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A SIZING METHOD FOR HYDRONIC TEMPERED CONCRETE AND UNDERFLOOR HEATING

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Abstract: *Heating systems: tempered concrete and underfloor heating are beginning to be taken more and more to our space, as buildings with an appropriate degree of envelope insulation are being built. Designers generally used for dimensioning of such systems, computer programs that make available material suppliers system. But since buildings vary greatly in terms of the degree of thermal insulation envelop, thermal inertia of the building floor area spaces against the calculated heat load, etc., the use in any situation of the same program calculation makes that in many cases sizing of such systems should not be made with appropriate accuracy. This material presents a method of sizing calculation more accurately, of such systems.*

Key words: *floor surface temperature, uniform heat flux maximum rated heat flow.*

1. Introduction

As is well known, the ideal distribution in terms of occupant comfort, of the interior temperature of a living room is a curve shaped as in Figure 1a, namely:

- the floor surface temperature should be between 22 ... 25 [° C];
- temperature at the head level(at 1,8 m from the floor), between 19 and 20 [°C].

The Heating system that ensures the most comfortable temperature distribution, namely: constant temperature on the horizontal floor surface and close to the ideal curve vertical variation of temperature, radiant floors is presented in Figure 1b.

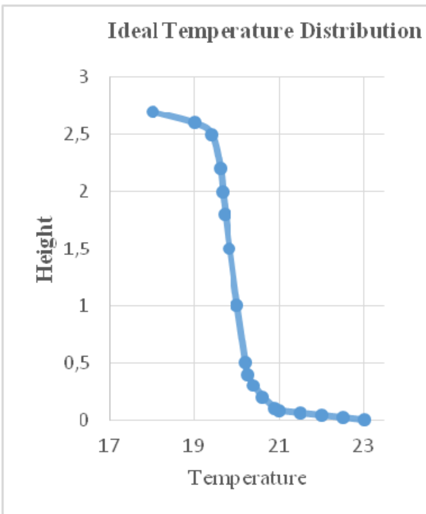

Fig. 1a. *Ideal temperature distribution*

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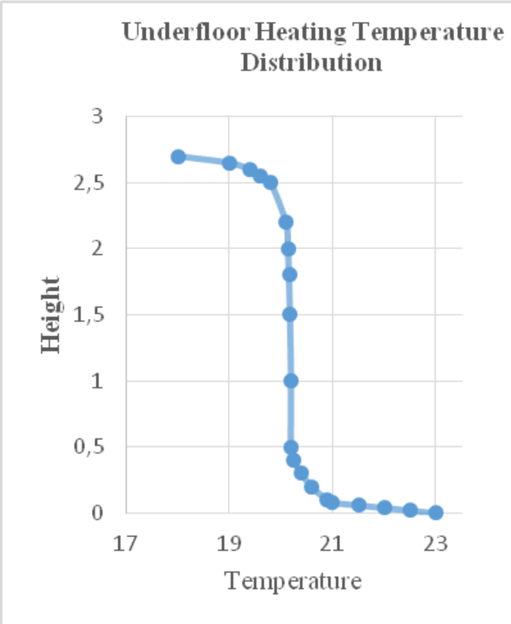

Fig. 1b. *Temperature distribution for underfloor heating*

2. Materials and Methods

Regardless of the type of heating system, the sizing is based on the heat of heated space determined in accordance with the requirements of SR 1907/1 & 2 from 1997. The standard contains specific provisions for rooms fitted with low temperature radiation underfloor heating.

Floor heating is part of the still heating surfaces, with radiators, convectors, etc. It is a result of adaptation of a building element to a heating element, namely floor. Basically, a network of pipelines (coil) through which the heat is embedded:

- either directly to the floor slab, in which case the system is known as "tempered concrete";
- either in a layer of screed poured concrete slab of the floor, in which the system is known as underfloor heating or "warm floor".
- steps that must be taken in order to dimension of such a system are:
- type of coil is adopted to satisfy the application requirements largely concerned;
- surface temperatures on the floor and in the adjoining rooms;
- calculate temperature differences and heat resistance of the component layers of the slab;
- calculate the flow of heat from the floor, water flow required and the pipes diameter and the distance between them.

The calculus of heating systems with radiant flooring is made basically following the algorithm:

a) Determine the heat flow unit that should be provided in order to cover the whole quantity of heat needed for the room:

$$q_{nec} = \frac{Q_{nec}}{S_{pl}} \quad (1)$$

Q_{nec} – heat demand calculation according to SR 1907/1-97 [W];

S_{pl} – the surface of the floor that is being heated by means of hydronic systems [m^2].

b) Determine the temperature that should have the floor surface in order to provide uniform heat flow determined above:

$$\theta_{pl} = \theta_i + \frac{q_{pl}}{\alpha_{pl}} \quad (2)$$

θ_i – indoor temperature calculation, according to SR 1907/1-97 [° C];

α_{pl} – surface coefficient of heat exchange from the floor.

Maximum floor surface temperature, according to health and hygiene, is: $\theta_{pd}^{\max} = 29\left[{}^{\circ}\mathrm{C}\right]$.

Namely, we have two situations:

- θ_{pl} determined by the relation above) $< \theta_{pl}^{\max} = 29\left[{}^{\circ}\mathrm{C}\right]$, which means that the floor can provide the heat throughout the room;
- θ_{pl} determined by the relation above) $> \theta_{pl}^{\max} = 29\left[{}^{\circ}\mathrm{C}\right]$, which means that the floor can not provide all the heat of the room

In this case must be studied the possibilities of adding other heating systems for the part of the heat load that cannot provide floor.

To do this, firs take the maximum allowed floor temperature ($\theta_{pd} = \theta_{pd}^{max} = 29[°C]$. Than, accordingly to the temperature difference, with a chart will determine the heat flow coefficient from the floor to the inside air.

For our example $\alpha_i = 8{,}92\,\frac{W}{m^2K}$ and calculate the maximum heat flow unit that floor can provide in this case:

$$q_{pi} = \alpha_i(29 - \theta_i) \tag{3}$$

The difference is the calculus of heat load that is supposed to be provided from auxiliary sources:

$$q_{aux} = q_{nec} - q_{pl} \tag{4}$$

c) Determine global heat transfer coefficients of the flooring (k_{po}), ceiling (k_{tv}), and floor (k_{pl}):

$$k_{tv} = \frac{1}{\dfrac{1}{\alpha_{tv}} + \sum \dfrac{d_{tv}}{\lambda_{tv}}} \tag{4}$$

The sum of the reports d/λ in the above equation is the appropriate layers beneath the coil system that is embedded inside the heating system (excluding the screed layer which embeds the coil with thickness equal to the diameter).

$$k_{pl} = k_{tv} + k_{po} \tag{5}$$

d) Characteristic environment temperature is established for the under floor heating and the average temperature of the adjacent floor spaces, θ_i.

There are two cases:

1. if the room is located above the basement, the temperature of the environment is being known;
2. if the room is placed on the ground, then the average ground temperature should be calculated using the following:

$$\theta_s = \frac{\dfrac{S_c / S_{pl}}{R_C}\theta_e + \dfrac{S_{sl} / S_{pl}}{R_{sl}}\theta_{sl}}{\dfrac{S_c / S_{pl}}{R_C} + \dfrac{S_{sl} / S_{pl}}{R_{sl}}} \tag{6}$$

θ_e outside air temperature (SR 1907/1-97);

θ_{sl} – groundwater temperature (SR 1907/1-97);

S_c – surface of the heated floor related to 1m contour band besides exterior walls;

S_{sl} – heated floor area related to the central zone;

$$S_{pl} = S_c + S_{sl}$$

R_{sl} – Thermal resistance of the central area of the floor [m^{2}K/W];

$$R_{sl} = R_{tv} + R_{sol}$$

R_{tv} – conductive thermal resistance of the heated floor lower layer (between the radiantsurface and soil) [m^2K/W];

R_{sol} – conductive thermal resistance of soil layer between the slab and the groundwater [m^2K/W];

R_c – corresponding thermal resistance of the band contour [m^2K/W].

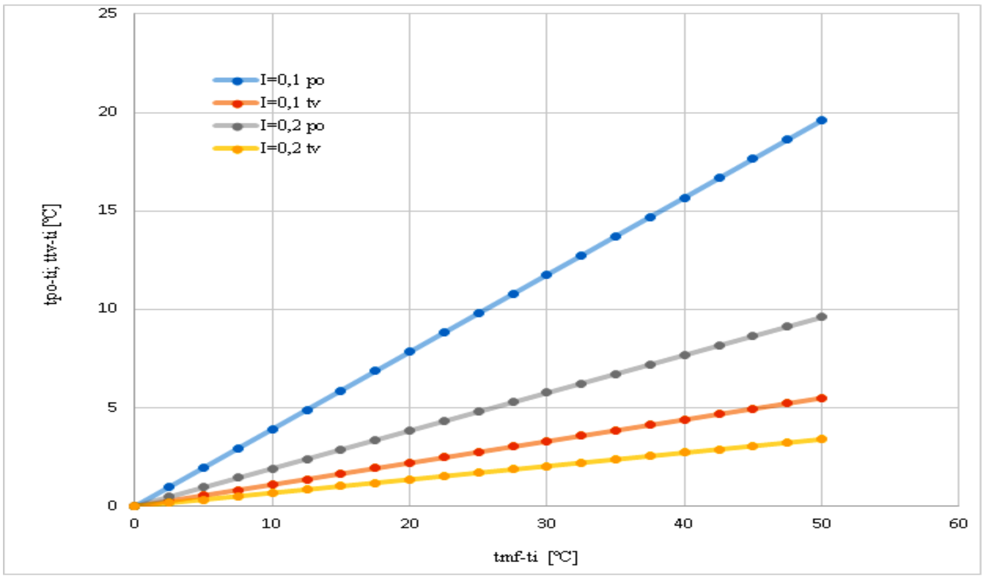

Fig. 2. *Thermal characteristic of low temperature heating surfaces*

This is calculated by the formula:

$$R_C = \frac{\lambda_{sol}}{\pi} \bullet \ln \frac{R_{tv} + \frac{\pi}{\lambda_{sol}}\left(1 - 0,5 \bullet \delta_p\right)}{R_{tv} + \frac{\pi}{\lambda_{sol}} \bullet 0,5 \bullet \delta_p} \quad (7)$$

λ_{sol} – thermal conductivity of the soil [W/mK];

δ_p – wall thickness [m];

e) The average temperature of the adjacent floor spaces is established, as the weighted average/mean temperature of the adjacent enviroments :

$$\theta_i^* = \frac{k_{po} \bullet \theta_i + k_{tv} \bullet \theta_s}{k_{po} + k_{tv}} \quad (8)$$

θ_s – characteristic temperature environment under the floor which has been choosen and which was decided in advance.

f) Determine the average temperature of the fluid heater using the thermal diagram feature of the heating floor Fig. 2., as follows:

– to enter into the ordonate with a temperature difference ($\theta_{po} - \theta_i^*$), corresponding to a distance by means of selected between adjacent pipes of the heating coil 1;

g) abscissa is determined by the temperature difference ($\theta_{mf} - \theta_i^*$), so the average temperature of the fluid heater will be used to determine heat input temperature in the floor heating coil;

h) Is established ceiling heat flux

delivered to the room below the environment considered, q_{tv}, the relationship:

$$q_{tv} = \alpha_{tv}(\theta_{tv} - \theta_s) \quad (9)$$

i) Determine the total heat flow given the floor by the relationship:

$$q_{pl} = q_{po} + q_{tv} \quad (10)$$

j) Determine the flow rate of the heat to be circulated. Should be chosen firstly for a given amount of gap temperature of the water. For good temperature uniformity floor heating is recommended that this difference (θ_n) to take be about 8-14 [° C]:

$$G = \frac{3,6 \bullet 10^6 \left(q_{pl} \bullet S_{pl}\right)}{\frac{\left(\rho \bullet c_p\right)}{\Delta\theta_n}} \quad (11)$$

ρ – density of water at temperature θ_{mf} [kg/m^3];

c_p – specific heat of water at room temperature θ_{mf} [J/kgK].

k) Determine the temperature of the coil heat input relation:

$$\theta_{dn} = \theta_{mf} + \frac{\Delta\theta_n}{2} \quad (12)$$

3. Results and Discussions

In technical literature there is currently a unanimous reference about the changing of the operational temperature inside the heated enclosures using radiant heated floor, because of the average temperature increase radiation from the surface of the floor, knowing that the floor has the highest coefficient of mutual irradiation compared to occupants, especially in high rooms.

There is also an accurate assessment of the heat change following the implementation of these systems in heated spaces.

This change is a function of:

- reducing ventilation heat requirement, because the indoor air temperature is lower;
- increase heat loss by conduction through structural elements in contact with the ground.

The results obtained with the above methodology and the MC4 SUITE Table 1

Calculated Physical measures	MC4 SUITE HVAC CAD Results	Result obtained with the above methodology
Underfloor heating surface	S_{pl} = 54,8 m^2	S_{pl} = 54,8 m^2
Floor surface temperature	t_{po} = 25,6 °C	t_{po} = 25,9 °C
Global heat exchange coefficient for floor	-	k_{po}=5, 9 W/m^{2}K
Global heat exchange coefficient for ceiling	-	k_{tv}=0,6 W/m^{2}K
Global heat exchange coefficient for entire system	-	k_{pl}=6,5 W/m^{2}K
Conduction bound heat resistance for the elements between the radiant surface and soil	-	R_{tv}=1,2 m^{2}K/W
Heat resistance of the central area of the floor	-	R_{sl}=9,8 m^{2}K/W
Soffit concrete slab temperature	-	t_s=19,6 °C
Heat flux generated downwards	-	q_{tv}=13,1 W/m^2
Heat flux generated upwards	q_{pl}=53,8 W/m^2	q_{po}=67,1 W/m^2

4. Conclusions

Generally designers in Romania use in order to calculate such a system, computer programs that are available from the materials suppliers of the system.

Calculation method presented in this article represents a more precisely instrument to calculate such a system. Therefore, the authors recommend it where sizing should be done more accurately. Respectively where the floor surface is small compared with the calculated heat load for the premises in question, or where thermal insulation and/or thermal inertia premises considered allows a reduction of investment costs with the tempered concrete or underfloor heating.

More than that, in the Civil Engineering Department are in development researches that are aimed at contributing to the expansion of knowledge in terms of dynamic behavior of both the underfloor and temperate concrete heating and cooling. Thus, are under development models and numerical simulation of the thermal behavior of such systems. We intend to implement such simulation models that can be used in research work and simplified models, which is sufficiently fast to be used in the design practice in order to optimize the solutions.

On the basis of the described methodology has been designed an underfloor heating system in the Low Radiant Temperature Heating Systems Laboratory. Table 1 show that the heat flux obtained with the above methodology was lower than the heat flux obtained with the MC4 SUITE HVAC CAD, which ensures that the designing processes are more accurate. That means the MC4 SUITE HVAC CAD will generate higher cost regarding the investment.

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