**REHVA**

# Federation of European Heating, Ventilation and Air-conditioning Associations

**Address:**
**Rue Washington 40**
**1050 Brussels**
**Belgium**

- **www.rehva.eu**
- **info@rehva.eu**
- **Tel:  +32 2 514 11 71**
- **Fax: +32 2 512 90 62**

# Use of REHVA Guidebook Power Point Presentations

- **This Power Point Presentation can be freely used for training purposes by REHVA members.**

- **It is prepared by the main author to the REHVA Guidebook.**

- **Please refer the original author always when making the presentation.**

- **Inform REHVA secretariat each time the presentation is used: info@rehva.eu**

REHVA

Federation of European Heating, Ventilation and Air-conditioning Associations

# REHVA Guidebook No 7:
# Low temperature heating and high temperature cooling
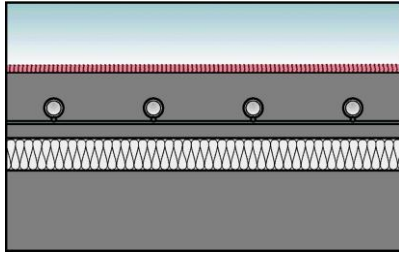
**Jan Babiak**

**Bjarne W. Olesen**
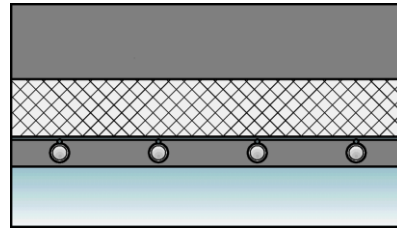
**Dusan Petras**

# List Of Content

REHVA

# 1. Terminology

- **Embedded surface heating and cooling system**
  - A system consists of circuits of pipes embedded in floor, wall or ceiling construction, distributors and control equipment

- **Embedded systems insulated from the main building structure**
  - Floor, wall and ceiling surface system thermally insulated from building structure (slabs, walls)

- **Floor (wall, ceiling) heating and cooling system, water based**
  - Floor (wall, ceiling) system where pipes carrying water with or without additives as a medium are laid in the floor (wall, ceiling)

- **Thermally-Active Building System, TABS**
  - Surface heating and cooling systems with pipes thermally coupled and embedded in the building structure (slabs, walls)

- **Radiant ceiling panels, heating and cooling**
  - Suspended, usually metal panels distant under the ceiling with fluid temperature relative close to room temperature. May be insulated from building structure (slabs)
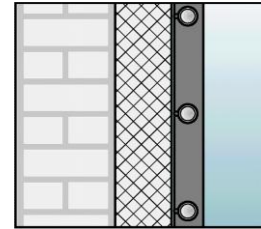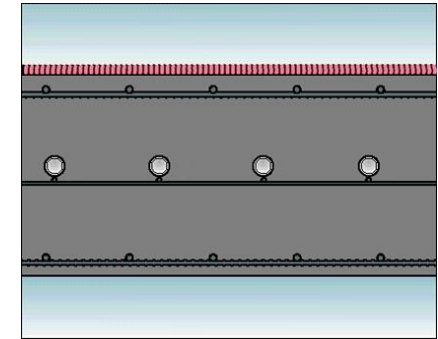
# Type of systems

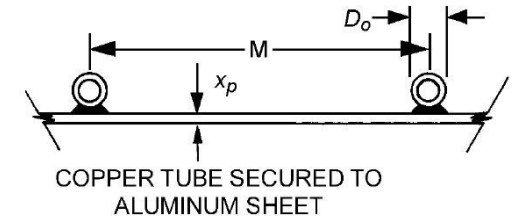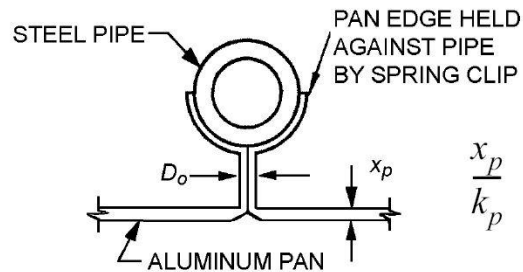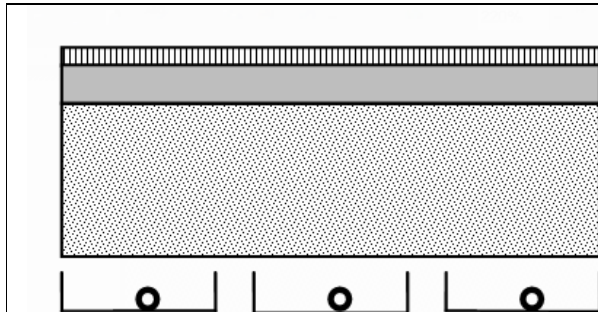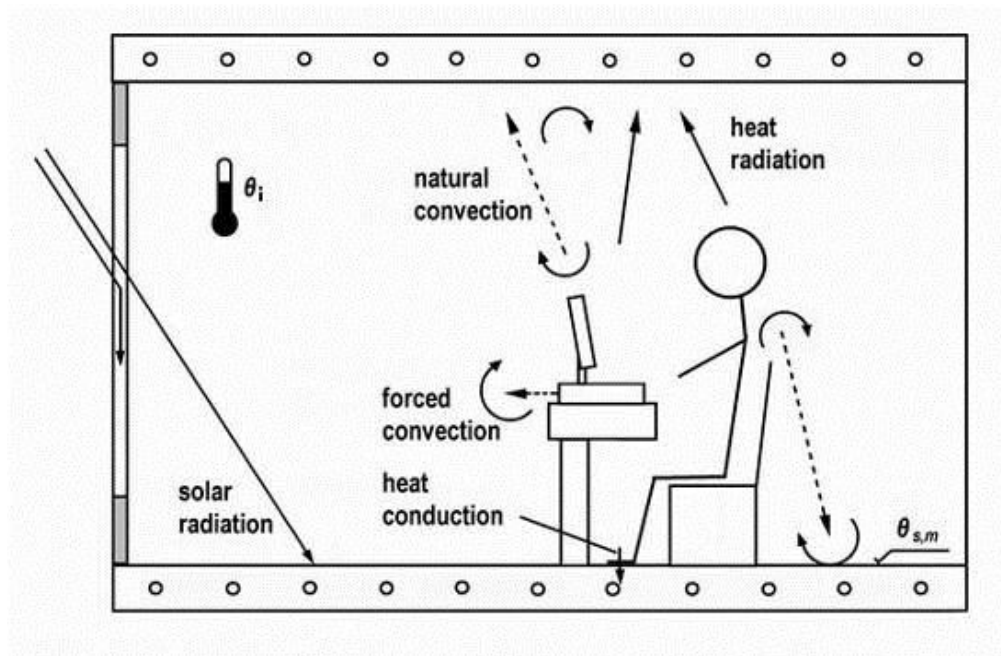

| a | b | c | d |

Figure 4.1 - Examples of water based radiant systems

# 2. Basic principles

**- Three Physical mechanisms of Heat transfer**
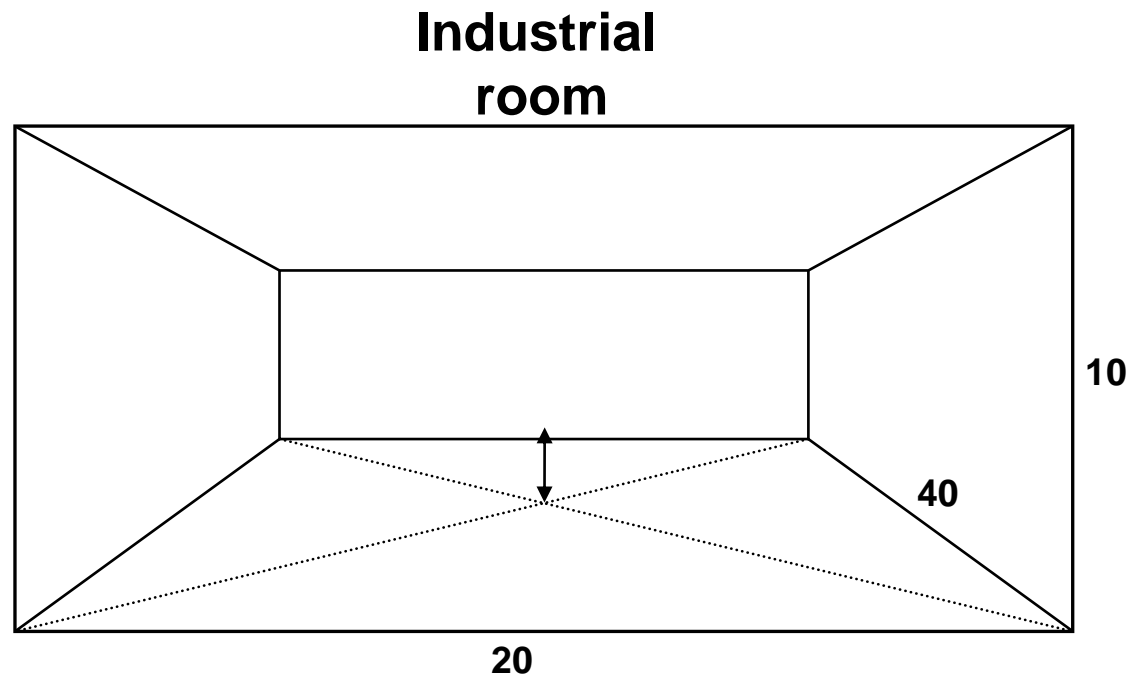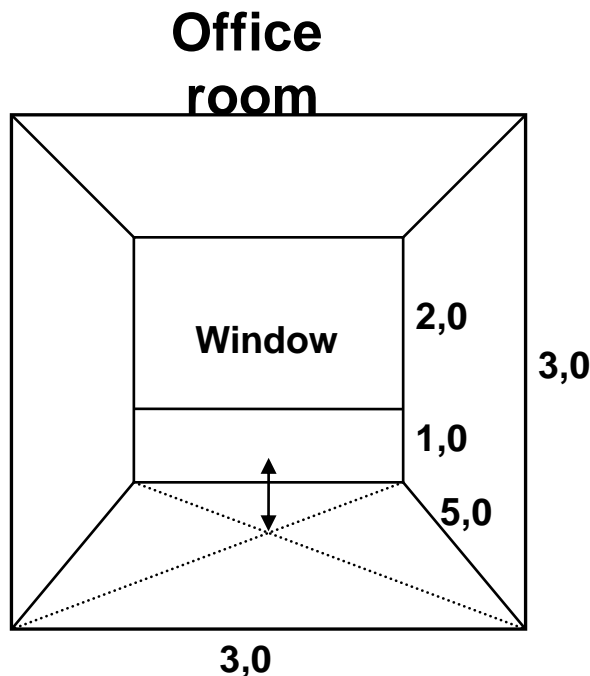
**- Convection, conduction, radiation**



**- Thermal balance of a room with radiant surface heating/cooling**

# 2. Basic principles

**Heat exchange:**

**- View and angle factor – two examples:**

**Office room**

**Industrial room**



Window

2,0

3,0

1,0

5,0

3,0

10

40

20

# 2. Basic principles

## Angle factor – typical values:

| Surface | Angle factor $F_{p-N}$ | | | |
| | office room | | industrial room | |
| | Seated | Standing | Seated | Standing |
|---|---|---|---|---|
| floor | 0,32 | 0,24 | 0,48 | 0,48 |
| ceiling | 0,12 | 0,12 | 0,22 | 0,22 |
| front wall (win) | 0,03 | 0,04 | 0,03 | 0,03 |
| window | 0,06 | 0,06 | - | - |
| back wall | 0,09 | 0,10 | 0,03 | 0,03 |
| right side wall | 0,19 | 0,22 | 0,12 | 0,12 |
| left side wall | 0,19 | 0,22 | 0,12 | 0,12 |

# 3. Indoor environmental conditions

**Thermal Environment**

- **Operative Temperature**

- **Surface Temperature (Wall, floor, ceiling)**

- **Vertical Air Temperature Difference**

- **Radiant Temperature Asymmetry**

- **Draft – Air velocity**

    – Calculation of down draft from cold surfaces

**Indoor Air Quality**

**Air temperature and Humidity**

**Acoustic Comfort and Noise**

# 4. Types of systems, heating cooling capacity

**- Heat exchange coefficient between surface and space**

**Radiant heating and cooling panels**

**Pipes isolated from main building structure**

**Thermo Active Building Systems (TABS)**

- **System description**

- **Heating and cooling capacity**

- **System testing**

- **Dynamic capacity calculations**
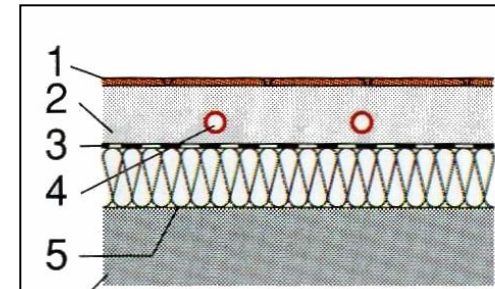
# 4. Types of systems, heating cooling capacity

## Heat exchange coefficient between surface and space

| | | Total heat exchange coefficient W/m².K | | Acceptable surface temperature °C | | Maximum capacity W/m² | |
|---|---|---|---|---|---|---|---|
| | | Heating | Cooling | Max. Heating | Min. Cooling | Heating | Cooling |
| Floor | Perimeter | 9-11 | 7 | 35 | 20 | 165 | 42 |
| | Occupied Zone | 9-11 | 7 | 29 | 20 | 99 | 42 |
| Wall | | 8 | 8 | ~40 | 17 | 160 | 72 |
| Ceiling | | 6 | 9-11 | ~27 | 17 | 42 | 99 |

# Types of systems, EN 15377

**Pipes isolated from main building structure**

**A - System with pipes embedded in the screed or concrete**

**B - System with pipes embedded outside of the screed**

**C - System with pipes embedded in the screed**

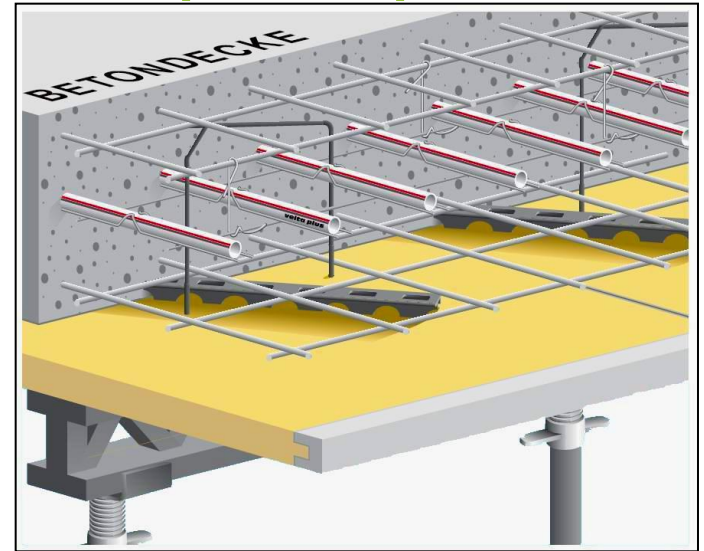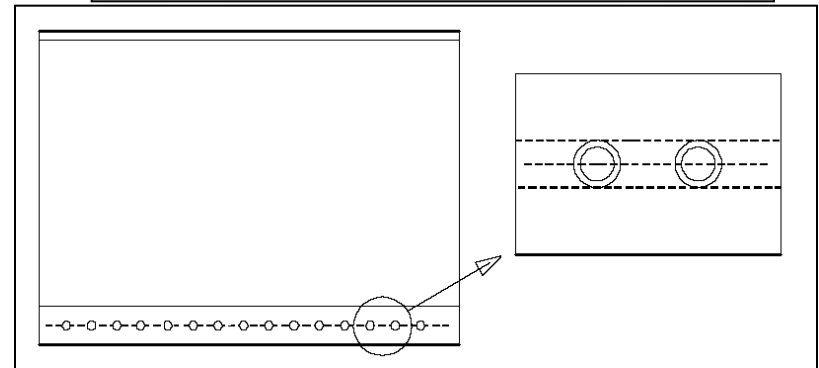**D – Plane section systems**



Typ A

Typ B

Typ C

Type D

# Types of systems, EN 15377

**Thermo Active Building Systems (TABS)**

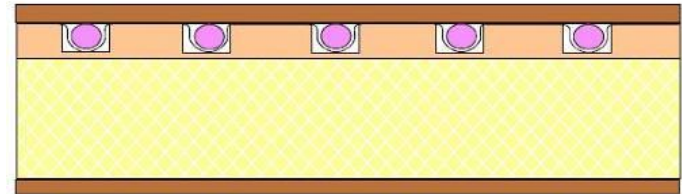**E - System with pipes embedded in the massive concrete slabs**
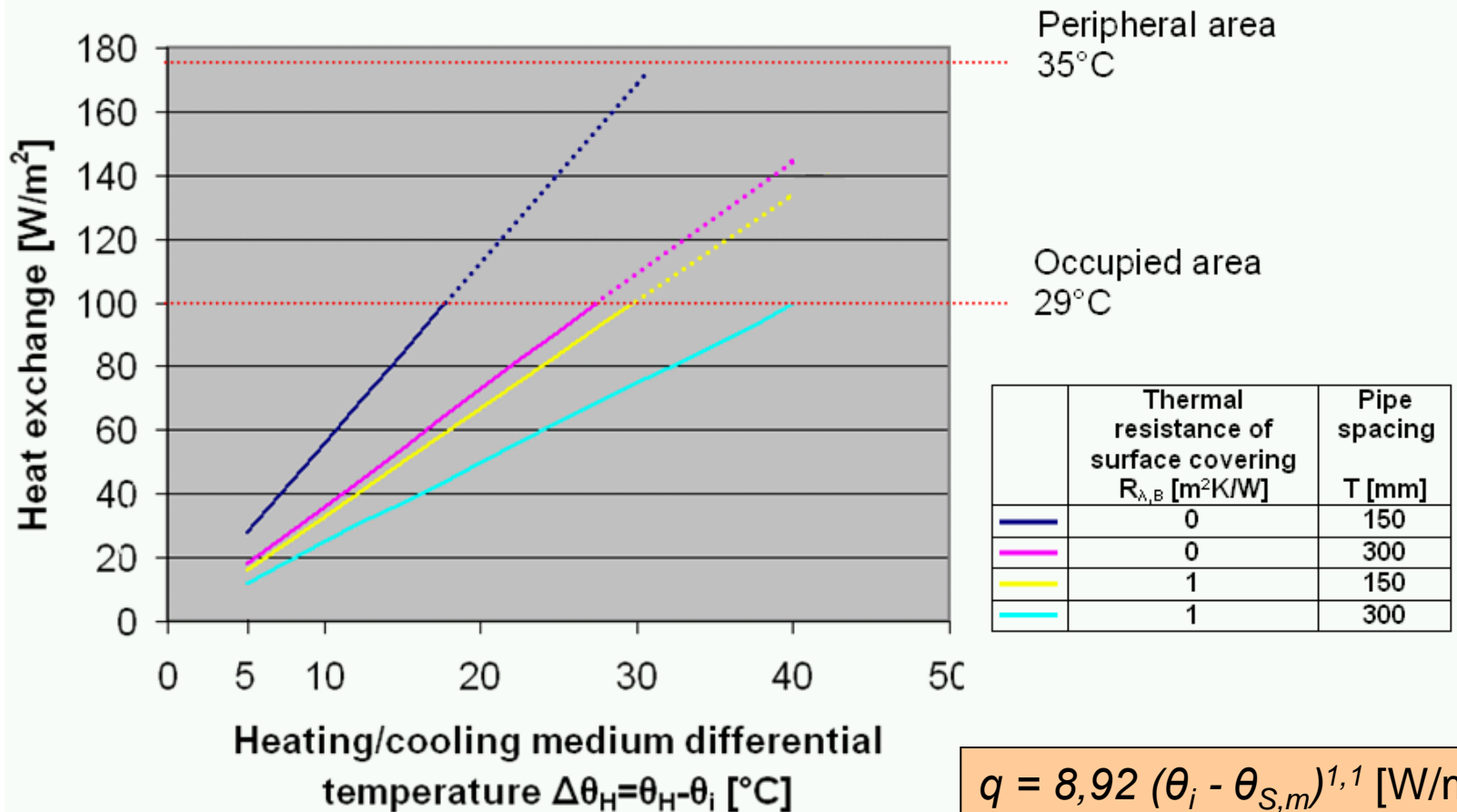
**F - Capillary pipes embedded in a layer at the inner surface**

# Types of systems, EN 15377

## G - System with pipes embedded in the a wooden construction

# 4. Types of systems, heating cooling capacity

**Floor Heating**



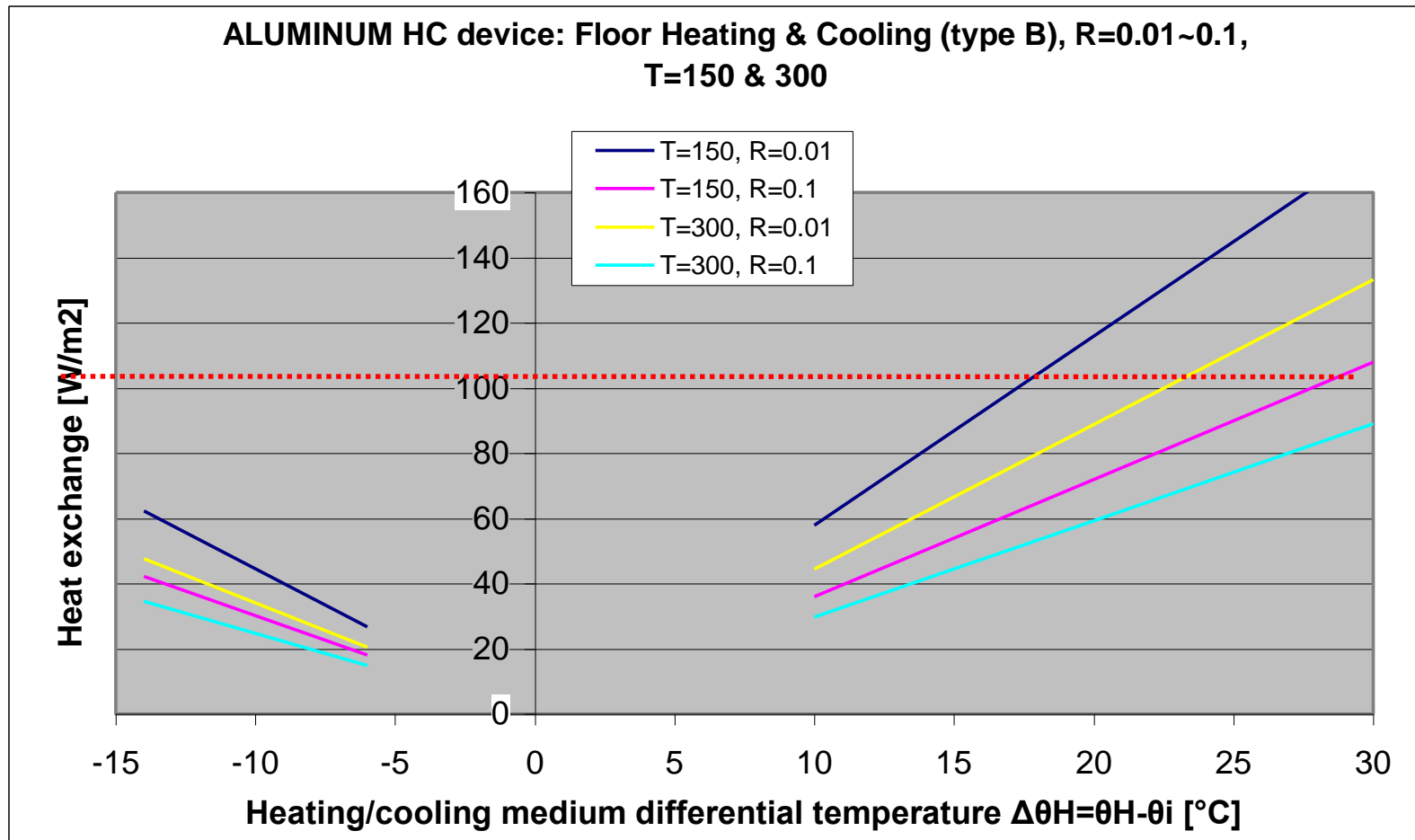$q = 8,92 \, (\theta_i - \theta_{S,m})^{1,1} \; [W/m^2]$

Figure 4.17 Heat exchange between the surface (with ceramic tiles, wooden parquets or carpet $R_{\lambda B}=0.1$ and no covering $R_{\lambda B}=0$) and the space when aluminium heat conductive device used

# Heating/ cooling capacity

## Standard method (EN1264), Types A, B, C, D

### - Universal single power function

$$q = B \cdot \prod_i (a_i^{m_i}) \cdot \Delta T_H$$

$B$ — - system-dependent coefficient in W/(m²K)

$\prod_i (a_i^{m_i})$ — - power product

$\Delta \theta_H$ — - heating/cooling differential temperature

**Power product ≈ f (floor covering, pipe distance, diameter, vertical position)**

$$\Delta \theta_H = \left| \frac{\theta_V - \theta_R}{\ln \frac{\theta_V - \theta_i}{\theta_R - \theta_i}} \right|$$

$\Delta \theta_H$ — - Supply water temperature

$\Delta \theta_H$ — - Return water temperature

$\Delta \theta_H$ — - Room air temperature

# Heating/ cooling capacity

## Standard method (*EN15377*), for Types E, F

## - Thermal resistance method Layouts
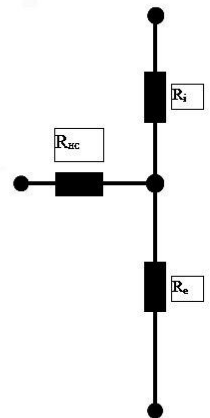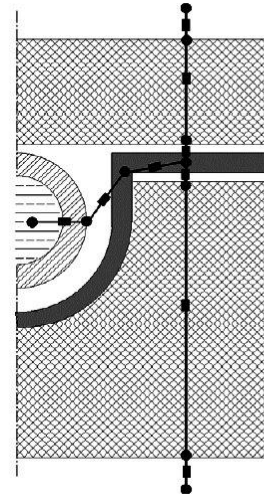
### Type E:



### Type F:

# Heating/ cooling capacity, EN 15377

## Standard method (EN 15377), for Types G

### - Thermal resistance method (prEN 15377-1)

$$R_{HC} = T.R'_R + T.R'_{R,con} + T/2 . R'_U + R_{CL}$$



$R_{CL}$     *Fictive thermal resistance of the conductive layer*

$R'_U$     *Resistance in U-profile of the heat-conducting device*

$R'_{R,con}$     *Thermal contact resistance between the conducting plate and the heating pipe*

$R'_R$     *Total thermal resistance through the pipe wall*

REHVA

Figure 4.21 Heat exchange between the surface (with ceramic tiles, wooden parquets or carpet and no covering) and the space when steel heat conductive device used. Thermal insulation of 3cm from back side.

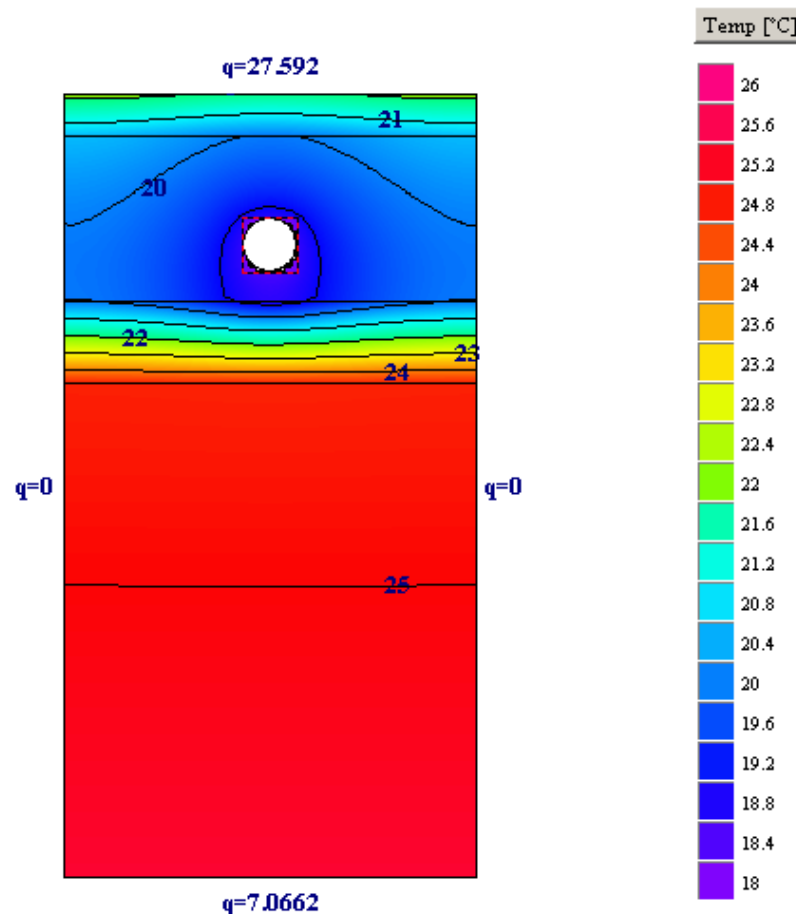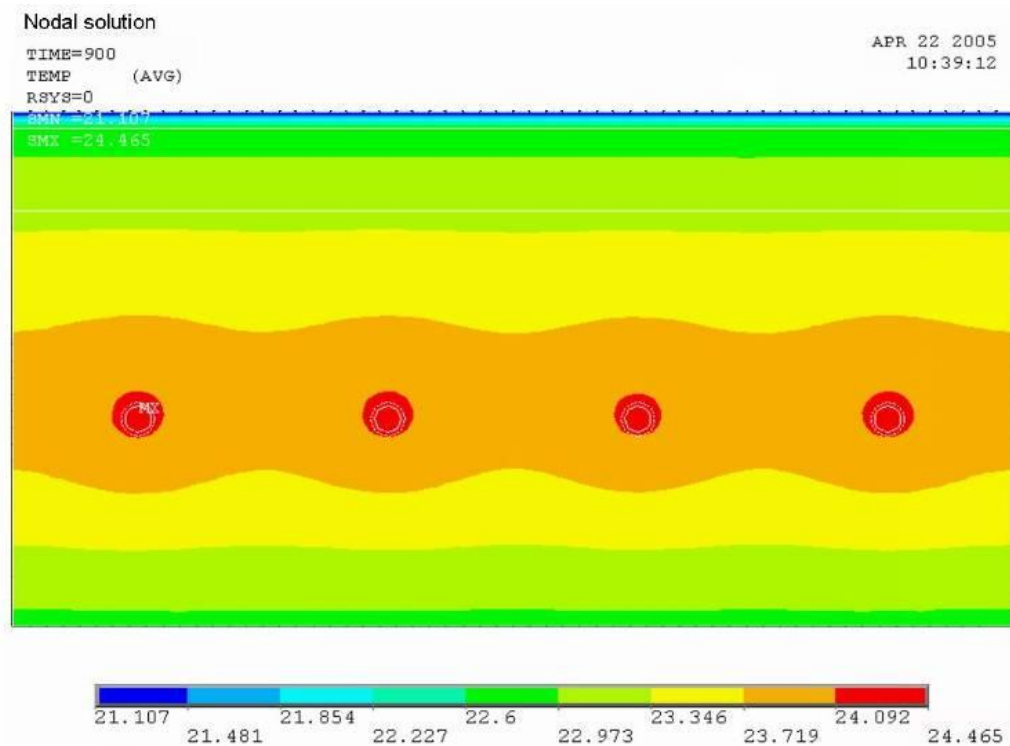# Method for verification of FEM and FDM calculation programs



**Structure S 4**

q=0   q=0

**MATERIAL**

**floor covering**
$\lambda = 0.23 \dfrac{W}{m\,K}$
s = 0.015 m

**screed**
$\lambda = 1.2 \dfrac{W}{m\,K}$
s = 0.06 m

**thermal insulation**
$\lambda = 0.04 \dfrac{W}{m\,K}$
s = 0.03 m

**concrete**
$\lambda = 2.1 \dfrac{W}{m\,K}$
s = 0.18 m

REHVA

# Method for verification of FEM and FDM calculation programs
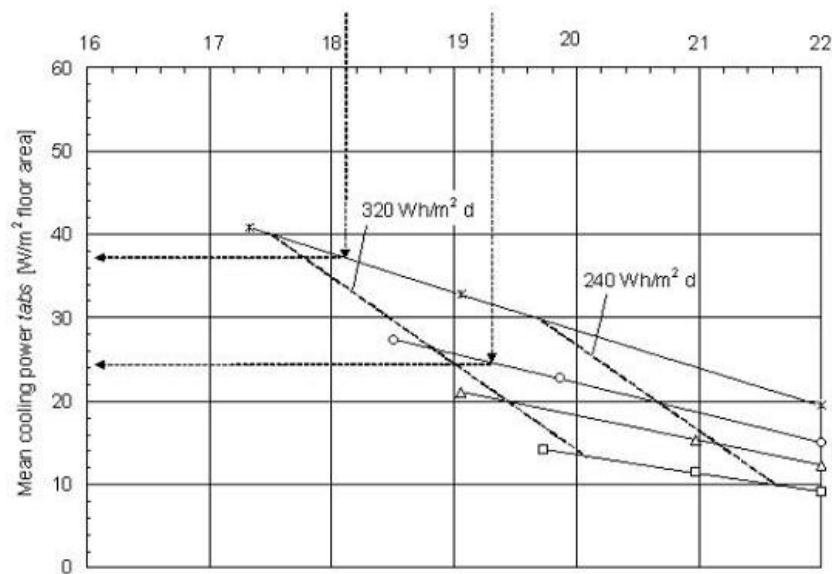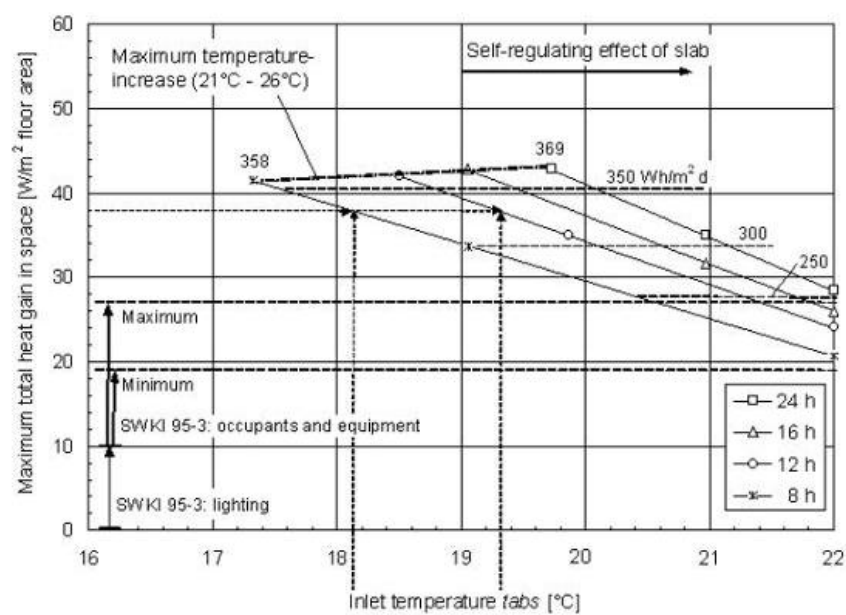
# Finite Elements Calculations-EN15377

Figure 5 – Working principle of TABS

# 5. Control and operation

*General description, Classification (EN12828)*

- **Local, Zone, Central**
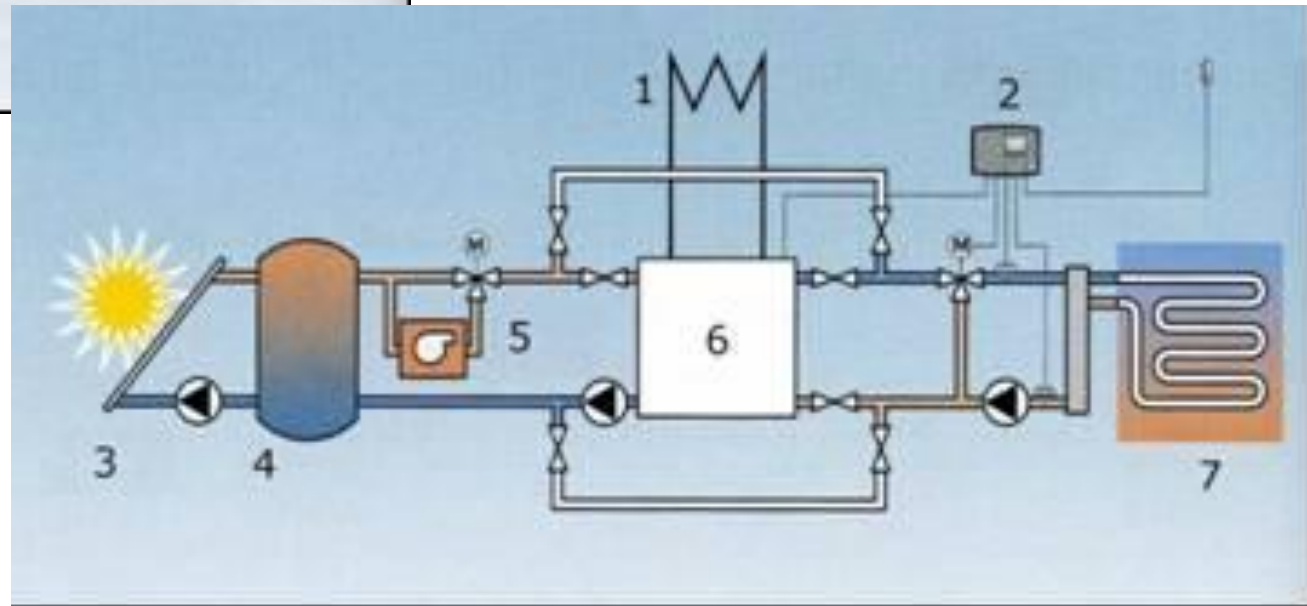
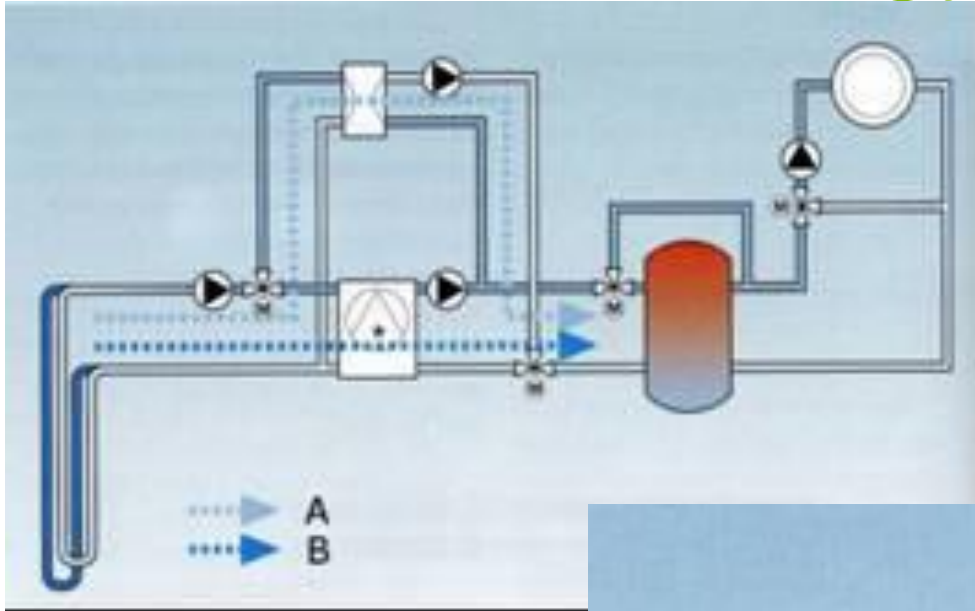- **Manual, Automatic, Timing function**

*Radiant Heating System Controls - principles*

- **Time delay**

- **The duty cycle**

- **Self-regulating effect**

*Radiant Cooling System Controls - principles*

*TABS controls*
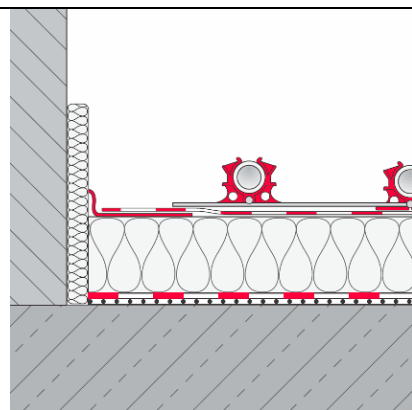
# 6. Energy sources

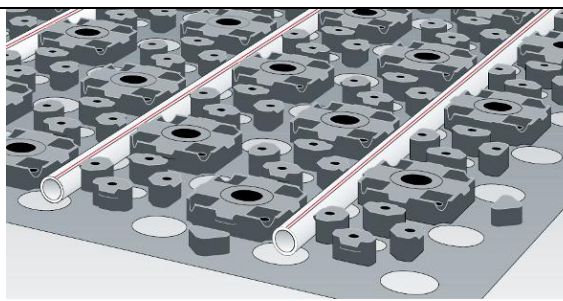Figure 7.1 a Construction type A, holder 1



Figure 7.1 b Construction type A, holder 2
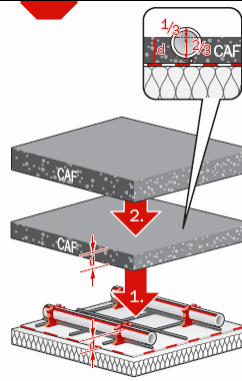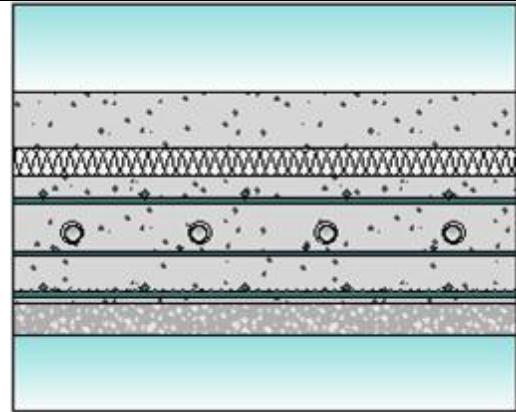


Figure 7.1 c Construction type A, holder 3





Figure 7.1 d Construction type F

# 7. Installation

# 8. Safety

*Durability of the system*

- Durability of plastic pipes

- Water Pipes Leakage

- Ventilation Ductwork/pipe system  Leakage

*Indoor environment impact*

- Hand Burning

- Physical Injury

# 9. Application in buildings

**Residential buildings**

**Single family houses, Apartments**

**Offices**

**Educational facilities**

**Sports facilities**

**Swimming pool, Sport hall,**

**Football and Ice-hockey Stadiums,**

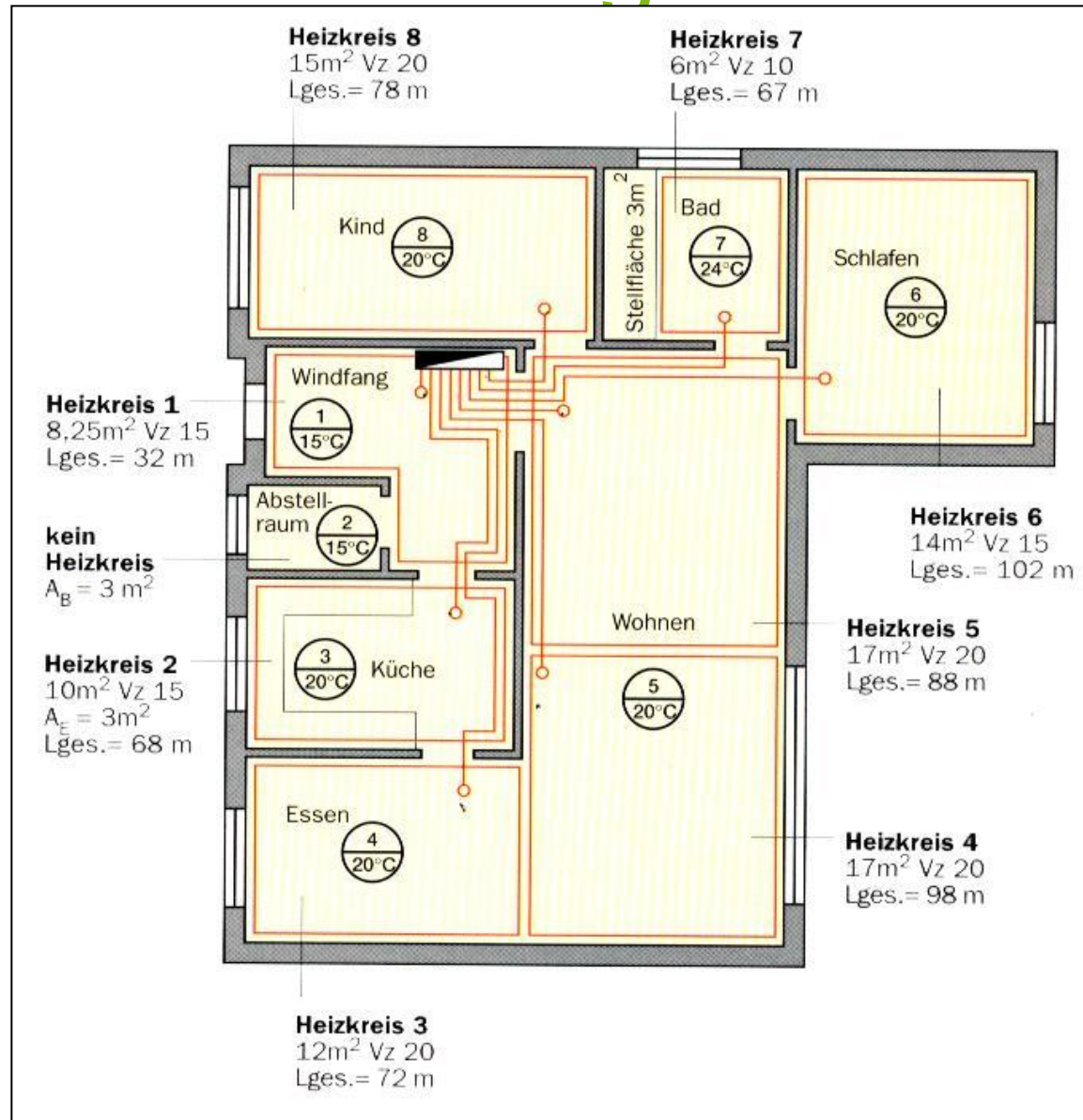**Industrial buildings**

**Storage places, hangars**

**Other public buildings**

**International Airport Bangkok**

# Residential buildings
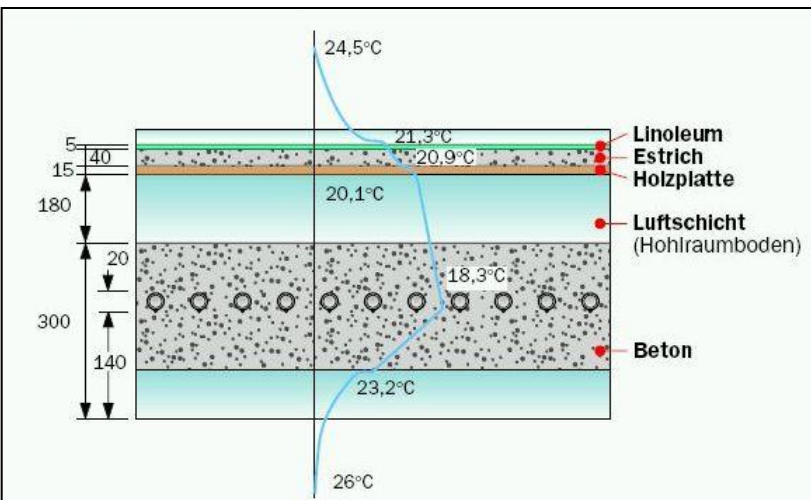
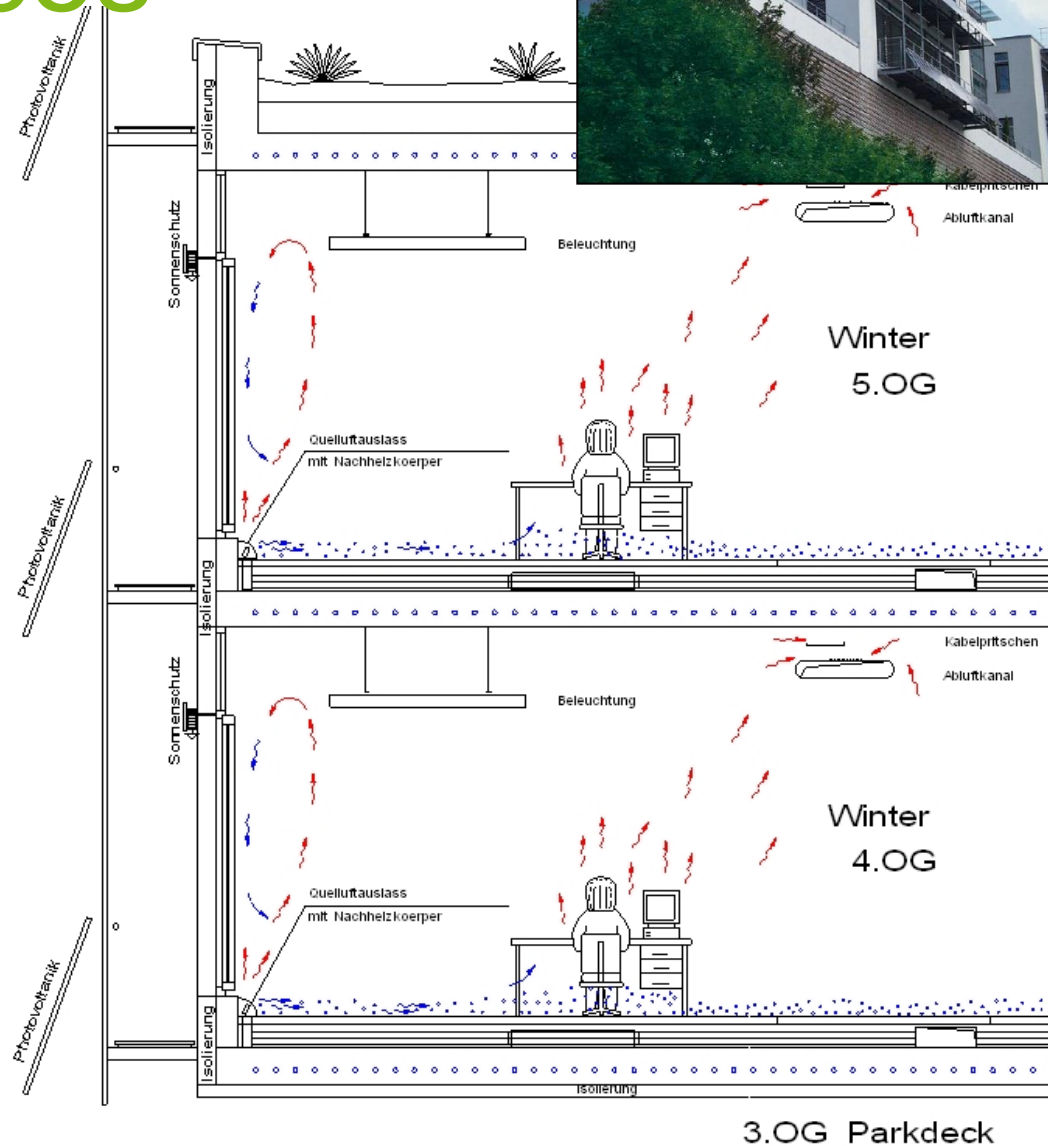- **Floor surface systems**

- **Single family houses**

- **Apartments**

# Offices

**M+W Zander**

**Stuttgart, Germany**

- **TABS –**

    **- in 6.500 m²**

# Museums



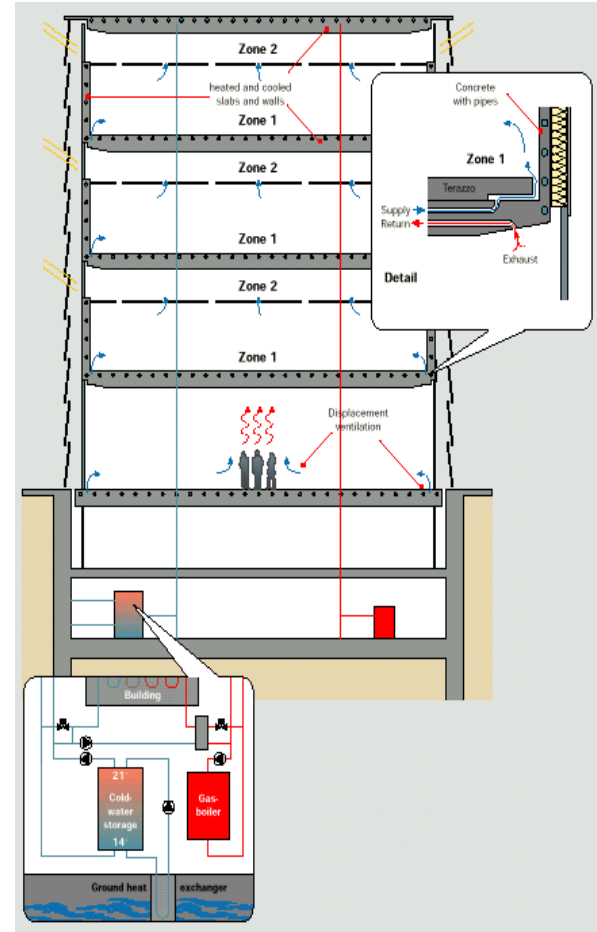Figure 9.16 a Art museum Bregenz [18]



Figure 9.16 b HVAC systems with TABS in walls and concrete slabs for heating and cooling, Details show the displacement ventilation and the heat source/sink for cooling and heating [18]

# Educational facilities



- *Sports Academy, Munich, D*

- **Floor heating - in 22,500 m²**
  1. Sport halls
  2. Seminar
  3. Overnight stay
  4. Leisure and utility area
  5. Sport free areas
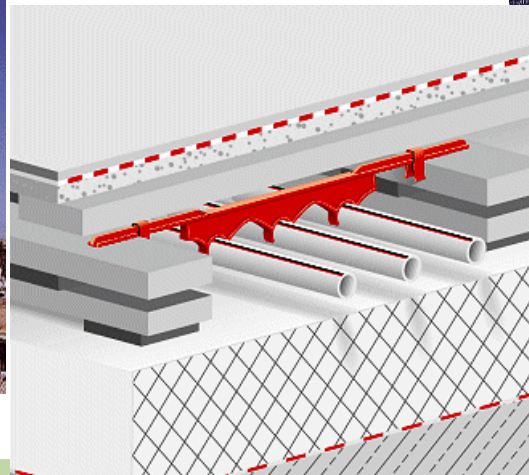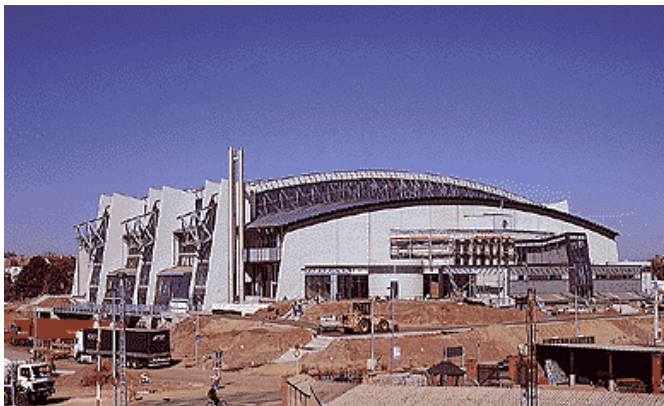
# Sports facilities

**Floor surface systems**

- **Swimming pools**


- **Sprung floor - 1.800 m²**

**Hall in Magdeburg, Germany**

# Sports facilities



Ice area
Cooling layer
Thermal insulating layer
Heating (tempering)
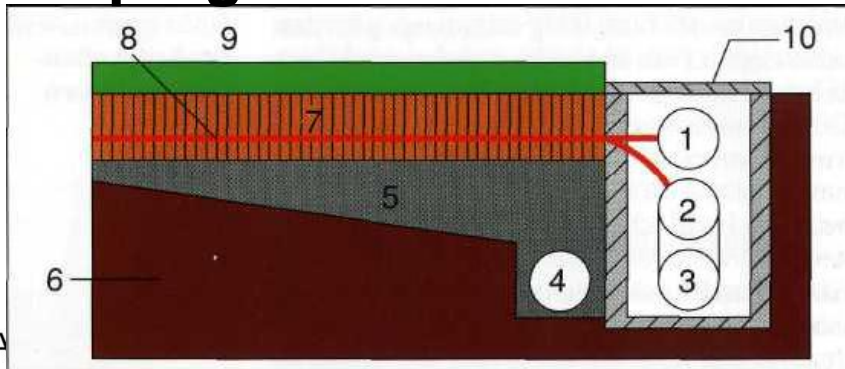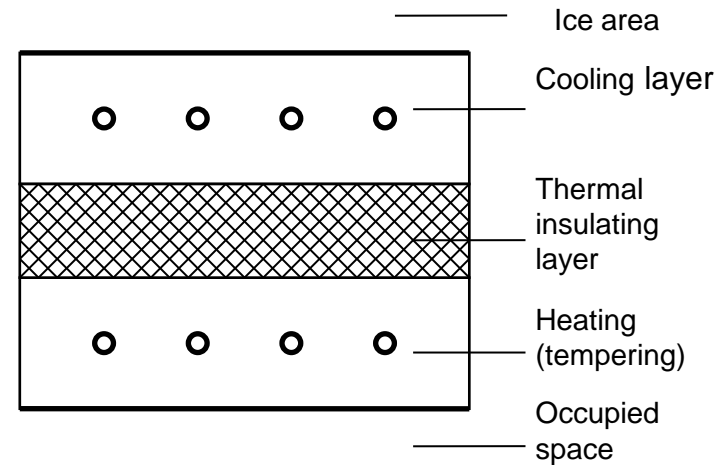Occupied space

## Ice ice-hockey arena

**Low temperature ice cooling –**

**- Low temperature heating (tempering)**





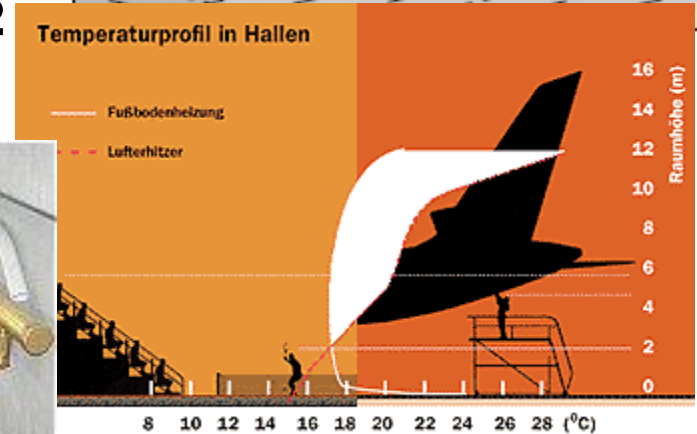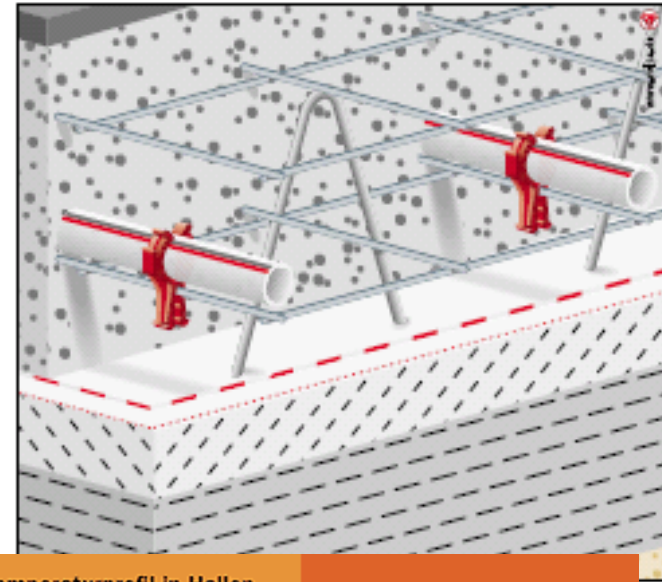## Lawn heating/ Football stadiums

**- keeping clear from snow & ice**







REHVA

# Industrial buildings

**Storage places, hangars**

**-  AIRBUS, Hamburg**

**floor heating - 20,000 m²**



Temperaturprofil in Hallen

Fußbodenheizung

Lufterhitzer

# Airports

## International Airport Bangkok

## - Floor heating / cooling – 150.000 m²

# 10. Design Tools

- **Steady state analysis**
  - EN15377-1 and 2
  - Calculation algorithms
  - FEM-FDM

- **Dynamic**
  - EN15377-3
  - Computersimulations
  - FEM-FDM

# Thank you for your attention

To order the REHVA guidebooks :
www.rehva.eu / section Bookstore
or through your national member