Cumhuriyet Üniversitesi Fen Fakültesi
Fen Bilimleri Dergisi (CFD), Cilt:36, No: 4 Özel Sayı (2015)
ISSN: 1300-1949

Cumhuriyet University Faculty of Science
Science Journal (CSJ), Vol. 36, No: 4 Special Issue (2015)
ISSN: 1300-1949

# BUILDING ENVIRONMENT DESIGN - DESIGN, INSTALLATION AND CONTROL OF EMBEDDED RADIANT HEATING AND COOLING SYSTEMS

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Received: 22.03.2015; Accepted: 29.05.2015

**Abstract.**The purpose of establishing standard is to determine methods and situation to provide heating flow based on water and cooling and heating systerm toward differnce temrature for systems. Determining temprature performance of water based on cooling and heating system and its conicidence with this standard is done by estimating dimension of planand a model. Therefore, integrated evaluation and estimation of water based on cooling and heating system is possible.

Surface tempreture and integration of heating surface tempreture /cooled, density of nominal heat between water and space, average difference temprature related to nominal and specified diagrams for relationship between heating density and variables determination are provided as results.

**Keywords:** Building Environment, Dimension, Embedded Heating and Colling Systems

## INTRODUCTION

This study consists of a general method based on limited difference methods and limited elements and simple estimated methods based on situation of pipes and kind of building structure.

This study is applied for the water based cooling and heating systems in the residents, commercial and industrial building. The methods in the integrating systems in the wall, surface or ceiling of the building is applied without any open crack and is not applied in the panel systems with air open cracks which are not integrated in the building.

These results are applied fot other flow except water as heating or cooling environment and is not applied for testing. The methods are not applied for panels or heated or cooled ceiling beams.

Necessary documents consist of regulations which are referred to in the Iran national standard context.In this study, definitions related to ISO 11855-1 standard is used.Also, In the present study, the symbols in table 1 were applied.

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*Special Issue:* Technological Advances of Engineering Sciences

**Table 1.** Symbols and Abbreviations.

| Unit | Symbol | Quantity |
|---|---|---|
| – | $a_i$ | Parameter factors to calculate the characteristic curves |
| $m^2$ | $A_A$ | The occupied area |
| $m^2$ | $A_F$ | The surface area of the heating / cooling |
| $m^2$ | $A_R$ | The periphery |
| – | $b_u$ | Depending on the distance factor calculated pipe |
| W /($m^2$.K) | $B, B_G, B_O$ | Coefficients depending on the system. |
| m | $D$ | The outer diameter of the pipe, including special materials wherever prescribed coverage |
| m | $d_a$ | The outer diameter of the tube |
| m | $d_i$ | Internal diameter of pipe |
| m | $d_M$ | Specific heat capacity of water |
| kj/(kg.K) | $c_W$ | The overall heat transfer coefficient (convection + radiation) between surface and space |
| W /($m^2$.K) | $h_t$ | Heat transfer coefficient |
| W /($m^2$.K) | $k_H$ | The parameter for the heat-conducting material |
| – | $K_{WL}$ | The parameter for the heat-conducting material |
| – | $k_{CL}$ | The parameter for the heat conductive layer |
| $m$ | $L_{WL}$ | The width of the heat-conducting material |
| $m$ | $L_{fin}$ | Blade width (the horizontal part by conducting heat as a heating blade) |
| m | $L_R$ | Length of pipe installed |

**Table 1.** Continued.

| Unit | Symbol | Quantity |
|---|---|---|
| – | $m$ | Ability to determine the characteristic curves |
| kg/s | $m_H$ | Design average flow rate of heating / cooling |
| – | $n, n_G$ | The exponents |
| W/$m^2$ | $q$ | Heat flux on the surface |
| W/$m^2$ | $q_A$ | Heat flux in the occupied |
| W/$m^2$ | $q_{des}$ | Heat flux design |
| W/$m^2$ | $q_G$ | The heat flux |
| W/$m^2$ | $q_N$ | Nominal heat flux |
| W/$m^2$ | $q_R$ | The heat flux at the periphery |
| W/$m^2$ | $q_u$ | Heat flux to the outside |
| $m^2$.K/W | $R_O$ | The resistance of the surface structure of partial transfer of heat to the inside |
| $m^2$.K/W | $R_u$ | The resistance of the surface structure of partial transfer of heat to the outside |
| $m^2$.K/W | $R_{\lambda,B}$ | Heat resistant cover |
| $m^2$.K/W | $R_\lambda, ins$ | Heat resistance, thermal insulation |
| m | $s_h$ | The system type B, the thickness of the thermal insulation of the outer edge to the inner margin of insulation of pipes (see Figure 2) |
| m | $s_i$ | The system type B, the thickness of the thermal insulation of the inner edge to the outer edge insulation of pipes (see Figure 2) |
| m | $s_{ins}$ | Thick thermal insulation |
| m | $s_R$ | Tube wall thickness |
| m | $s_u$ | The thickness of the upper layer of the pipes |
| m | $s_{WL}$ | The thickness of the heat-conducting device |
| m | $S$ | Tape thickness (excluding pipe systems Type A) |
| m | $W$ | Distance tube |
| W/($m^2$.K) | $\alpha$ | Heat transfer coefficient |
| ℃ | $\theta_{s,max}$ | The maximum surface temperature |
| ℃ | $\theta_{s,min}$ | Low surface temperature |
| ℃ | $\theta_i$ | Internal temperature |
| ℃ | $\theta_m$ | The average temperature of the heating / cooling |
| ℃ | $\theta_R$ | The average temperature of return heating / cooling |
| ℃ | $\theta_V$ | Average supply temperature heating / cooling |
| ℃ | $\theta_u$ | The internal temperature of the surrounding environment |
| K | $\Delta\theta_H$ | The difference between the average temperature of the heating / cooling |

**Table 1.** Continued.

| Unit | Symbol | Quality |
|---|---|---|
| K | $\Delta\theta_{H,des}$ | The difference between the average temperature of the heating / cooling plan |
| K | $\Delta\theta_{H,G}$ | The difference between the average temperature of the heating / cooling |
| K | $\Delta\theta_{N}$ | The difference between the average temperature of the heating / cooling nominal |
| K | $\Delta\theta_{V}$ | The difference between average supply air temperature heating / cooling |
| K | $\Delta\theta_{V,des}$ | The difference between average supply air temperature heating / cooling plan |
| $W/(m.K)$ | $\lambda$ | Thermal conductivity |
| K | $\sigma$ | Temperature drop) $\boldsymbol{\theta_V - \theta_R}$( |
| $-$ | $\varphi$ | Conversion temperatures |
| $-$ | $\psi$ | The volume bar attached blades |

## Concept of determination method of heating and cooling capaity

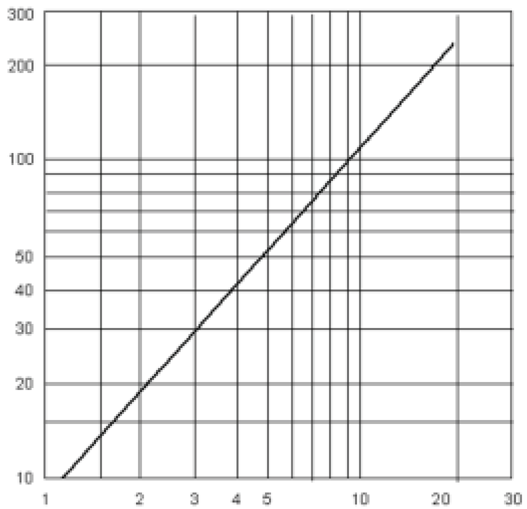
A provided surface (roofing, wall, ceiling) in the average tempreture and internal tempretures (applicative tempreture $\boldsymbol{\theta_i}$) provide equal heating charges in any space independent of any kind of the system. Therefore, it is possible to determine a basic formula or specific diagram for cooling and a basic formula or specific diagram for heating for each of surface (roofing, wall, ceiling) independent of the system and this is applied for all heating and cooling surfaces (refer to clause 6)

1.There are two methods in this standard
a.Simple estimated methods related to kind of system (refer to clause 7)
b.Limited element method and limited difference method (refer to clause 8)
4. Estimated methods in clause 7 to estimate surface tempreture (average, maximum and minimum tempreture is provided based on structure (kind of pipe, diameter of pipe, pipe distance, pipe installation, distribution layer) and structure of roofing / wall/ ceiling (covering of insulator layer, embeded air layer). Simple estimated methods for the kind of provided system and bound situation in clause 7 should be estimated. In the estimated reporting, applied estimated method should be explained clearly.
5.While simple estimated method for one kind of provided system is not available, basic estimated method using two or three dimensional limited element method or limited difference method should be applied (refer to clause 8 and index t)
Note: in addition, laboratory test (for example : EN 1264-2) maybe is used.
Determining static cooling or heating capacity is possible based on measured average tempreture in combination of environment tempreture (water) and space tempreture.

## Coefficient of heat exchange between the surface and the atmosphere

Correlation between thermal flux and average of difference temperature of surface is related to kind of surface (roofing, wall, ceiling) and the lower surface temperature or higher (heating) of atmosphere temperature.

Heating
q charge
(W/m$^2$)




Different tempreture of surface based on celvin
$(\theta_{s,m} - \theta_i)$

**Figure 1.** The basic characteristic curve for floor heating and cooling ceiling.

For floor heating and cooling ceiling in Figure 1, the density of heat flow is calculated by equation (1):

$$q = 8.92(\theta_{S,m} - \theta_i)^{1.1} \text{ (W/m}^2\text{)} \quad (1)$$

In which

$\theta_{S,m}$ Average surface temperature in degrees Celsius;

$\theta_i$ Used Nominal internal temperature in degrees Celsius

For other types of heating and cooling systems, heat flux q with Eq. (2) it results:

$$q = 8(|\theta_{s,m} - \theta_i|) \text{ (W/m}^2\text{)} \quad \text{wall heating and wall cooling} \quad (2)$$

$$q = 6(|\theta_{s,m} - \theta_i|) \text{ (W/m}^2\text{)} \quad \text{ceiling heating} \quad (3)$$

$$q = 7(|\theta_{s,m} - \theta_i|) \text{ (W/m}^2\text{)} \quad \text{roofing cooling} \quad (4)$$

Thermal transition coefficient is a combination of Convection and radiation.

Note: In most of building system simulation using dynamic computer models, transferring thermal to convection part (between heated surface / cooled and atmosphere) and radiation part (between heated/ cooled surface and surface of surround atmosphere) is divided. Coefficient of transferring convention heat depends on kind of surface, heating, cooling, speed of temperature or difference between surface and the air.

To use simple estimated method in appendix A, feature diagram, thermal flux is shown as a function of difference between average temperature of heating / cooling and internal temperature. For user in appendix A, not means any direct estimation is done by thermal coefficient on cooling and heating surface

Therefore, value of $\alpha$ in table A- 12 is not considered to direct estimate of thermal flux. In fact, they are prepared to convert feature diagram according to equation (A-32) in clause A-3. These estimations are based on simplifying thermal transition coefficient for ceiling heating and roofing cooling k W/m$^2$6/5 For each surface of cooling / heating system, there is a maximum thermal flux, limited thermal flux QG. This value is specific for internal temperature of $\theta_i$ room (heating 20°C and cooling 26°C) in maximum or minimum of surface level $\theta_{F,max}$ and temperature drop

$\sigma = 0$ K

In estimation, cooling or heating surface regardless kind of system, is used as reference for $\boldsymbol{\theta}_{\boldsymbol{S},\mathbf{max}}$ Average temperature of surface which specify $\boldsymbol{\theta}_{\mathbf{S},\mathbf{m}}$ density of heating folw is related to maximum or minimum tempreture of surface and $\boldsymbol{\theta}_{\boldsymbol{S},\mathbf{max}} < \boldsymbol{\theta}_{\mathbf{S},\mathbf{m}}$ و $\boldsymbol{\theta}_{\boldsymbol{S},\mathbf{min}} > \boldsymbol{\theta}_{\mathbf{S},\mathbf{m}}$ is always done.

Availability of $\boldsymbol{\theta}_{\mathbf{S},\mathbf{m}}$ depends on kind of system and function situation (temperature drop $\boldsymbol{\sigma} = \boldsymbol{\theta}_{\mathbf{V}} - \boldsymbol{\theta}_{\mathbf{R}}$, thermal flow to outside qu and thermal resistance $\boldsymbol{R}_{\boldsymbol{\lambda},\boldsymbol{B}}$)

Below presumptions forms base of thermal flux

a. Thermal transition occurs between heated or cooled surface and the atmosphere according to feature diagram.
b. Thermal drop is zero. Diagram dependence to thermal drop is determined using average of difference temperature (logarithm function) $\boldsymbol{\Delta\theta}_{\mathbf{H}}$
c. Turbulent flow in pipes $\frac{\mathbf{m_H}}{\mathbf{d_i}} > \mathbf{4000}\,\frac{\boldsymbol{kg}}{\boldsymbol{h}.\boldsymbol{m}}$
d. There is no sub- flow of heating.

7- Simplified calculation methods for determining the capacity of the heating and cooling or temperature

Two simple calculation methods can be used here as follows:

(A) A method based on the strength of a single product all relevant parameters developed finite element method (FEM);

(B) Another method is based on the calculation of equivalent thermal resistance between heating or cooling temperature and surface temperature (or room temperature).

A structure with a simple system can be calculated. The correct method to use depends on the type of system A to G (the pipes, concrete or wooden structures) and boundary conditions are listed in Table 2

**Table 2.** Criterion to select simplified estimation method.

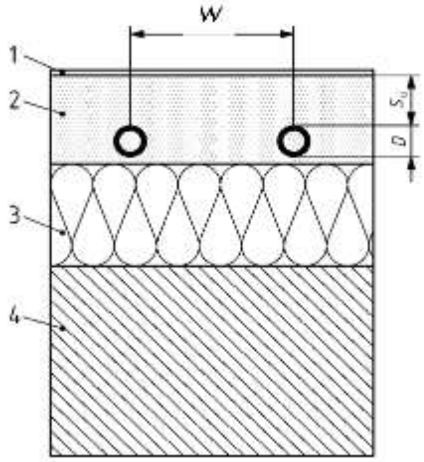
| **Method reference** | **Board situation** | **Form** | **Kind of system** | Position of tube |
|---|---|---|---|---|
| 1-7<br>2-2-*A* | $w \geq 0{,}050\ m\ s_u \geq 0{,}01\ m$<br>$0{,}008\ m \leq d \leq 0{,}03\ m$<br>$s_u/\lambda_e \geq 0{,}01$ | *A*-2 | A, C | bar |
| 1-7<br>3-2-*A* | $0{,}05\ m \leq W \leq 0{,}45 m$<br>$0{,}014\ m \leq d \leq 0{,}022\ m$<br>$0{,}01\ m \leq s_u/\lambda_e \leq 0{,}18$ | *B*-2 | B | Thermal separation of the structure of the building with thermal insulation |
| 1-7<br>4-2-A | | *P*-2 | D | The insulation materials, conductive |
| 2-7<br>1-*B* | $S_T/W \geq 0{,}3$ | 4 | E | The wooden structures with the exception of the thermal diffusion layer is not dependent on weight |
| 2-7<br>2-*B* | $d_a/W \leq 0{,}2$ | 5 | F | Flat system |
| 2-7<br>*Appendix P* | $\lambda_{WL} \geq 10\lambda_{\mathrm{surrounding material}}$<br>$S_{WL}\ \lambda \geq 0{,}01$ | 6 | G | concrete |

1.7- Basic single power function

Heat flux between the pipes embedded (temperature heating or cooling) and space (5) is calculated:

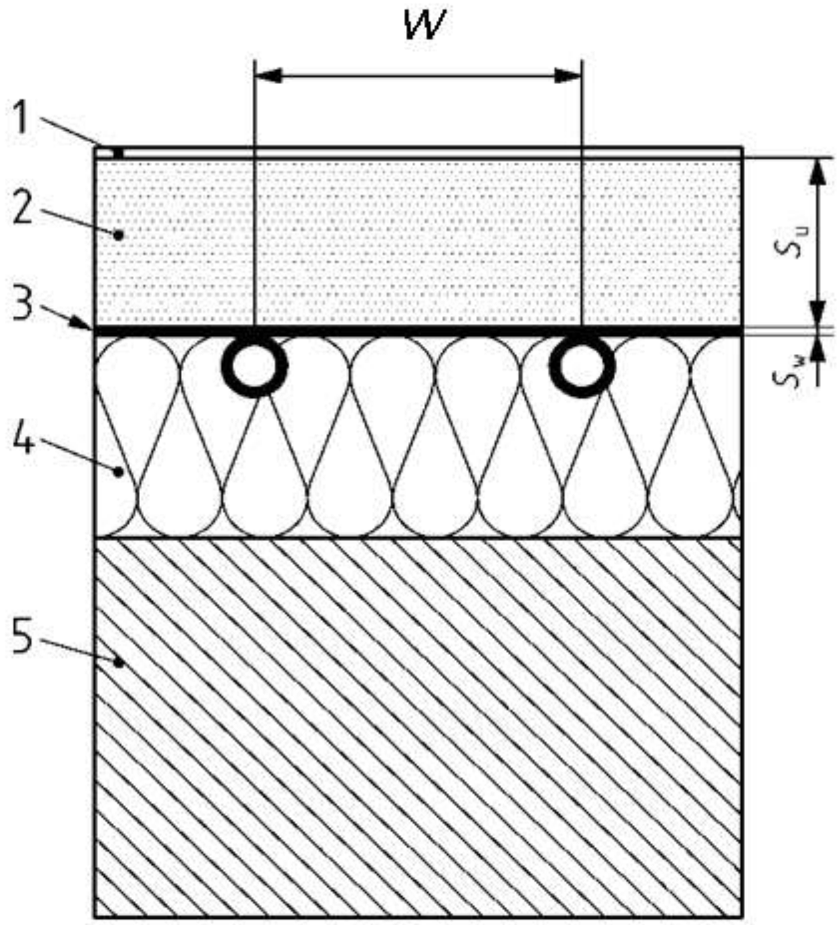
$$\boldsymbol{q} = \boldsymbol{B}.\prod_i(\boldsymbol{a}_i^{\boldsymbol{m}_i}).\Delta\boldsymbol{\theta}_{\mathbf{H}} \quad (\mathrm{W/m^2}) \tag{5}$$

In which
B is a dependent variable to system in term of ($W/m^2.K$). This depends on kind of system.
$\prod_i (a_i^{m_i})$ Is the product of the power that connected building parameters (coverage, the pipe diameter of the pipe and casing) d with each other.
Calculation method in Annex A for the four systems is provided below:
A- Type A tape or tubing embedded in the concrete (see Figure 2 and paragraph A-2.2);
B. Type B with embedded tubing out of the bar (see Figure 2 and paragraph A-2-3);
C. Type of C with tubing embedded in the bar (see Figure 2 and paragraph A-2.2);
D. Type D flat section systems (refer to Section A-2-4);
Figure 2 shows a variety of built-in floor, but the methods can be used for wall and ceiling systems, with the corresponding tubing.



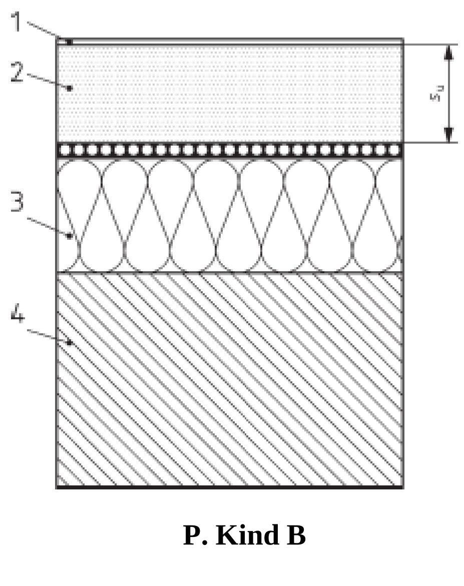

**A- Kind C and A**

Guide
1- Flooring
2- Surface weight and thermal diffusion layer (plaster, cement, strip without water, asphalt strip)
3- Thermal insulation
4- Levels of dependence




**B- Kind B**

Guide
1- Flooring
2- Surface weight and thermal diffusion layer (plaster, cement, strip without water, asphalt strip)
3-thermal penetration tool
4- Thermal insulation
5- Levels of dependence




**P. Kind B**

Guide
1- Flooring$R_{\lambda,B}$
2- Surface weight and thermal diffusion layer (plaster, cement, strip without water, asphalt strip)
3- Thermal insulation
4- Levels of dependence

Figure A, B and C systems are covered by Annex A

**Method of thermistor**

Heat flux between the pipes embedded (heating or cooling temperature) and thermal resistance using the space or area has to be calculated. The concept is shown in Figure 3.

An equivalent resistance, RHC is determined between the artificial heating or cooling for the core (conductive layer heat) in Position tubing. This includes the impact resistance of the pipe, distance the pipe and the installation of pipes (concrete structures, wood, etc.). In this way, the core temperature measured dummy screw. Heat transfer between the layers and levels dummy Ri and Re (or space and adjacent space) using linear resistances (add layers above and below layers of conductive heat resistance) calculated.

Resistance conductive layer of heat in different ways depending on the system are calculated.The method of calculating is provided by using the concept of resistance, in Annex B for two types of systems below:

A. Type E with pipes embedded in the concrete compression plate (see Figure 4 and paragraph (b) -1);
B-Class F capillary tube embedded in a layer on the inner surface (see Figure 5 and Section B-2);

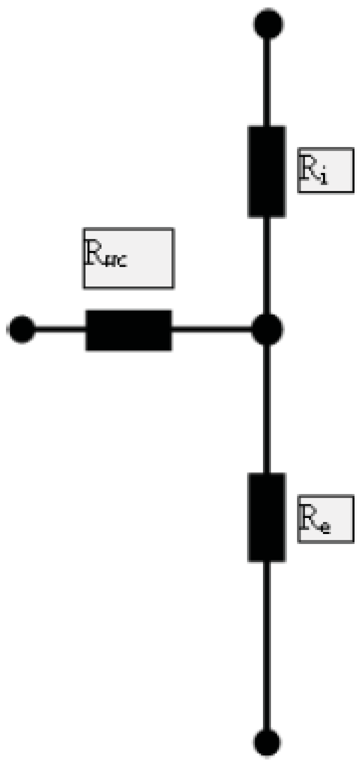



**Figure 3.** Basic networks thermistor.

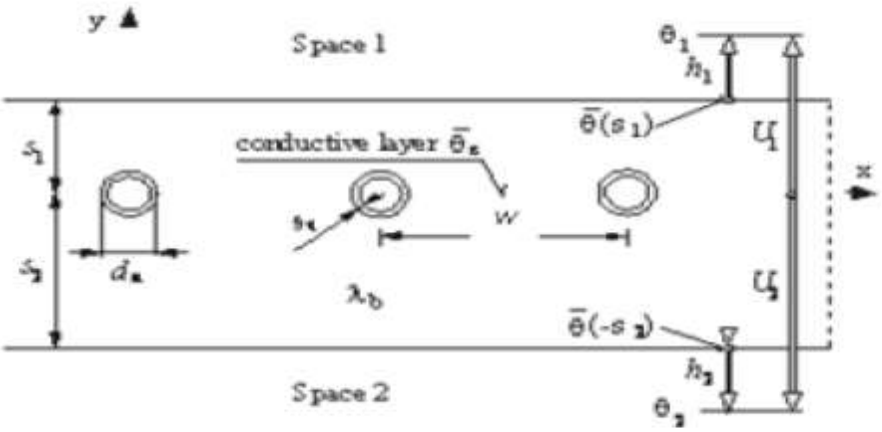



**Figure 4.** Pipes embedded in the concrete compression layer, type E.

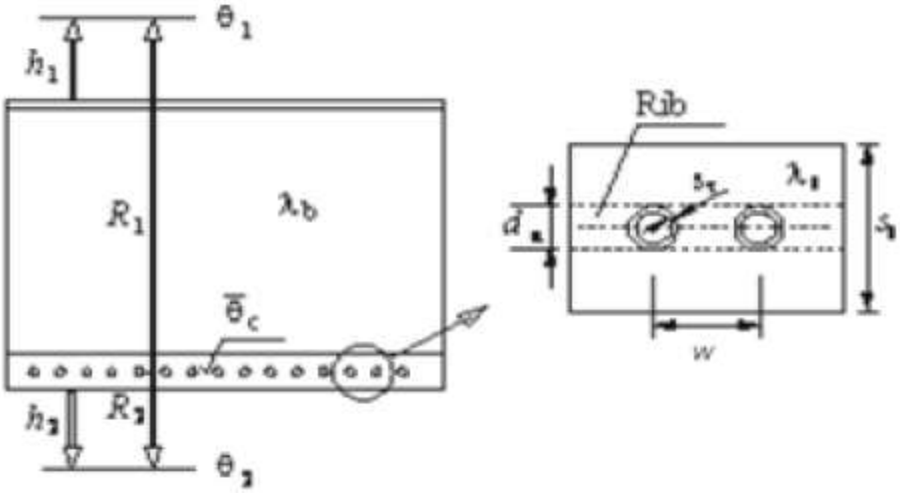



**Figure 5.** Capillary tubes embedded in a layer on the inner surface, Type F.

This calculation method is shown using the concept of resistance, in Annex C to the pipes embedded in buildings with wooden floor using heat conductive plates (see Figure 6)

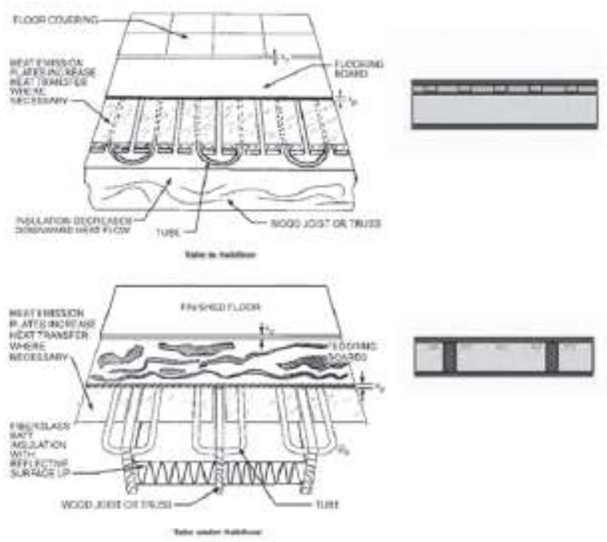


**Figure 6.** Pipes in wooden structures, Type G.

Resistance of the conductive layer may be calculated using finite element analysis method or finite difference method (see paragraph 8) or laboratory test (Annex B standard EN 1264-2.

**Use of basic computing**

**Basic computing applications**

Numerical analysis using finite element or finite difference method should be in accordance with applicable laws and regulations and set new technology standards in a way that is easy to recognize. The program used to calculate the verification shall be attached.

Numerical analysis is used possible to calculate the capacity or resistance of heating and cooling. On the basis of equivalent strength, heating and cooling capacity is calculated for the difference between the surface and the room temperature.

**Items listed in a document full calculation**

The following is a full documentation of the calculation:
(A) Provide and document structure analysis, by drawing diagrams and a technical design;
(B) Display of the material used as the base and resources necessary data;
(C) Describe used bars mode as the base, including confirmation of codes and standards;
D) Numerical model used to describe and display of mathematical and physical basis, for example the type of element, the functions, the number of elements, nodes and degrees of freedom;
E) Name, acknowledge, if available, and the source of the estimate;
C) A description of technical assumptions, simplifications and model limitations.

**Conclusion: The calculation of heating and cooling capacity**

In some ways, the described calculated of heating and cooling capacity are determined directly. Other methods described in the calculation, and the average surface temperature is determined by heating and cooling capacity is calculated as follows:

$$q_{des} = h_t(\left|\theta_{s,m} - \theta_i\right|)$$

To evaluate the performance of the system and the heating and cooling when calculating the total power requirements of the energy system (boiler, heat exchangers, chillers, etc.), the exchange of heat (backwards) should also be considered to the outside. The heat exchanger should be considered as a loss, if the outside exteriors, an unconditioned space or the other building, place, and it depends on the temperature difference between the pipe layers, such as resistance to transfer heat and temperature adjacent space or out.

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