Simplified Calculation Method of Ground Contact Heat Losses
Application for Residential Buildings

ABSTRACT:

The ground contact energy loss is an important phenomenon we have to take into account to evaluate the energetic performance of buildings. The EN ISO 13370 Standard is based on the calculation of the thermal transmittance for walls and floors in contact with the ground. This method is quite complex, and heavy to use. In this paper will be presented a simplified method, using the EN ISO 13370 Standard but with some assumptions and simplifications. This method has the advance to require fewer input parameters and to need less calculation steps. That is why this simplified method is more suitable for general energy performance calculations.

INTRODUCTION:

Face to the concern about the reduction of energy consumption and the increasing expectation on a comfort point of view, we have keep on progressing in the knowledge of energy. In this paper, we will focus on the energy in the building field, and more precisely on the energy losses because of the conduction phenomenon through the ground. These energy losses are an important part of the energy consumption in buildings, so it represents a big stake to reduce them in the challenge of improving energy performance in buildings. Some experimental, analytical and numerical models have already been developed; they are really complex. This complexity comes from the fact that it is a 3-dimensional problem, and that several parameters are subjected to annual periodic variations because of the important thermal inertia. The presented simplified method is based on the EN ISO 13370 method, which allows us to calculate heat transfer coefficient, including heat flow through the wall, the slab-on-ground or suspended floor.

METHODOLOGY DEVELOPMENT

The advantages of this simplified method are that it requires fewer input parameters. To reach this goal, it has been studied that some parameters has a lower influence than others on the result. We will start by developing the exhaustive theory, taking into account all the parameters. Then we will analyze which parameters are less influent in order to fix their values in the formula. In this way, we will have the advance to get simplified calculations, what enables us to draw some tables of the thermal transmittance of the floor and the walls for example.
1) Thermal transmittance of elements in contact with the ground

We consider a steady-state heat transfer between the building elements and the ground. We can also define the following heat transfer coefficient:

\[ H_g = \left( A \cdot U_{bf} \right) + (z \cdot P \cdot U_{bw}) + (P \cdot \Psi_g) \]  

\[ \text{(W/°C)} \]  

\( A \) is the inside floor area in m\(^2\), \( U_{bf} \) is the thermal transmittance of the floor in W/(m\(^2\).°C), \( z \) is the floor depth below ground level in m, \( U_{bw} \) is the thermal transmittance of walls in W/(m\(^2\).°C), \( P \) is the perimeter of the inside area in m, and \( \Psi_g \) is the linear thermal transmittance in W/(m\(^2\).°C), obtained in accordance with European Standards ISO 10211 or ISO 14683. Then we need to define some parameters for the floor: the “characteristic dimension” and the “equivalent thickness”.

The “equivalent thickness” \( d_t \) for the floor represents the depth of the ground which has the same thermal resistance than the walls. Its expression is presented below.

\[ d_t = \lambda \left( R_{si} + R_f + R_{se} \right) + d \]  

\[ \text{(m)} \]  

This involves the ground conductivity \( \lambda \) in W/m.°C, the wall thickness \( d \) in m, and the thermal resistances of the internal and external surface and the one of the floor \( \left( R_{si} , R_{se} \right) \).

And the “characteristic dimension” of the floor using the inside area of the floor \( A \) and the perimeter \( P \) of this area is defined by the following equation.

\[ B’ = 2 \frac{A}{P} \]  

\[ \text{(m)} \]  

So we can define the thermal transmittance of the floor \( U_{bf} \) by these two following expressions.

\[ - \text{if } (d_t + 0.5z) < B’ \text{ then} \]

\[ U_{bf} = \frac{2 \lambda}{\pi z + d + 0.5z} \ln \left( \frac{\pi d + z}{d_t + 0.5z} + 1 \right) \]  

\[ \text{(W/m\(^2\).°C)} \]  

\[ - \text{if } (d_t + 0.5z) \geq B’ \text{ then} \]

\[ U_{bf} = \frac{\lambda}{0.44578 \pi z + d + 0.5z} \]  

\[ \text{(W/m\(^2\).°C)} \]

As well as for the floor, we can define the “equivalent thickness” \( d_w \) for walls, representing the depth of the ground which has the same thermal resistance than the walls.

\[ d_w = \lambda \left( R_{si} + R_w + R_{se} \right) \]  

\[ \text{(m)} \]  

It depends as well on the ground conductivity \( \lambda \), and the thermal resistances of the internal and external surface and the one of walls \( \left( R_{si} , R_{se} \right) \).

Then we can calculate the wall thermal transmittance according to the following equations.

\[ - \text{if } d_w \geq d_t \text{ then} \]

\[ U_{bw} = \frac{2 \lambda}{\pi z} \left( 1 + 0.5 \frac{d_t}{d + z} \right) \ln \left( \frac{z}{d_w} + 1 \right) \]  

\[ \text{(W/m\(^2\).°C)} \]  

\[ - \text{if } d_w < d_t \text{ then} \]

\[ U_{bw} = \frac{2 \lambda}{\pi z} \left( 1 + 0.5 \frac{d_t}{d_w + z} \right) \ln \left( \frac{z}{d_w} + 1 \right) \]  

\[ \text{(W/m\(^2\).°C)} \]

Some analysis have been carried out to evaluate the influence of the different parameters on the thermal transmittances \( U_{bw} \) and \( U_{bf} \). The parameters have been tested in different ranges of values (available in the Table1). This leads us to the following

\[ \text{Table 1} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor characteristic dimension</td>
<td>B’ (m)</td>
</tr>
<tr>
<td>Roof thermal resistance</td>
<td>R_T (W/m°C)</td>
</tr>
<tr>
<td>External walls thickness</td>
<td>w (m)</td>
</tr>
<tr>
<td>External wall thermal resistance</td>
<td>R_w (W/m°C)</td>
</tr>
<tr>
<td>Ground thermal conductivity</td>
<td>( z ) (W/m°C)</td>
</tr>
<tr>
<td>Roof depth</td>
<td>z (m)</td>
</tr>
</tbody>
</table>
conclusions:

- The ground conductivity $\lambda$ has an important influence on $U_{bw}$ coefficient, but this parameter is very variable according to the ground features.

- The thickness of external walls and ground conductivity don’t influence a lot $U_{bw}$, and don’t influence a lot $U_{bf}$ as well in the case of high floor thermal resistance.

The previous statements assure us that we can keep coherent and quite accurate values of $U_{bf}$ and $U_{bw}$ if we fix the values of some parameters. We can fix the external wall thickness $w$ of 0.3m and the ground conductivity $\lambda$ of 2 W/(m.°C) according to the EN ISO 13370. This will allow us to get easier calculations and to build a table (Table 3) of $U_{bw}$ depending only on the depth $z$ and the thermal resistance of walls $R_{w}$. Still, the calculation of $U_{bf}$ remains more complicated because it depends on the building shape too. And it has been noticed that, for slab-on-ground floors, we get the same values of $U_{bf}$ for different pairs of $B'$ and $R_f$. So a linear function has been created, representing an equivalent thermal resistance of the floor:

$$R_{f,eq} = R_f + 0.19 B' - 0.38 \quad (m^2.°C/W)$$  \hspace{1cm} (9)

By this way, we can build a table (Table 2) of the values of $U_{bf}$ depending only on the depth $z$ and on the equivalent floor thermal resistance $R_{f,eq}$. In the two tables, the values are the highest values of the floor thermal transmittance in the intervals of depths. The errors to 25%, but it’s usually around 6%.

2) Thermal transmittance for slab-on-ground floor with edge insulation

In the case of a steady heat transfer for a slab-on-ground floor with edge insulation, we can describe the heat transfer coefficient as shown in the following expression.

$$H_g = (A . U_{f,e}) \quad (W/°C)$$  \hspace{1cm} (10)

The parameter of thermal transmittance $U_{f,e}$ includes directly the effects of edge insulation, therefore its value is going to decrease and eventually reach a negative value. Its expression is presented below.

$$U_{f,e} = U_0 + \frac{2\psi_{g,e}}{B'} \quad (W/(m^2.°C))$$  \hspace{1cm} (11)

$U_0$ is the initial thermal transmittance of the floor which can be calculated with equations (4) and (5). $\psi_{g,e}$ in (W/(m.°C)) is the linear transmittance associated with the edge insulation. It can be calculated thanks to the two following equations:

- if horizontal insulation, then
If vertical insulation, then

\[
\psi_{g,e} = -\frac{2}{\pi} \ln \left( \frac{D}{d_z} + 1 \right) - \ln \left( \frac{D}{d_z + d'} + 1 \right)
\]

(12)

\[
\psi_{g,e} = -\frac{2}{\pi} \ln \left( \frac{2D}{d_z} + 1 \right) - \ln \left( \frac{D}{d_z + d'} + 1 \right)
\]

(13)

D is the main length of the insulation. Let’s notice that a vertical insulation produces the same effect as horizontal one with half D. And d’ which is the “equivalent thickness” corresponding to the edge insulation is given in the following equation.

\[d' = \lambda R_n - d_n\] (m) (14)

This expression uses the edge insulation layer thickness \(d_n\).

And like in the first part, a sensitivity analysis has been carried out to evaluate the influence of the different parameters in different ranges (Table 4). Both cases horizontal and vertical edge insulation have been considered. The results lead to these conclusions:

- Placing thicker layer of edge insulation on longest lengths provides a smaller \(U_{f,e}\)

- Low ground conductivity values and high exterior walls thickness values imply a low \(U_{f,e}\)

- The higher floor thermal resistance, the less the effect or the insulation is significant.

The building shape has to be taken into account through the parameter \(B’\). As before, a model of an equivalent thermal resistance has been found, it is developed in the expression below.

\[R_{f,eq} = R_f + 0.18 B' - 0.36\] (m²°C/W) (15)

One more time, the previous conclusions insure that fixing chosen parameters (w and \(\lambda\)) doesn’t affect the accuracy. The goal is to get simplified calculations to build the table of the \(U_{f,e}\) values depending only on D and \(R_{f,eq}\) for vertical edge insulation layer (the same value than for vertical edge insulation layer with 2 times D). The external walls thickness w has been fixed of 0.3m and the ground conductivity \(\lambda\) of 2 W/(m²°C). However, \(U_{f,e}\) still depends on the edge insulation layer thickness \(d_n\), but the influence of this parameter remains not relevant. Therefore, we can fix it: the value 0.04m is usually involved. So we have built two tables of the values of \(U_{f,e}\): one based on the \(d_n = 0.04m\) assumption (Table 5) which is considered valid for \(d_n \leq 0.04m\), and the other one built with the value \(d_n = 0.06m\) (Table 6) considered valid for \(d_n > 0.06m\). The values in the tables are the highest values in the ranges of D, and these ranges of D are chosen with the purpose to keep the error inferior to 25%.

**CONCLUSION**

The calculation method of the heat losses for elements in contact with the ground which has been presented is based on the EN ISO 13370 Standard. The different tables of thermal transmittance values build in this
paper come from the assumption of some parameter values. And the advance of this method is that it requires less input data so lightens the calculations, without reducing the accuracy. Therefore, it could be used at a profit in general buildings energy performance calculation procedures.

REFERENCES


