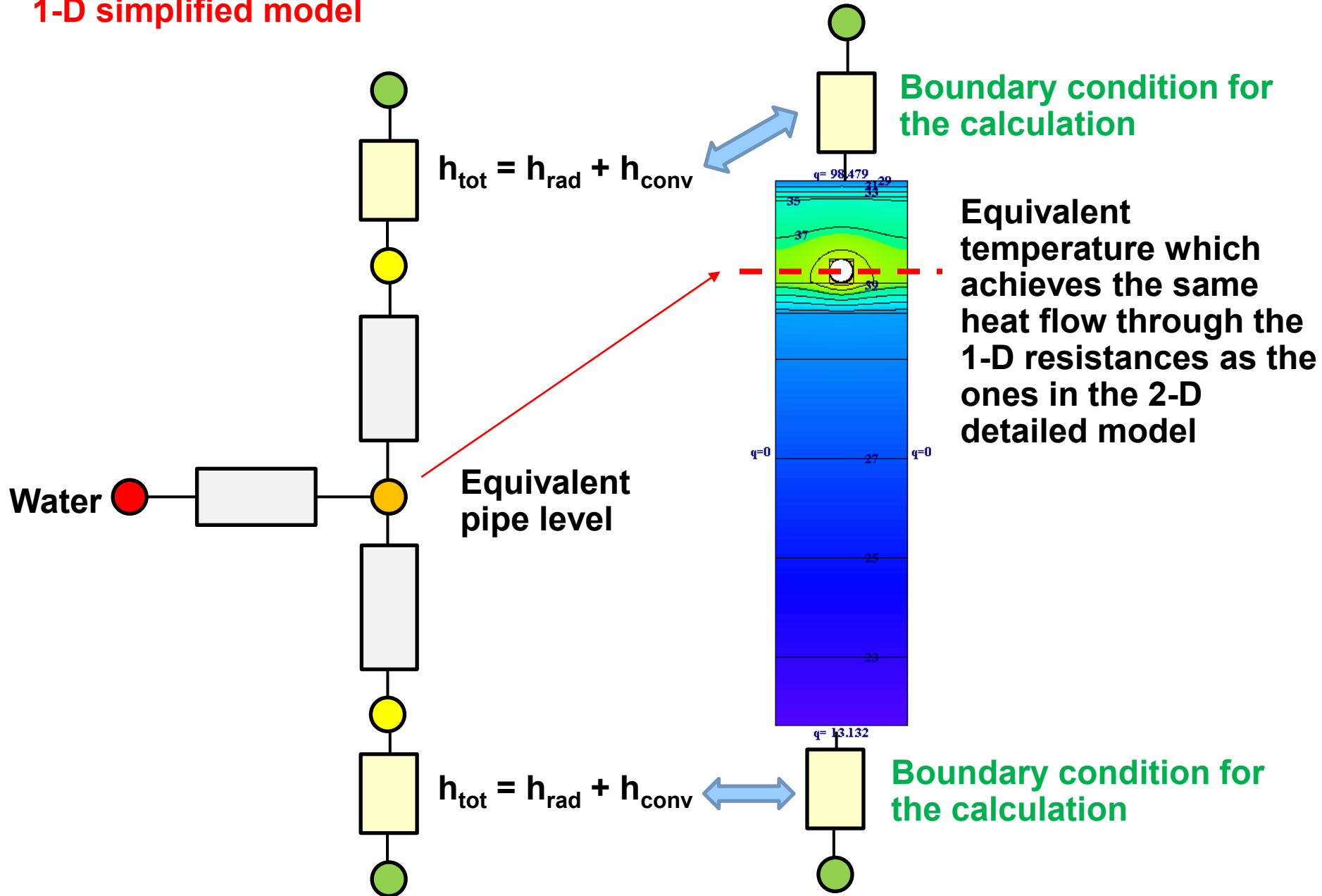
Heat exchange between the surface and the room: both radiant and convective



Embodied losses

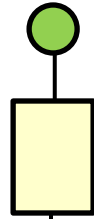
1-D simplified model

2-D detailed model



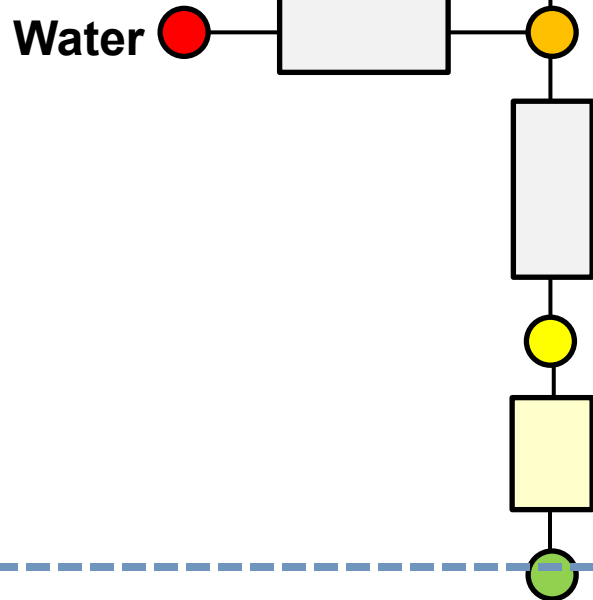
Design steps for sizing the radiant system

Step 1



Useful heat exchange between the surface and the room = f (indoor temperature, peak load, surface orientation, local discomfort parameters)

Step 2

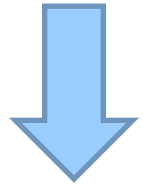


Heat exchange between the water and the structure = f (surface orientation, pipe diameter, layer, surface finishing, pipes spacing)

Step 1: heat exchange between the surface and the room

Overall surface heat exchange coefficients

System Type



Floor

Heating

RADIANT
[W(m² K)]

5.5

CONVECTIVE
[W(m² K)]

5.5

TOTAL
[W(m² K)]

11

Cooling

5.5

1.5

7

Wall

Heating

5.5

2.5

8

Cooling

5.5

2.5

8

Ceiling

Heating

5.5

0.5

6

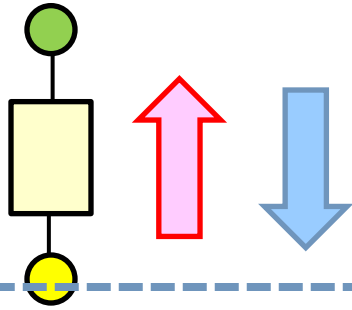
Cooling

5.5

5.5

11

Step 1



Specific Peak Load q:

$$q = \text{Peak power} / \text{active area} \text{ [W/m}^2\text{]}$$

$$q = h_{\text{tot}} \times |t_{\text{surf}} - t_i| \quad \text{[W/m}^2\text{]}$$

To compare against the maximum/minimum allowable temperature for local discomfort

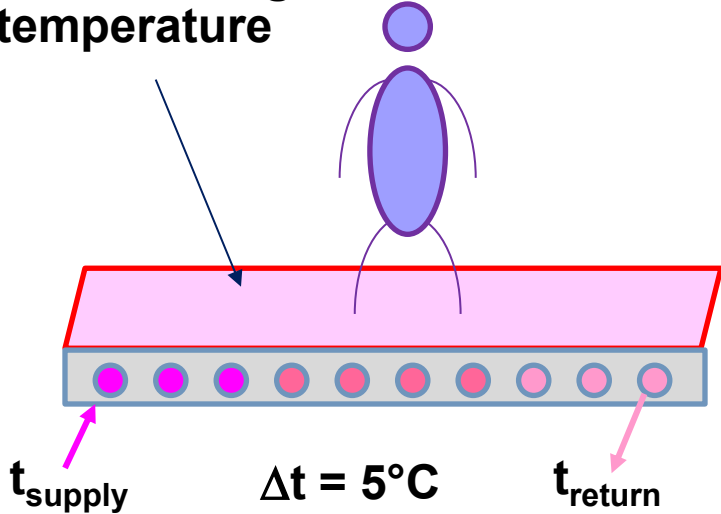
Maximum flow rate: flow rate with the maximum (in heating) and minimum (in cooling) allowable temperature for the surface

Heating: $q_{\text{max}} = h_{\text{tot}} \times |t_{\text{surf, max}} - t_i| \text{ [W/m}^2\text{]}$

Cooling: $q_{\text{max}} = h_{\text{tot}} \times |t_{\text{surf, min}} - t_i| \text{ [W/m}^2\text{]}$

Floor surface temperature limits:

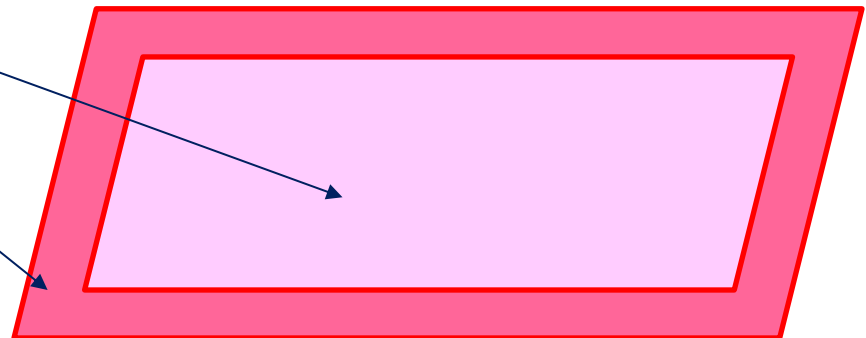
Limit: average surface temperature



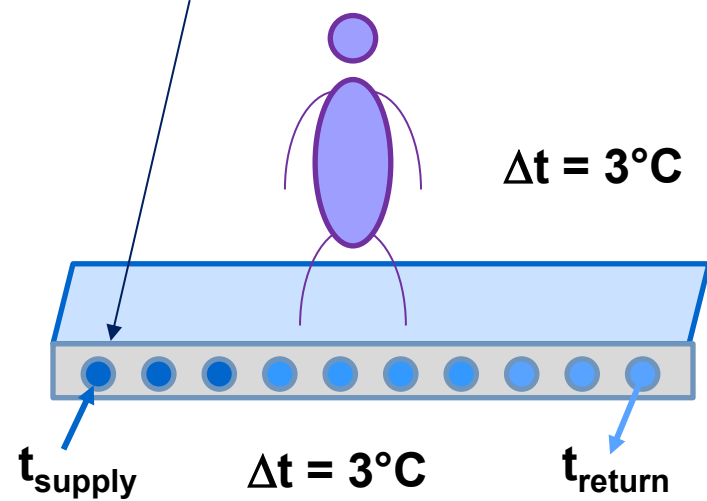
Maximum surface temperature:
average surface temperature.

29°C in the occupied area

35°C in the peripheral area



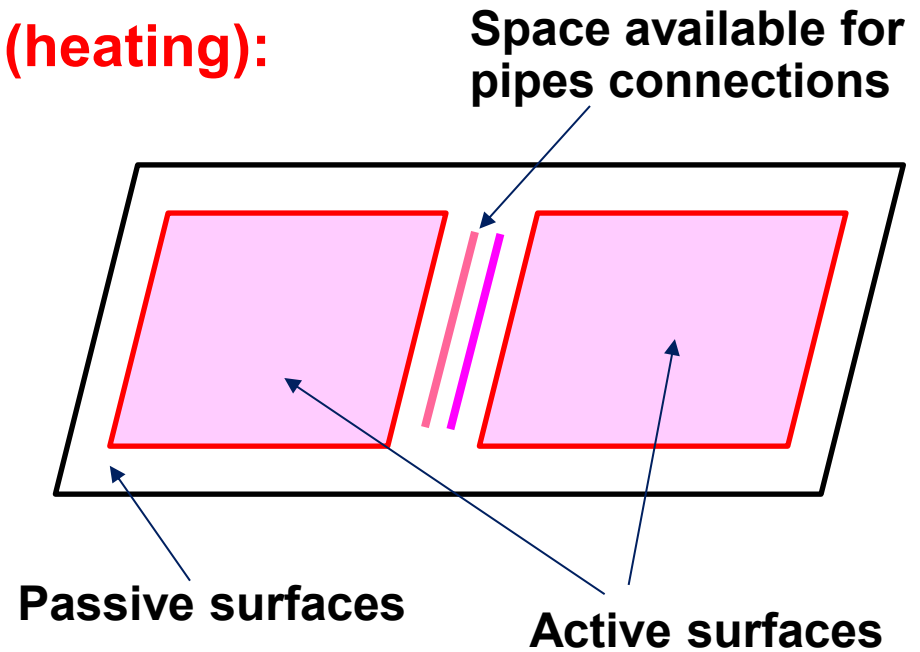
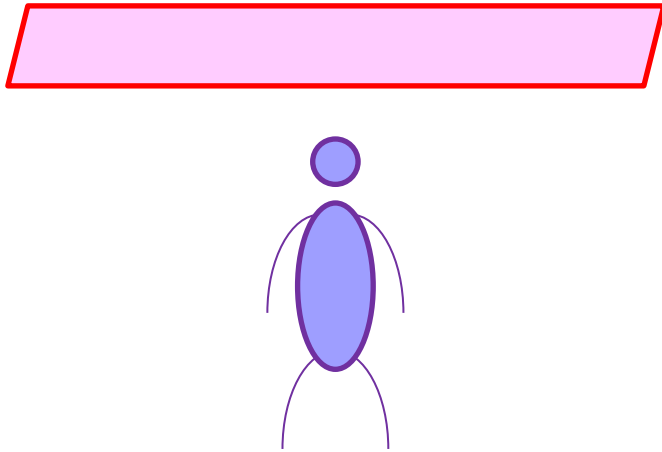
Limit: minimum surface temperature on the top of the room water inlet



Minimum local surface temperature: on the top of the room water inlet (19°C). The average temperature of the floor will be about $19 + 1.5 = 20.5^{\circ}\text{C}$

Ceiling surface temperature limit (heating):

Limit: average surface temperature



Active area: ~70% of overall area

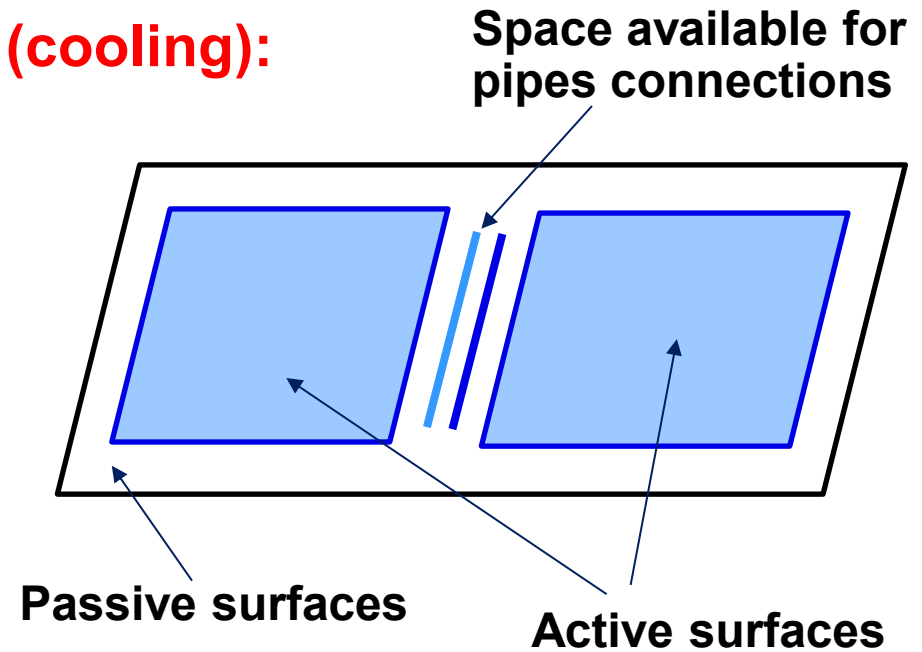
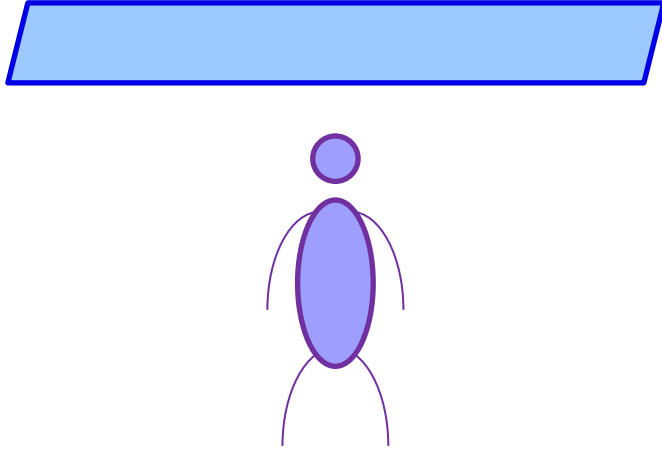
Maximum surface temperature of active area: radiant vertical asymmetry 5°C

Usually it is a difficult parameter to calculate in design phase. Hence approximately it is estimated as a maximum surface temperature. This parameter is under discussion and recently the temperatures have been risen compared to the past (when a suggested temperature of 30-32°C was provided). The following temperature can be used:

$t_{\max} = 35^{\circ}\text{C}$ in the active area

Ceiling surface temperature limit (cooling):

Limit: average surface temperature



Active area: ~70% of overall area

Minimum surface temperature of active area: not a question of radiant vertical asymmetry.

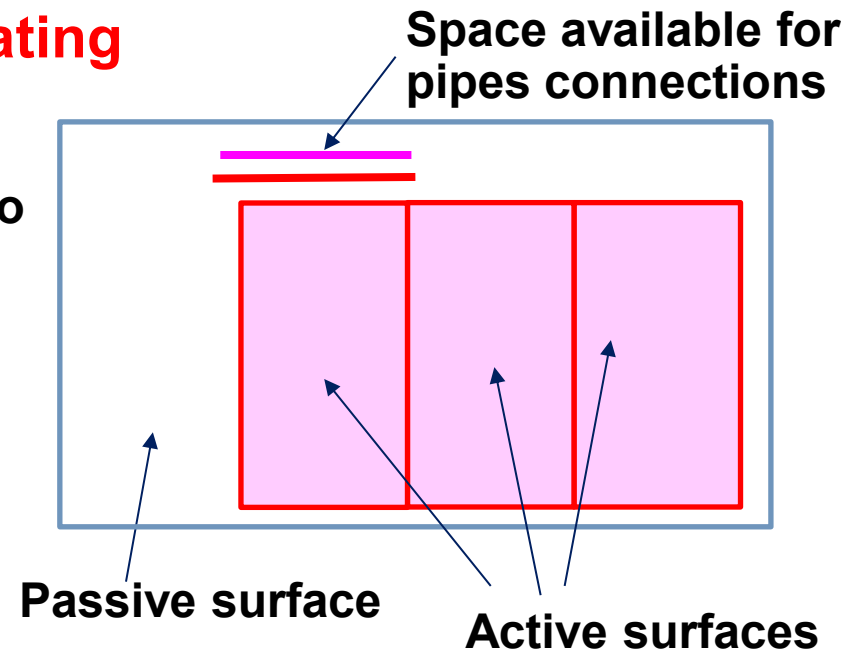
The minimum temperature depends on the dew point temperature. In general the following temperature can be assumed for the active area:

$t_{\min} = 18^{\circ}\text{C}$ in the active area

Wall surface temperature limits (heating and cooling):

Limit: active surface temperature (difficult to know the passive area and not very useful)

Maximum in the range 35 – 50 °C. The maximum may depend on the application of the wall heating system. If it is used in areas where the occupants may easily get contact with the surface or not. If it is used in buildings for more sensitive persons like children or elderly, the risk for burns and pain is a skin temperature of 42-45 °C.



The losses to the backside must be considered.

$t_{\max} = 40^{\circ}\text{C}$ in the active area

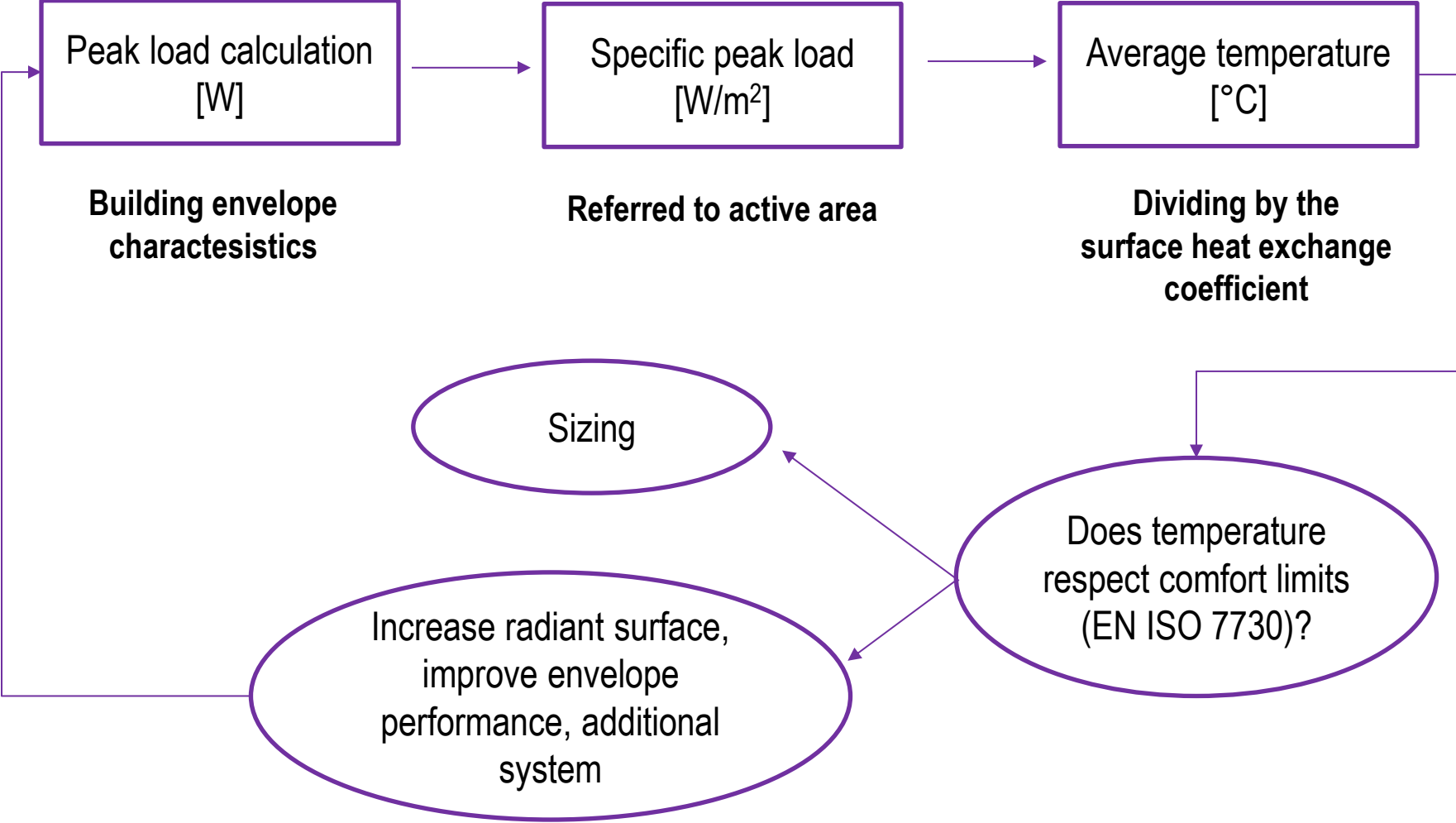
The minimum temperature depends on the dew point temperature. In general the following temperature can be assumed for the active area:

$t_{\min} = 18^{\circ}\text{C}$ in the active area

Maximum specific power of a radiant system

			t_{\min}/t_{\max} [°C]	h_{tot} [W/(m ² K)]	t_i [°C]	q_{max} [W/m ²]
FLOOR	Occupied	Heating	29	11	20	100
		Cooling	20	7	26	40
	Peripheral	Heating	35	11	20	165
		Cooling	19	7	26	50
CEILING	Active area	Heating	35	6	20	90
		Cooling	18	11	26	88
	Overall area	Heating	30.5	6	20	63
		Cooling	20.5	11	26	60
WALL	Active area	Heating	40	8	20	160
		Cooling	19	8	26	55

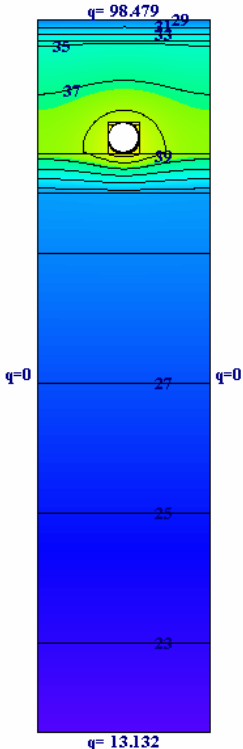
Step 1: Resume



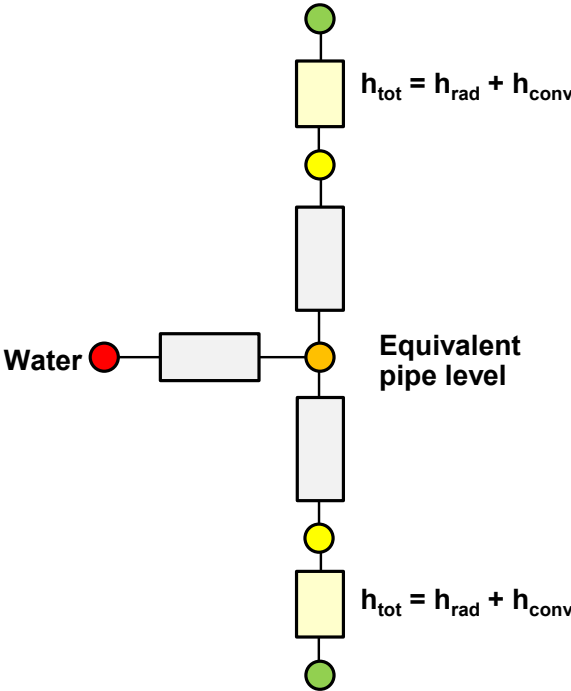
Step 2: Sizing

There are 4 methods for sizing a radiant system:

**Method 1:
Detailed 2-D
calculation
method**



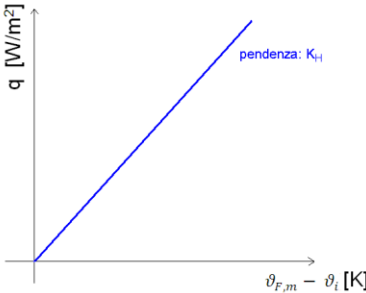
**Method 2:
Simplified 1-D
calculation
method**

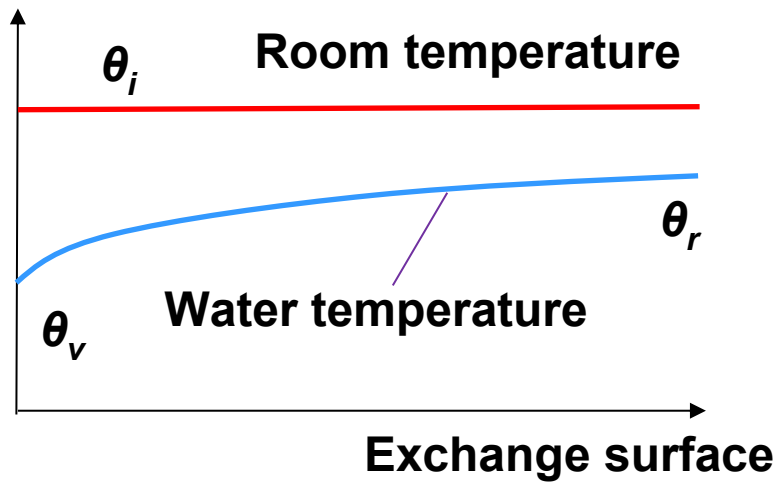
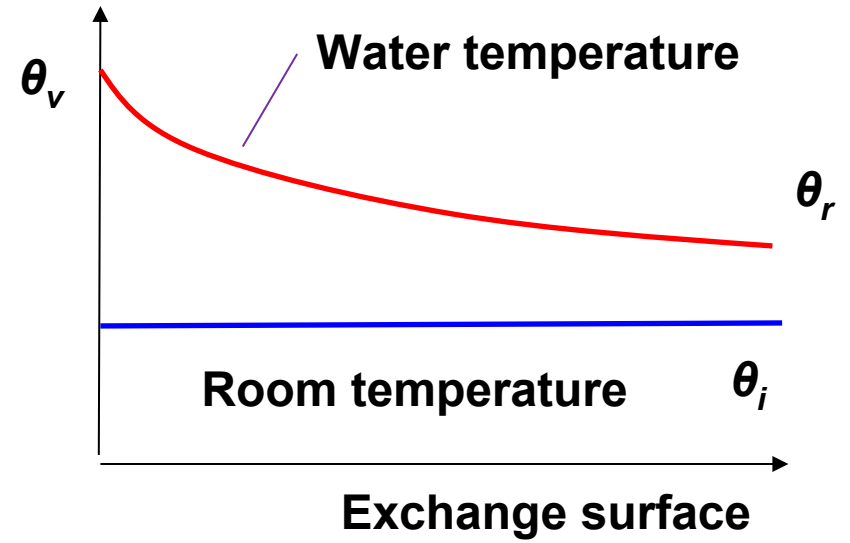
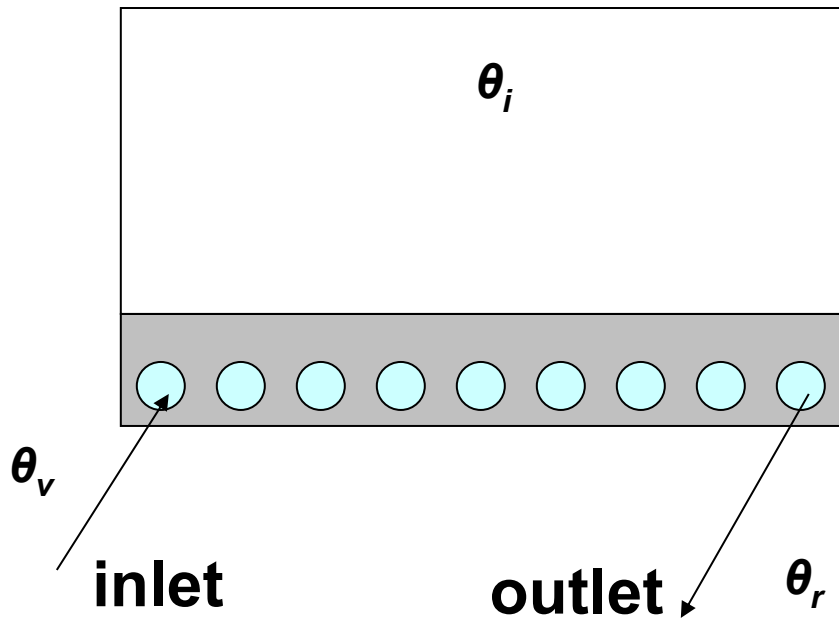


**Method 3:
Simplified
Black-box
calculation
method**

Geometry
Thermal
properties of
materials
Etc.

**Method 4:
Heat transfer
through
certified
tested values**





$$q_H = K_H \Delta\theta_H$$

$$\Delta\theta_H = \frac{\Delta_1 - \Delta_2}{\ln(\Delta_1/\Delta_2)}$$

$$q_C = K_C \Delta\theta_C$$

$$\Delta\theta_C = \frac{\Delta_1 - \Delta_2}{\ln(\Delta_1/\Delta_2)}$$

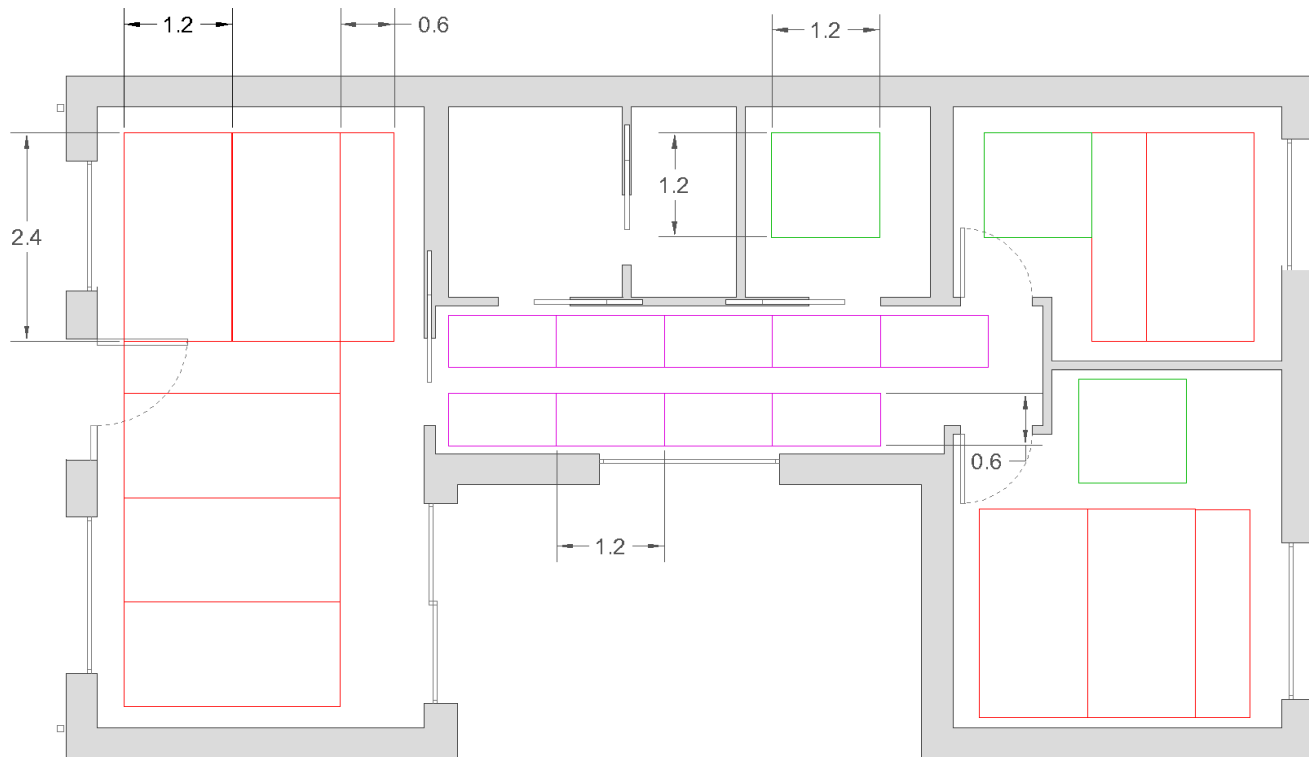
Sizing radiant walls and ceilings:

Check the available area and assume the possible amount of radiant systems, their distribution and connections.

Fix the mass flow rate/ $\Delta\theta_{\text{water}}$:

$$q_H = K_H \Delta\theta_H \longrightarrow q_H = \dot{m} c_p (\theta_{v,H} - \theta_{r,H})$$

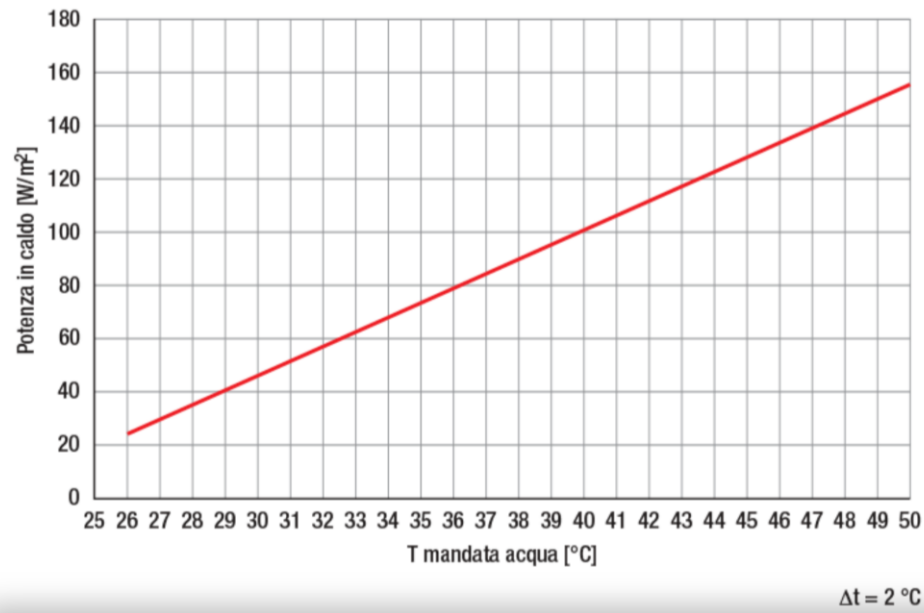
$$q_C = K_C \Delta\theta_C \longrightarrow q_C = \dot{m} c_p (\theta_{v,C} - \theta_{r,C})$$



In this case the systems are prefabricated. The producer will provide the curves for K_H , K_C and the Δp as a function of the flow rates of the system

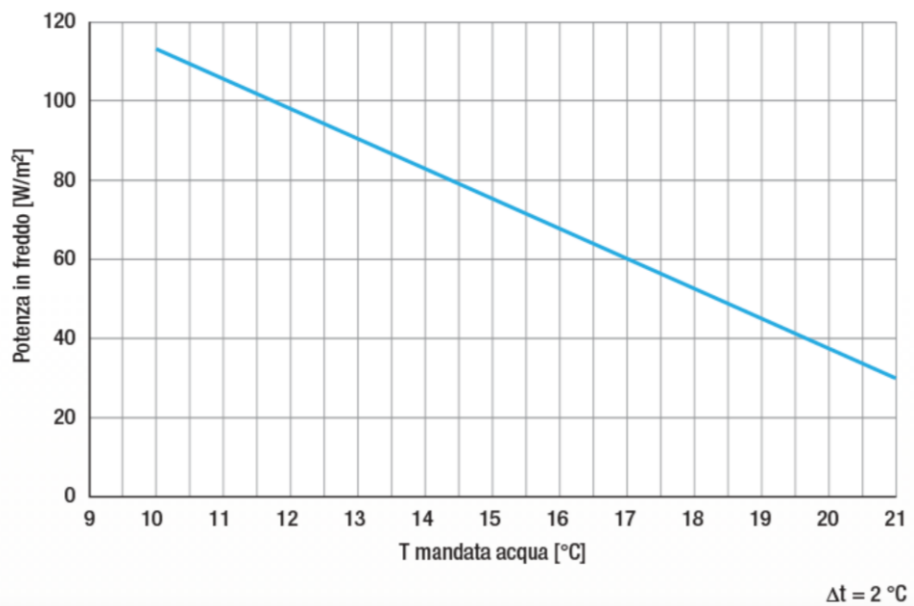
Example of K_H and K_C for a radiant ceiling provided with testing:

Same test room, used also for radiators (EN 442), but different testing methodology.

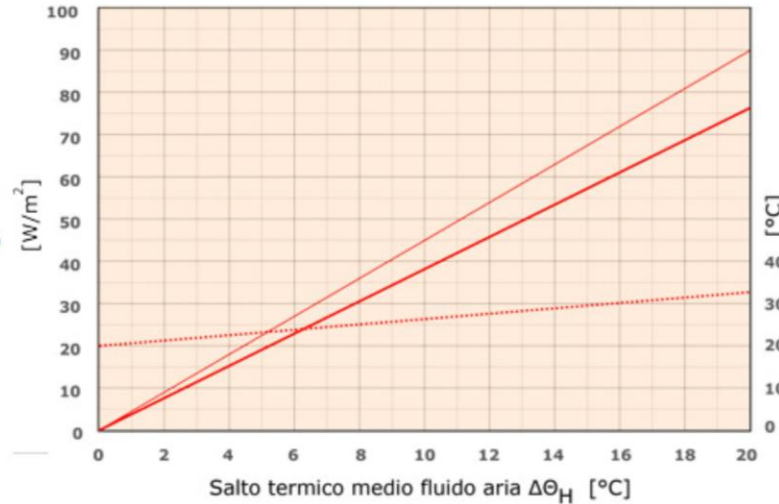
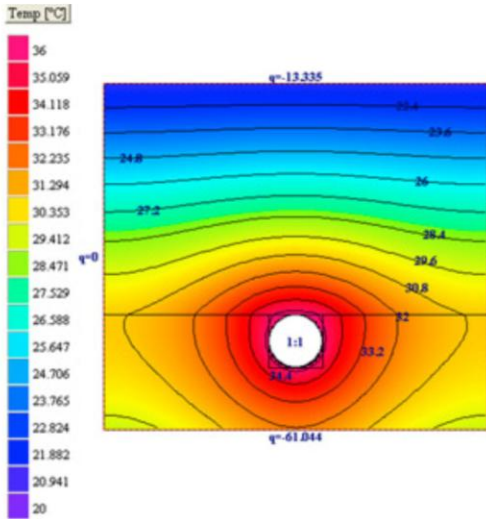


EN 14037-5 (laboratory test for radiant ceiling in heating)

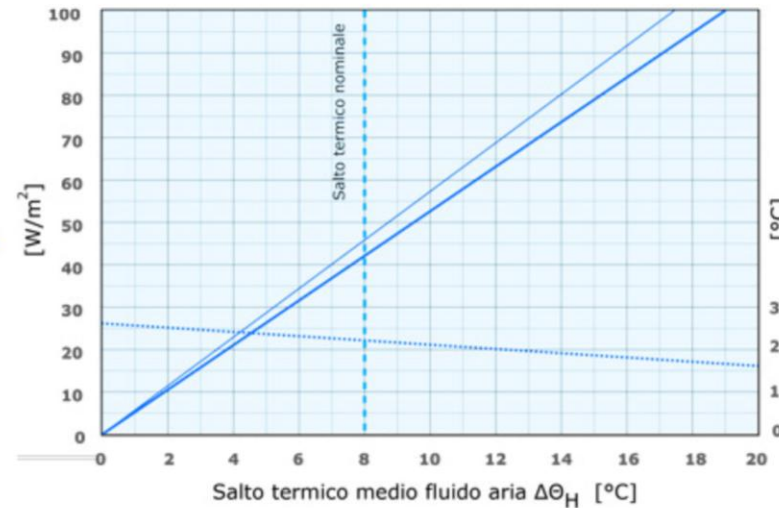
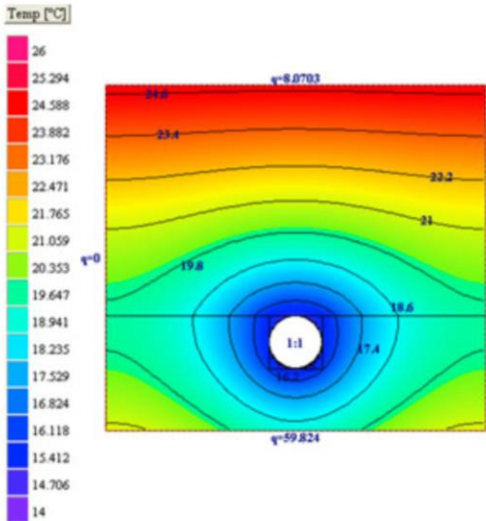
EN 14240 (laboratory test for radiant ceiling in cooling)



Example of K_H and K_C for a radiant ceiling calculated with a detailed 2-D method



— Water power
 - - - Useful power
 · · · Surface temperature



— Water power
 - - - Useful power
 · · · Surface temperature

Source:
Rossato

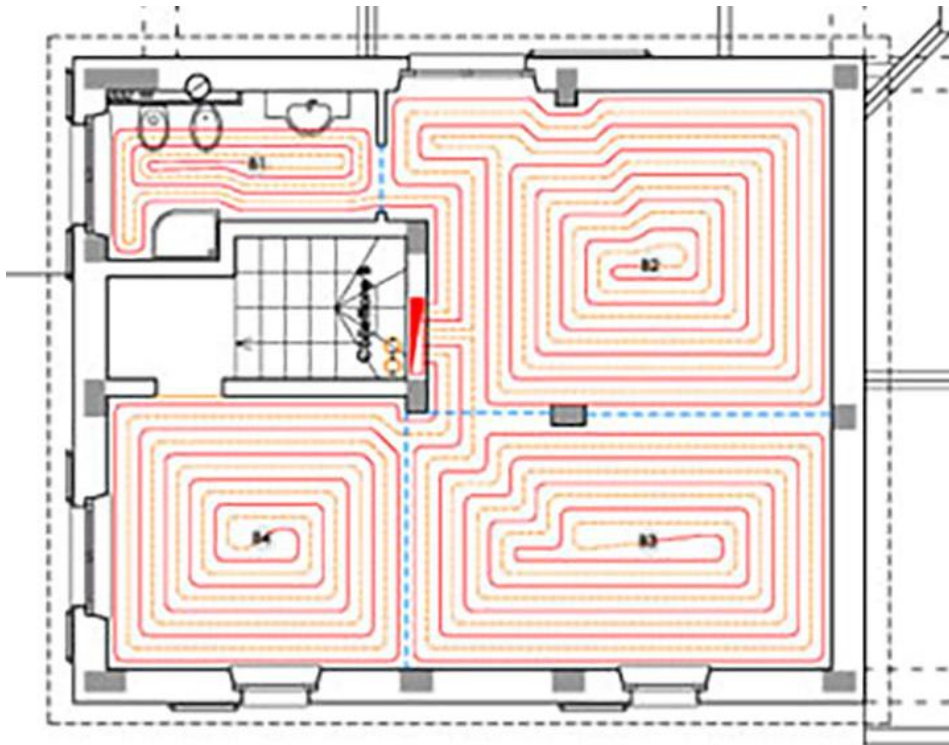
Sizing radiant floors:

Check the available area and assume the possible lay-out of the radiant floor. Define the floor covering, the type of radiant floor and concrete layer with embedded pipes. Then evaluate the

Fix the mass flow rate/ $\Delta\theta_{\text{water}}$:

$$q_H = K_H \Delta\theta_H \longrightarrow q_H = \dot{m} c_p (\theta_{v,H} - \theta_{r,H})$$

$$q_C = K_C \Delta\theta_C \longrightarrow q_C = \dot{m} c_p (\theta_{v,C} - \theta_{r,C})$$



In this case the systems are prefabricated. The producer will provide the curves for K_H , K_C and the Δp as a function of the flow rates of the system

Standard EN ISO 11855

General definition of hydronic radiant systems

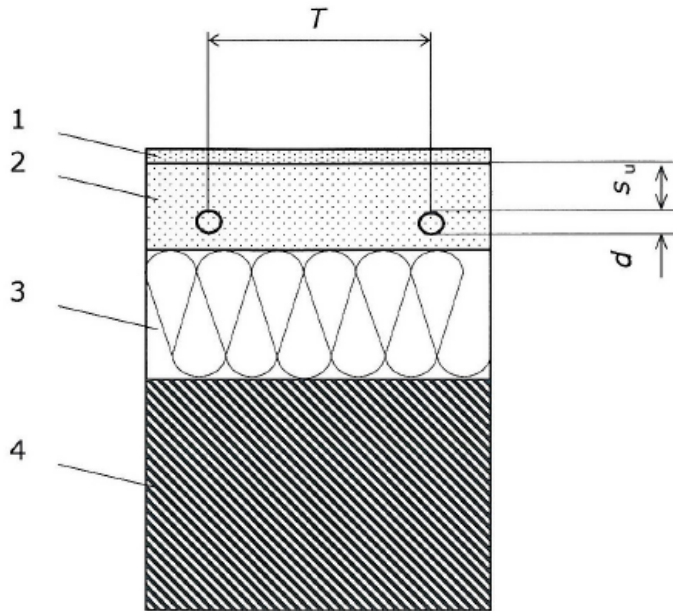
Depending on the position of the pipes in the building construction, hydronic radiant systems can be sorted into 4 main categories:

- **Embedded Surface Systems:** pipes embedded within the surface layer (not within the structure)
- **Thermally Active Building Systems (TABS):** the pipes thermally coupled and embedded in the building structure (slabs, walls)
- **Capillary Surface Systems:** pipes embedded in a layer at the inner ceiling/wall surface
- **Radiant Panels:** metal pipes integrated into panels (not within the structure); heat carrier close to the surface

Focuses on embedded water based surface heating and cooling systems and TABS. Depending on construction details, this norm distinguishes 7 different types of those systems (Types A to G)

- **Type A** with pipes embedded in the screed or concrete (“wet” system)
- **Type B** with pipes embedded outside the screed (in the thermal insulation layer, “dry” system)
- **Type C** with pipes embedded in the leveling layer, above which the second screed layer is placed
- **Type D** include plane section systems (extruded plastic / group of capillary grids)
- **Type E** with pipes embedded in a massive concrete layer
- **Type F** with capillary pipes embedded in a layer at the inner ceiling or as a separate layer in gypsum
- **Type G** with pipes embedded in a wooden floor construction

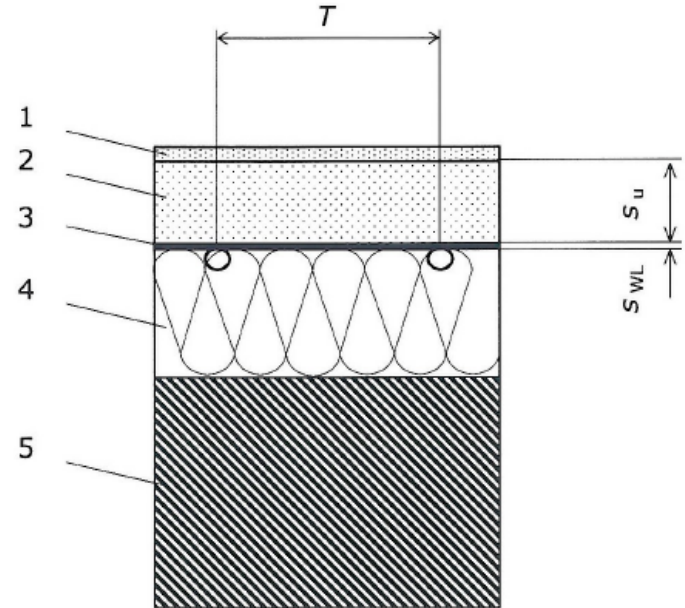
– Part 1 – definition of radiant systems



Key

- 1 floor covering
- 2 weight bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed)
- 3 thermal insulation
- 4 structural bearing

Figure 2 a) Systems of type A and C



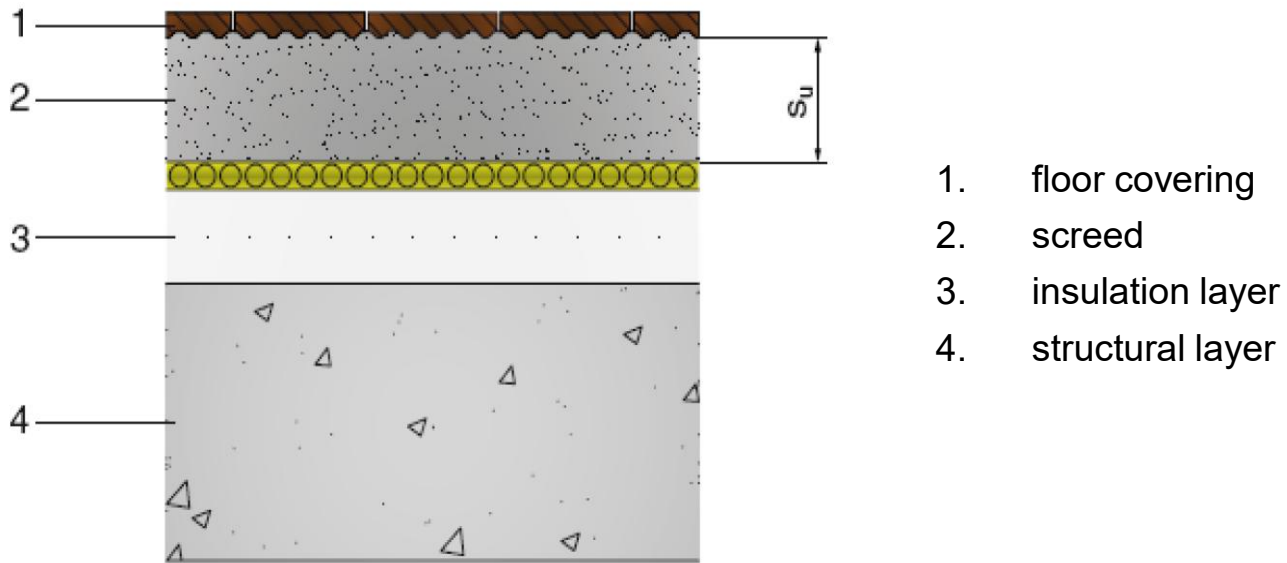
Key

- 1 floor covering
- 2 weight bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed, wood)
- 3 heat diffusion devices
- 4 thermal insulation
- 5 structural bearing

Figure 2 b) Systems of type B

Figure 2 — Systems of type A, B and C covered by the method in EN 1264

– Part 1 – definition of radiant systems



Plane section systems, type D covered by the method in EN 1264

– Part 1 – definition of radiant systems

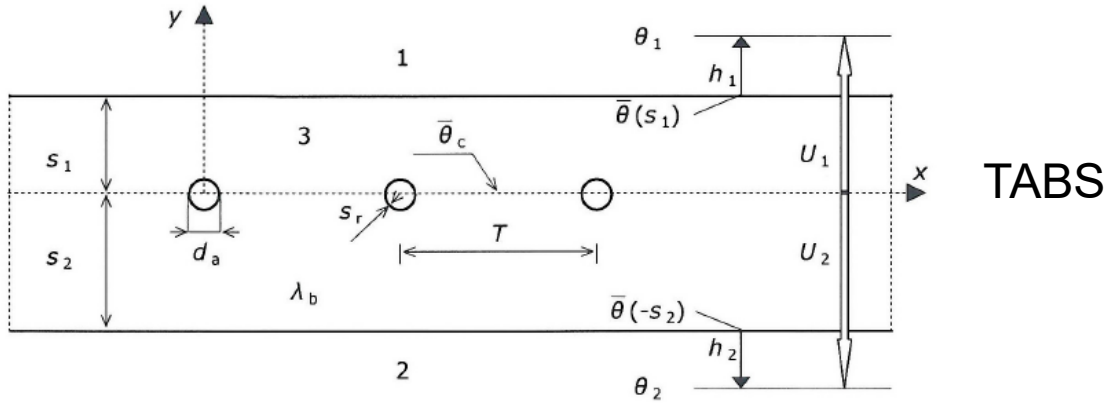


Figure 4 — Pipes embedded in a massive concrete layer, systems of type E

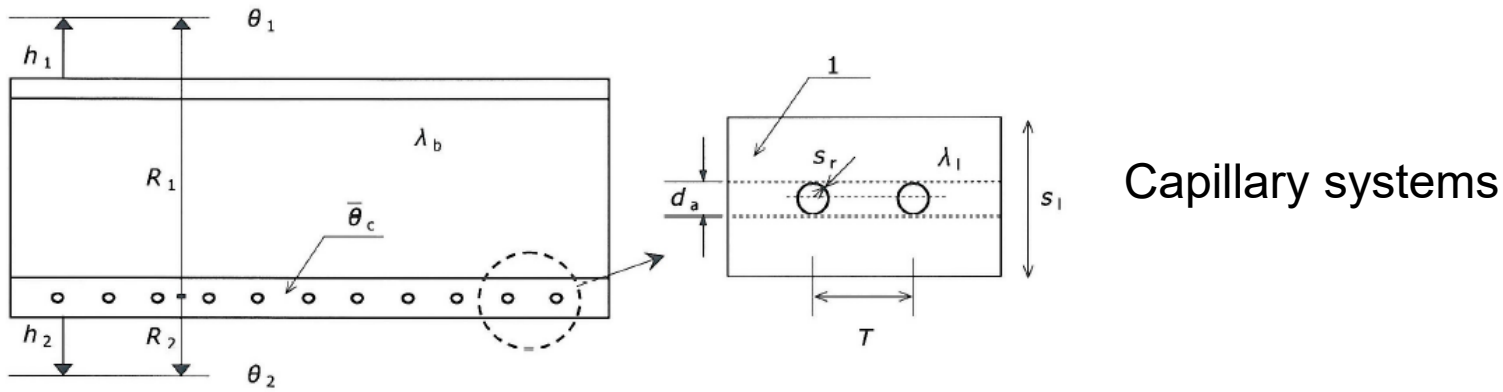
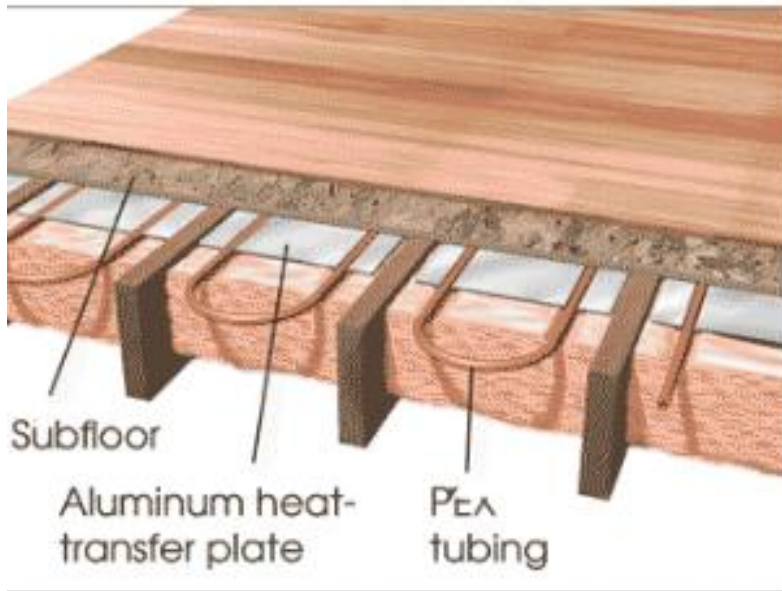


Figure 5 — Capillary pipes embedded in a layer at the inner surface, systems of type F

– Part 1 – definition of radiant systems



pipes embedded in wooden floor constructions using heat conducting plates, systems of type G

– Parte 1 – Determinazione delle potenze di riscaldamento e di raffrescamento

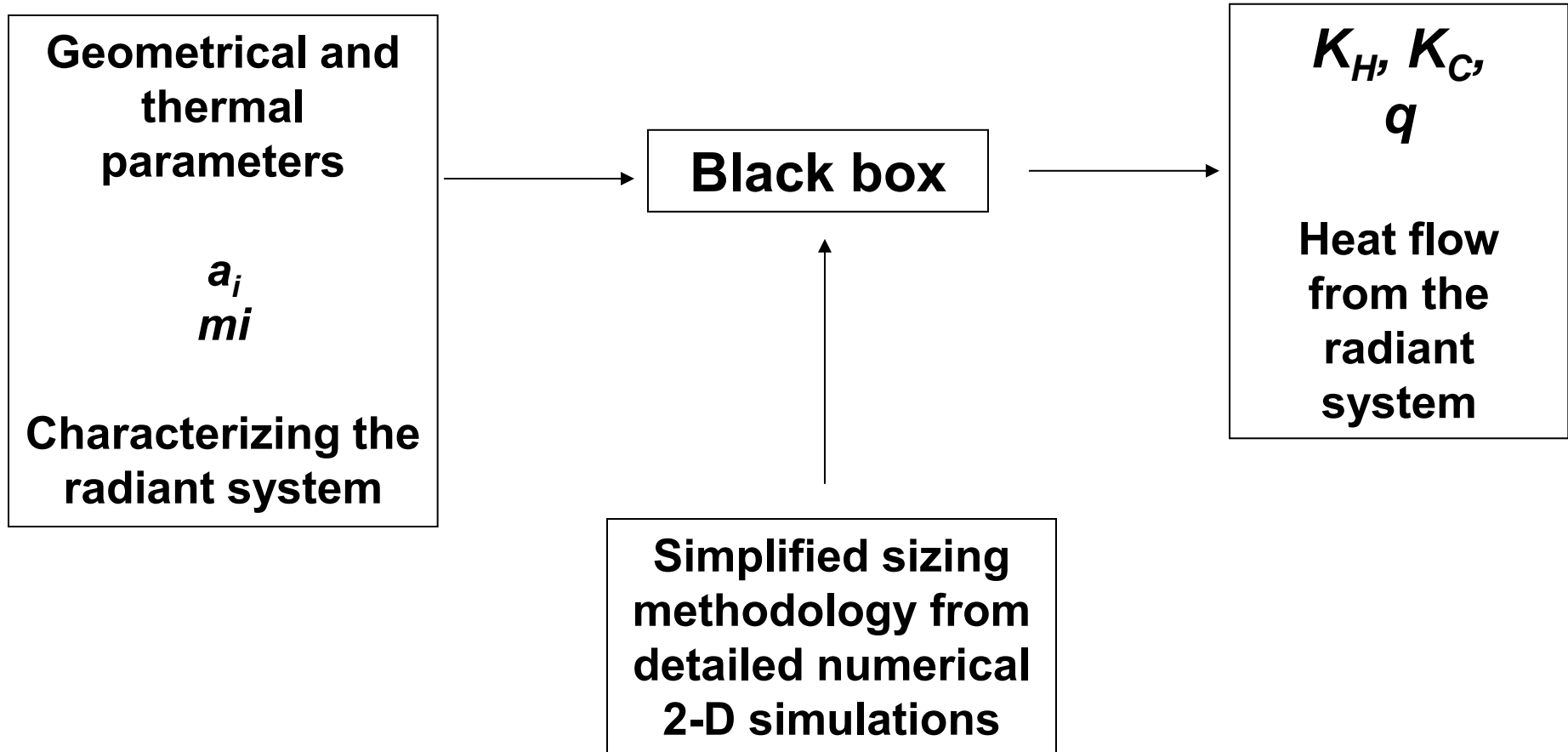
Table 2 — Criteria for selection of simplified calculation method

Pipe position	Type of system	Figure	Boundary conditions
In screed, one side loss less than or equal to 10 % of total	A, C	2a)	$T \geq 0,050m$ $S_u \geq 0,01m$ $0,008 m \leq d \leq 0,03 m$ $S_u / \lambda_e \geq 0,01$
In insulation, conductive devices, one side loss less than or equal to 10 % of total	B	2b)	$0,05 \leq T \leq 0,45m$ $0,014 m < d < 0,022 m$ $0,01 \leq S_u / \lambda_e \leq 0,18$
Plane section system	D		
In concrete slab	E	4	$S_T / T \geq 0,3$
Capillary tubes in concrete surface	F	5	$d_a / T \leq 0,2$
Wooden constructions, pipes in sub floor or under sub floor, conductive devices	G	6	$\lambda_{wd} \geq 10 \cdot \lambda_{surroundingmaterial}$ $S_{WL} \cdot \lambda \geq 0,01$

For each type of radiant system (A,B,C,D,F,G) there is a method for the calculation:

Method according to EN 1264

Backgrounds:



Thermal boundary conditions

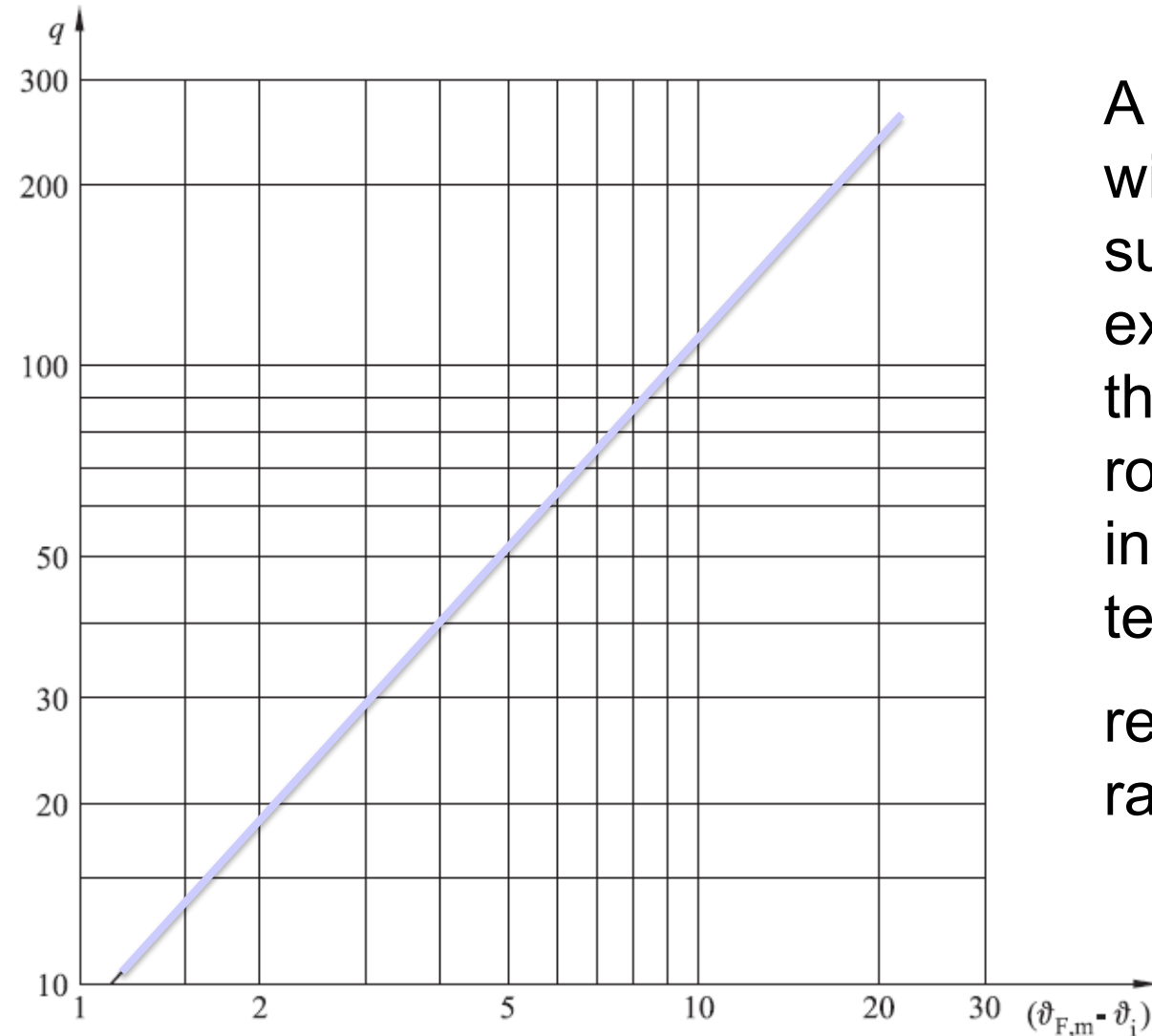
- A floor heating surface with a given average surface temperature exchanges the same thermal output in any room with the same indoor room temperature θ_i .
- It is possible to give a curve of the relationship between specific thermal output and average surface temperature that is independent of the heating system and applicable to all floor heating surfaces.
- In contrast, every floor heating system has its own maximum permissible specific thermal output, q_G .

q_G in design conditions:

$\theta_i = 20^\circ\text{C}$; $\theta_{F, \max} = 29^\circ\text{C}$ (for peripheral area $\theta_{F, \max} = 35^\circ\text{C}$) *water* temperature drop supply/return $\sigma = 0^\circ\text{C}$,

Basic Characteristic Curve

$$q = 8.92 * (\theta_{F,m} - \theta_i)^{1.1}$$



A floor heating surface with a given average surface temperature, $\theta_{F,m}$ exchanges the same thermal output, q in any room with the same indoor room temperature, θ_i

regardless of the type of radiating system

Thermal output of the radiant floor system

- The centre of the heating surface is used as the reference point for $\theta_{F,max}$.
- The average surface temperature $\theta_{F,m}$, determining the specific thermal output.
- The condition $\theta_{F,m} < \theta_{F,max}$ always applies.
- The value of $\theta_{F,m}$ is affected by both floor heating system and operating conditions (temperature drop σ , q_u , heat resistance of the floor covering $R_{\lambda,B}$).

Conditions for the calculation

- Heat transfer of the floor is calculated in according with the basic characteristic curve.
- The temperature drop of the heat carrier fluid is equal to $\sigma = 0^{\circ}\text{C}$ (if the temperature drop is $> 0^{\circ}\text{C}$ it can be used the equation with the logarithmically determined temperature difference $\Delta\theta_{\text{H}}$).
- Turbulent pipe flow: $m_{\text{H}}/d_i > 4\,000 \text{ kg}/(\text{h} \cdot \text{m})$.
- The lateral surfaces of the floor are adiabatics
- The heat-conducting layer of the floor heating system is thermally decoupled by thermal insulation from the structural base of the building.

General Approach

- For the calculation of q the following parameters and data are required:
 - $T \rightarrow$ pipe spacing (pitch)
 - $s_u \rightarrow$ thickness of the screed
 - $\lambda_E \rightarrow$ conductivity of the layer above the pipe
 - $R_{\lambda,B} \rightarrow$ heat conduction resistance of the floor covering
 - $D = d_a \rightarrow$ external diameter of the pipe
 - $\lambda_R \rightarrow$ conductivity of the pipe
 - $a_K \rightarrow$ factor for the evaluation of the contact between the pipes and the heat diffusion devices or the screed
 - $K_{WL} \rightarrow$ heat diffusion devices

B
type

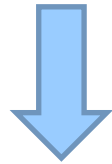
$$q = f[(\Delta\theta_H)^n] = f\left[\left(\frac{\theta_V - \theta_R}{\ln \frac{\theta_V - \theta_i}{\theta_R - \theta_i}}\right)^n\right] \text{ with } n = \boxed{1.0} - 1.05$$

The specific thermal output is calculated with:

$$q = f[(\Delta\theta_H)^n] \quad \Rightarrow \quad q = B * \prod_i(a_i^{m_i}) * \Delta\theta_H$$

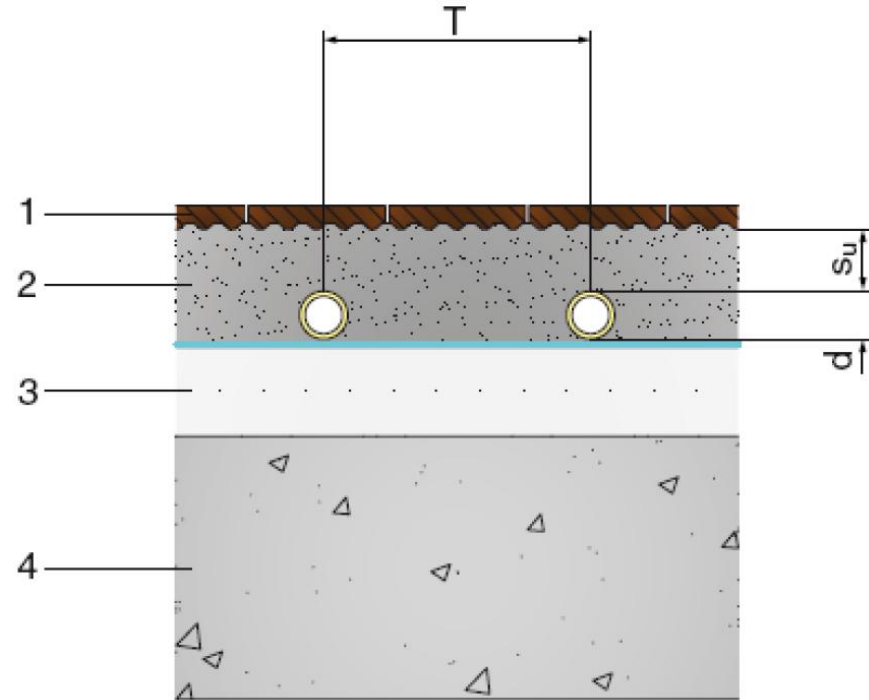
- B system-dependent coefficient [W/(m²K)];
- $\prod_i(a_i^{m_i})$ power product linking the parameters of the floor construction with one another;
- A distinction shall be made between systems, where the pipes are installed inside or below the screed or wood floors (A,C and B), and systems with surface elements (D, plane section systems). For usual constructions, the previous eq. can be apply directly.
- For systems with additional devices for heat distribution, for air filled hollow sections or for other components influencing the heat distribution, the thermal output is determined experimentally.

$$q = B \cdot a_B \cdot a_T^{m_T} \cdot a_u^{m_u} \cdot a_D^{m_D} \cdot \Delta\vartheta_H$$



$$q = K_H \cdot \Delta\vartheta_H$$

$B \rightarrow B_0 = 6.7 \text{ W}/(\text{m}^2\text{K})$ with
 $\lambda_R = \lambda_{R,0} = 0.35 \text{ W}/(\text{mK})$
 $s_R = s_{R,0} = 0.002 \text{ m}$



If pipe wall thickness and conductivity of the material are different it is possible to use the next equation:

$$\frac{1}{B} = \frac{1}{B_0} + \frac{1,1}{\pi} * \prod_i(a_i^{m_i}) * T * \left[\frac{1}{2\lambda_R} \ln \frac{d_a}{d_a - 2s_R} - \frac{1}{2\lambda_{R,0}} \ln \frac{d_a}{d_a - 2s_{R,0}} - \right]$$

- $a_B \rightarrow$ is the floor covering factor

type A and type C

$$a_B = \frac{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_{u,0}}}{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_E} + R_{\lambda,B}}$$

$$\alpha = 10,8 \text{ W}/(\text{m}^2 \cdot \text{K});$$

$$\lambda_{u,0} = 1 \text{ W}/(\text{m} \cdot \text{K});$$

$$s_{u,0} = 0,045 \text{ m};$$

$R_{\lambda,B}$ is the heat conduction resistance of the floor covering, in $\text{m}^2 \cdot \text{K}/\text{W}$;

λ_E is the heat conductivity of the screed, in $\text{W}/(\text{m} \cdot \text{K})$;

- $a_T \rightarrow$ is the spacing factor

$R_{\lambda,B}$ $\text{m}^2 \cdot \text{K}/\text{W}$	0	0,05	0,10	0,15
a_T	1,23	1,188	1,156	1,134

$$m_T = 1 - \frac{T}{0,075}$$

applies where $0,050 \text{ m} \leq T \leq 0,375 \text{ m}$

- $a_u \rightarrow$ is the covering factor

type A and type C

$R_{\lambda, B}$ m ² · KW	0	0,05	0,10	0,15
T (m)	a_u			
0,05	1,069	1,056	1,043	1,037
0,075	1,066	1,053	1,041	1,035
0,1	1,063	1,05	1,039	1,033 5
0,15	1,057	1,046	1,035	1,030 5
0,2	1,051	1,041	1,031 5	1,027 5
0,225	1,048	1,038	1,029 5	1,026
0,3	1,039 5	1,031	1,024	1,021
0,375	1,03	1,022 1	1,018 1	1,015

$$m_u = 100(0,045 - s_u)$$

applies where $s_u \geq 0,010$ m

type A and type C

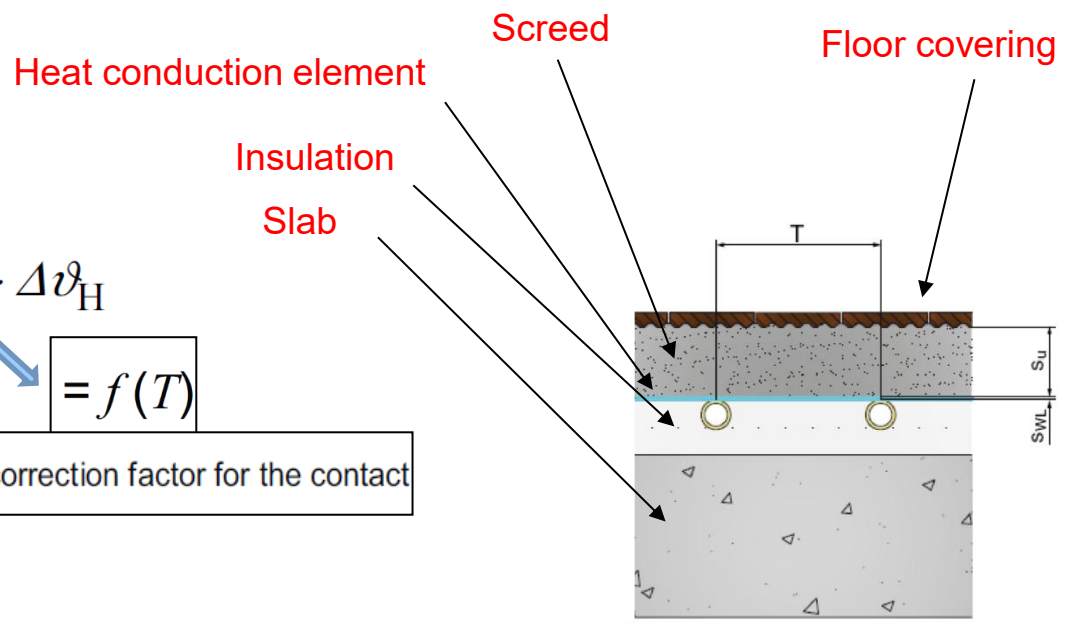
- $a_D \rightarrow$ is the pipe external diameter factor

$R_{\lambda, B}$ $m^2 \cdot KW$	0	0,05	0,10	0,15
T (m)	a_D			
0,05	1,013	1,013	1,012	1,011
0,075	1,021	1,019	1,016	1,014
0,1	1,029	1,025	1,022	1,018
0,15	1,04	1,034	1,029	1,024
0,2	1,046	1,04	1,035	1,03
0,225	1,049	1,043	1,038	1,033
0,3	1,053	1,049	1,044	1,039
0,375	1,056	1,051	1,046	1,042

$$m_D = 250(D - 0,020)$$

applies where $0,008 \text{ m} \leq D \leq 0,030 \text{ m}$

type B



$$q = B \cdot a_B \cdot a_T^{m_T} \cdot a_u \cdot a_{WL} \cdot a_K \cdot \Delta\vartheta_H$$

$= f(T)$

$B = B_0 = 6,5 \text{ W}/(\text{m}^2 \cdot \text{K})$ is the correction factor for the contact

a_T is the pipe spacing factor

m_T \longrightarrow $m_T = 1 - \frac{T}{0,075}$

a_u is the covering factor, which is calculated in accordance with the following equation:

$$a_u = \frac{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_{u,0}}}{\frac{1}{\alpha} + \frac{s_u}{\lambda_E}}$$

$\alpha = 10,8 \text{ W}/(\text{m}^2 \cdot \text{K});$
 $\lambda_{u,0} = 1 \text{ W}/(\text{m} \cdot \text{K});$
 $s_{u,0} = 0,045 \text{ m};$

$= f(T)$

a_{WL} is the heat conduction factor $a_{WL} = f(K_{WL}, T, D)$

$$K_{WL} = \frac{s_{WL} \cdot \lambda_{WL} + b_u \cdot s_u \cdot \lambda_E}{0,125}$$

a_B is the floor covering factor

$$a_B = \frac{1}{1 + B \cdot a_u \cdot a_T^{m_T} \cdot a_{WL} \cdot a_K \cdot R_{\lambda, B} \cdot f(T)}$$

$\longrightarrow 1 + 0,44 \sqrt{T}$

type D

$$q = B \cdot a_B \cdot a_T^{m_T} \cdot a_u \cdot \Delta\vartheta_H$$

where

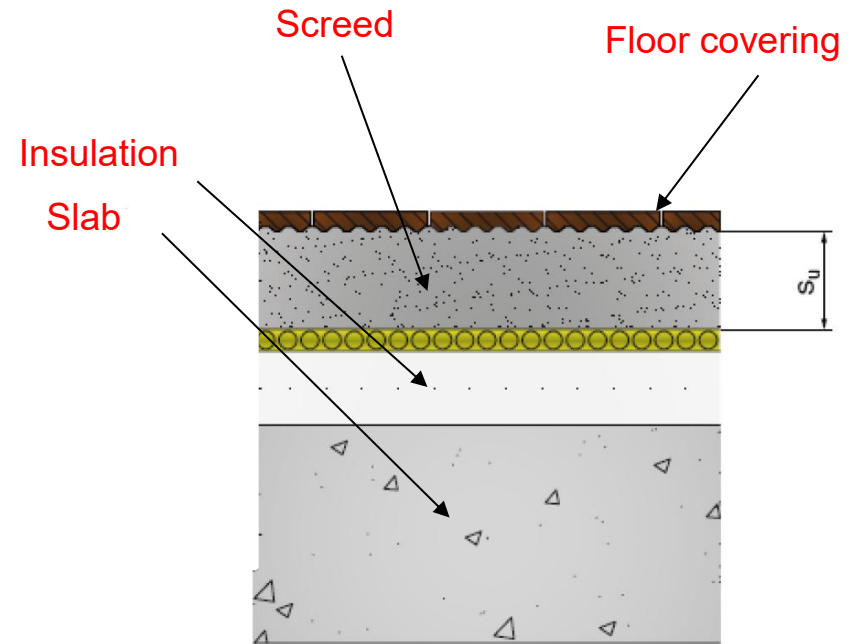
$$B = B_0 = 6,5 \text{ W}/(\text{m}^2 \cdot \text{K}) \text{ and}$$

$$a_T^{m_T} = 1,06;$$

a_u is the covering factor in accordance with Equation (12);

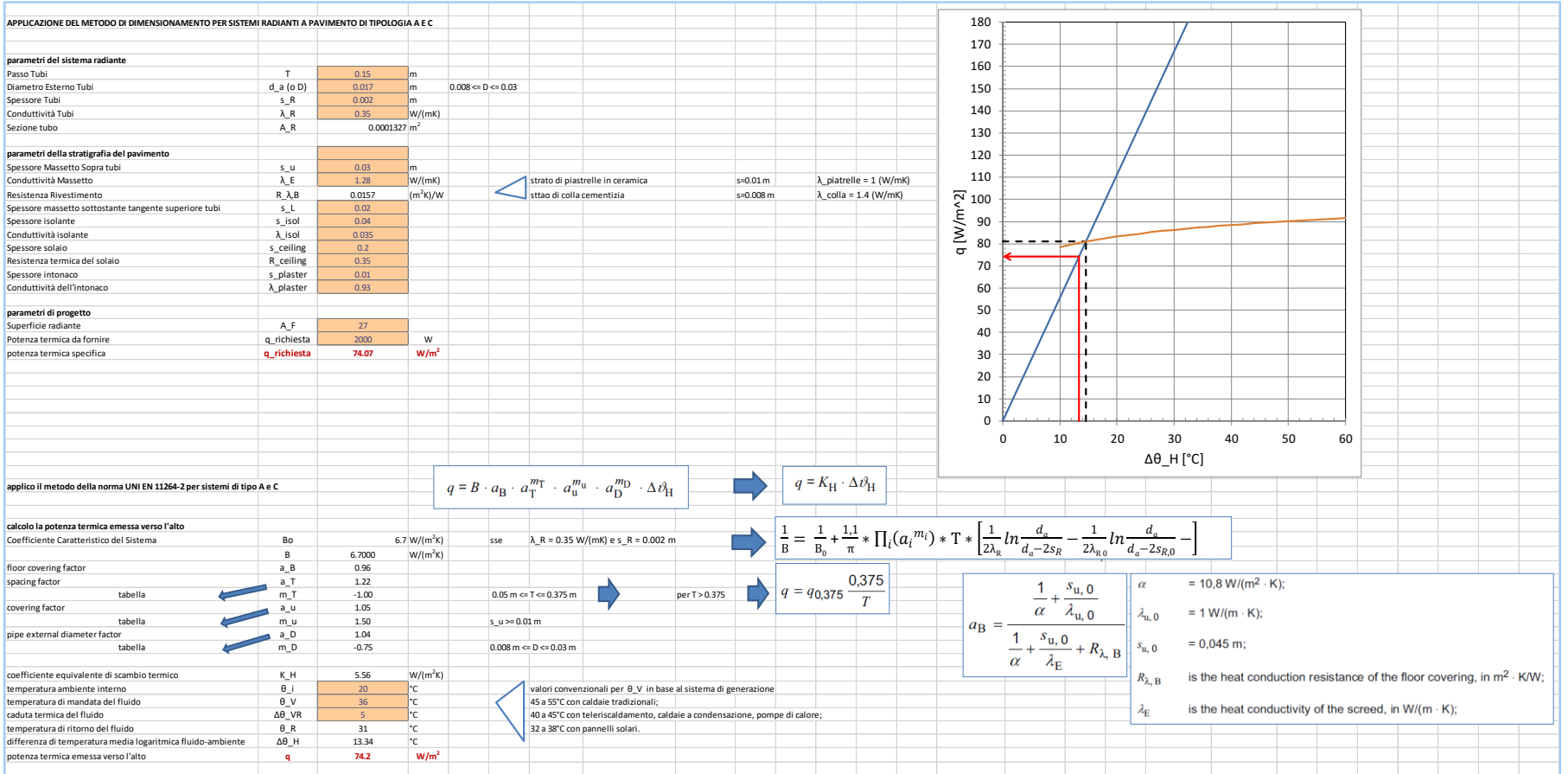
a_B is the floor covering factor:

$$a_B = \frac{1}{1 + B \cdot a_u \cdot a_T^{m_T} \cdot R_{\lambda, B}}$$



$$a_u = \frac{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_{u,0}}}{\frac{1}{\alpha} + \frac{s_u}{\lambda_E}}$$

Excel tool



Downward Heat Losses

- The downward specific heat loss towards rooms under the radiant heating system is calculated with the following equation:

$$q_U = \frac{1}{R_U} (R_0 * q + \theta_i - \theta_U)$$

where:

q_U downward specific heat loss

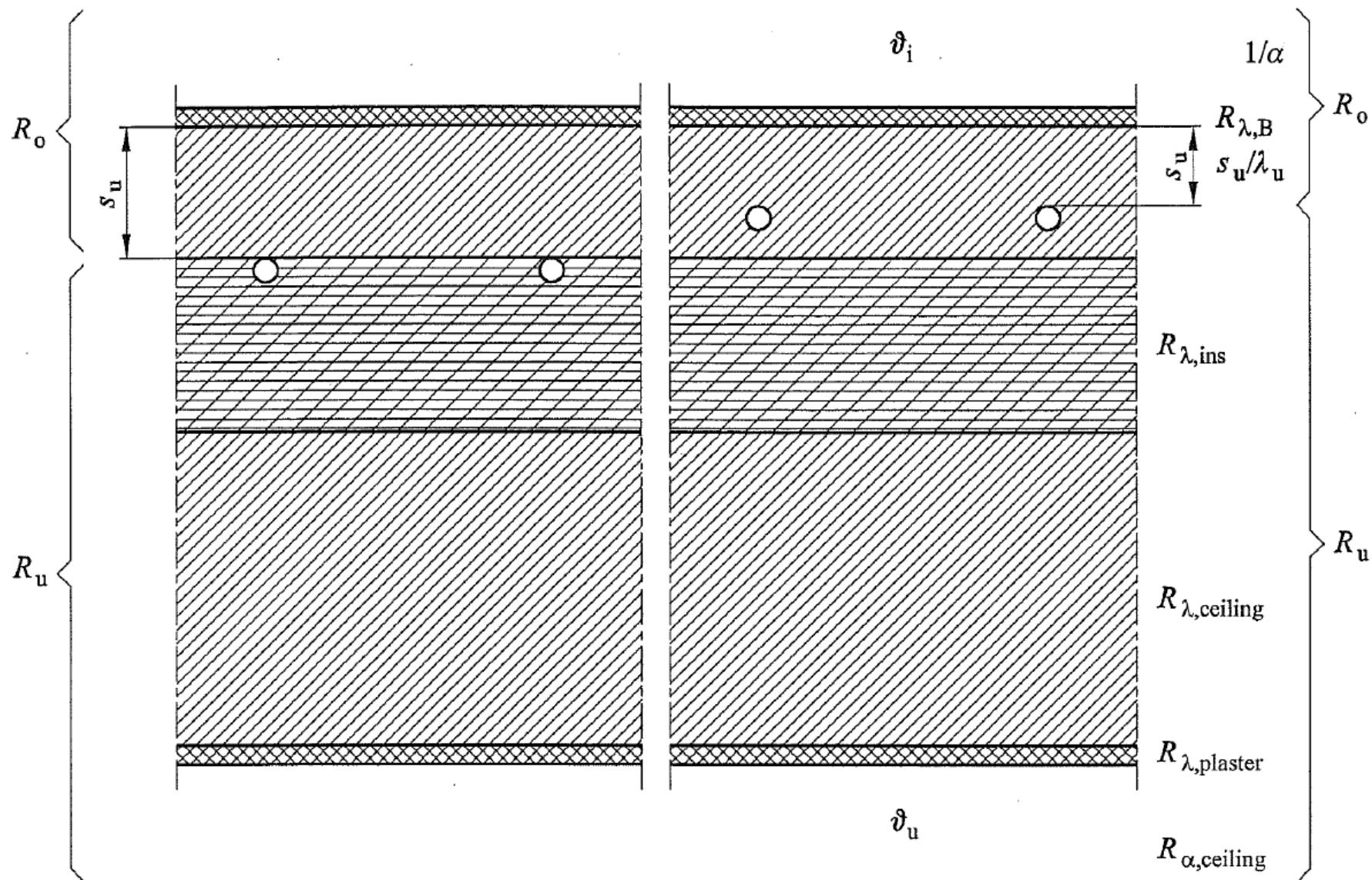
q specific thermal output of the floor heating system

R_U downwards partial heat transmission resistance of the floor structure

R_0 upwards partial heat transmission resistance of the floor structure

θ_i standard indoor room temperature of the floor heated room

θ_U indoor room temperature of a room under the floor heated room



type B

type A and type C

- Upwards partial heat transmission resistance of the floor structure

$$R_0 = \frac{1}{\alpha} + R_{\lambda,B} + \frac{s_U}{\lambda_U}$$

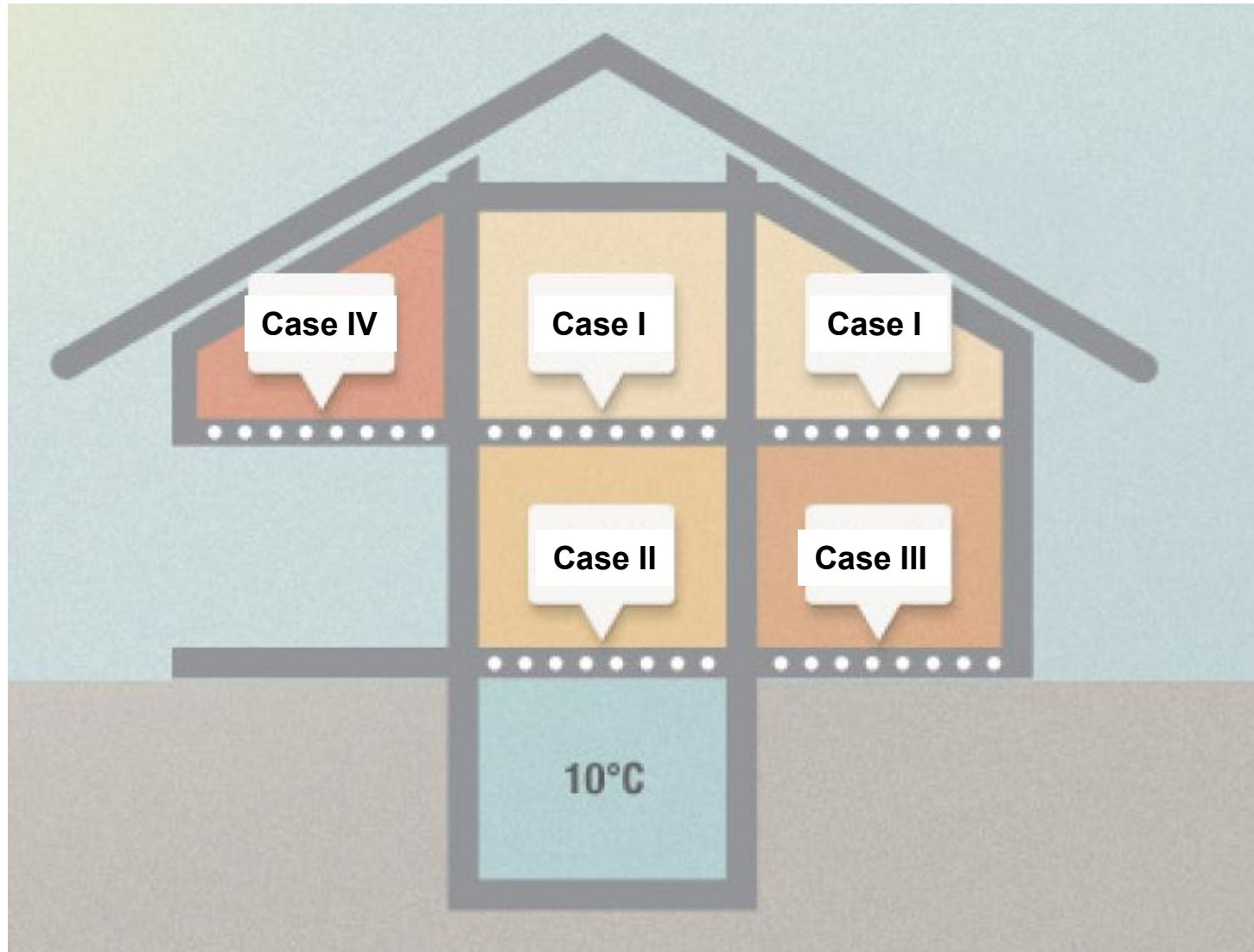
$$1/\alpha = 0.0926 \frac{m^2K}{W} \quad \text{con} \quad \alpha = 10.8$$

- Downwards partial heat transmission resistance of the floor structure

$$R_U = R_{\lambda,ins} + R_{\lambda,ceiling} + R_{\lambda,plaster} + R_{\alpha,ceiling}$$

$$1/\alpha = 0.17 \frac{m^2K}{W} \quad \text{con} \quad \alpha = 5.9$$

Thermal Insulation



Case	Boundary condition below	Th. Resist. [W/(m ² K)]	Minimum required thickness [mm]		
			k = 0.025 W/(m K)	k = 0.035 W/(m K)	k = 0.040 W/(m K)
I	Heated room	0,75	19	27	29
II / III	Unheated or ground	1,25	31	44	50
IV	Outdoor temp. >0°C	1,25	31	44	50
IV	-5°C < outdoor temp. < 0°C	1,50	38	53	60
IV	-15°C < outdoor temp. < -5°C	2,00	50	70	80

Design of the Water Flow Rate

- The total heat flow of the system is the sum of the thermal output of the system (q) and the downwards heat loss (q_U).
- The design water flow rate can be calculated with the following equation:

$$m_H = \frac{A_F \cdot q}{\sigma \cdot c_W} \cdot \left(1 + \frac{R_o}{R_u} + \frac{\vartheta_i - \vartheta_u}{q \cdot R_u} \right)$$