Choice of wall materials for summer comfort

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ABSTRACT
Before the construction of a building the choice of wall materials is highly important because it will give which characteristics you want depending on where the house is located. The goal of this project is to find a way to choose the good wall material in order to have the best summer comfort.

NOMENCLATURE
\[ \begin{align*}
x_i & \quad \text{thickness of the i-element} \\
c_i & \quad \text{specific heat, J/kg.K} \\
T & \quad \text{period time, s} \\
R & \quad \text{thermal resistance, Km²/W} \\
C & \quad \text{surface-thermal capacity, J/K.m}^3
\end{align*} \]

Greek Symbols
\[ \begin{align*}
\alpha_i & \quad \text{thermal diffusivity, m}^2/\text{s} \\
\rho_i & \quad \text{density, kg/m}^3 \\
\lambda_i & \quad \text{wavelength, m} \\
\tau_i & \quad \text{time lag, s}
\end{align*} \]

INTRODUCTION
For the population of Southern Europe, for example, the summer comfort is a priority. This comfort depends on many parameters and the choice of wall materials is one of them. Since centuries, inhabitants from warm and hot climates have found solutions in order to reduce the inside temperature. One of them is to build strong walls: in fact they had discovered the power of thermal mass. But now, with the increase of the human scientific knowledge and the new materials, we are able to calculate precisely and evaluate which kind of material should be used and its size. So project will aims at compare different type of wall materials with specific characteristics in order to evaluate which one could be the best for the summer comfort.

PROBLEM STATEMENT
First of all, we have to decide which kind of characteristic should be used for the study. 3 main characteristics can describe a wall material:

- **Thermal resistance**
  Thermal resistance \((R)\) is the reciprocal of thermal conductance. It is a measure of the resistance to heat transmission across a material, or a structure:
  \[ R_i = \frac{x_i}{\lambda_i} \]

Fig. 1 Conduction Thermal Resistance of a Composite Plane Wall [1]
In series, comparing with electricity:

\[ R = \sum R_i \]

**Time lag**

In this case, the time lag is the interval between the appearances of the highest temperature on the external surface of a component until the highest temperature is reached on the inside. It depends on the heat storage capacity of the building material. A high characteristic value > 12 hours is important for the summertime thermal insulation, a rapid breakthrough of the high temperatures being thus prevented. The time lag is directly connected with the damping effect which is more complex to calculate. Consequently we decide to evaluate the performance of time lag/damping with only the time lag.

![Fig. 2 Time lag and temperature reduction](image)

**Calculation of the time lag:**

Hypothesis:

- The surface temperature (outside of the wall) is considered to vary according to cosine function.
- The wall is considered as a semi-infinite body, as shown in the Fig. 3.

![Fig. 3 Semi-infinite body](image)

\[ \tau_i = \frac{T}{2\pi} \frac{x_i}{T_0 \alpha_i} \]

We will assume that the global time lag of a wall is the summation of all the layers time lag.

\[ \tau = \sum \tau_i \]

**Surface-thermal capacity**

The surface-thermal capacity will be used as an indicator of thermal mass. In [3] it has been calculated by summation of the thermal mass of the first 9 centimeters of wall thickness starting from the inside. It says that it give a reasonable accuracy.

\[ C = \sum_{x=0}^{x=9cm} c_i \rho_i \]

In order to simplify the study, the convection of both inside and outside surfaces is neglected.

**LITERATURE SURVEY**

Many studies have been made about the influence of the wall characteristics on the time lag or thermal mass on the inner temperature. Most of them are directly connected to a use for Passive House or more generally for eco-homes because in these cases it is highly important to minimize the consumption of conventional energies for cooling.

The project [2] shows for example the effect of outdoor absorption coefficient of an opaque wall on time lag, decrement factor and temperature variations. This project assumes a non-sinusoidal forcing function for the ambient temperature in order to increase the accuracy of the solution.
However the author decided to compare different wall formations instead of different walls materials.

In the project [4] the author cares about the influence of the thermal mass on the summer comfort by comparing different solutions including floor, walls, and roof. But we could be skeptical about the accuracy of the calculations because the global thermal inertia is obtained by summation of “scores” determined subjectively for each material. Concerning the project [5], the goal is to compare the behavior of a thick brick wall and a thick insulated wall using software.

![Fig. 4 Hourly temperature profile of the wall nodes for a typical summer day, calculated with SIMEDIF soft. The distances are measured for (a) 0.3 m thick brick wall and (b) 0.31 m thick insulated wall. [5]](image)

**PROJECT DESCRIPTION**

1. **Choice of coefficients**

In order to compare different materials, the first thing to do is to choose coefficients for each parameter:

- **Thermal resistance**: To isolate is relatively not very important in summer. The inhabitants will try to keep an average inner temperature a little bit under the value of outside. We will give to it a coefficient of 0.15.

- **Inertia**: To accumulate is important in summer. During the night, you will ventilate your house and “accumulate freshness”. During the day, your inner activities (shower, oven…) will increase the temperature. The heavy walls will store this heat and keep your home fresh. We will give to it a coefficient of 0.35.

- **Time lag/damping**: To damp and delay is a priority for summer comfort. The great differences of temperature are during the summer. The maximum temperature can be highly superior to 27° (in Southern Europe mostly) which represents the maximum acceptable temperature for the inner comfort. We will give to it a coefficient of 0.5.

2. **Choice of materials**

A basic wall is composed of a skeleton which is usually heavy with a strong thermal inertia and surrounded by an insulating body, which reflect the sun during the summer and provide a protection against the cold for the winter.

For this study, we will compare 3 common methods:
- Blocks of construction with skeleton + external insulation
- Blocks with shared insulation
- Wood construction
3. **Calculation**

The next table sums up the calculations of the 3 parameters needed for common wall materials (skeleton or insulation body). All the values required have been found at [7]. The thickness has been chosen in function of the usual dimension you can find easily in stores.

<table>
<thead>
<tr>
<th>Material (thickness in cm)</th>
<th>Thermal resistance (K/W)</th>
<th>Thermal mass (J/K.m³)</th>
<th>Time lag (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick (20)</td>
<td>0,44</td>
<td>163</td>
<td>5,2</td>
</tr>
<tr>
<td>Honeycombed brick (30)</td>
<td>2</td>
<td>213</td>
<td>15,6</td>
</tr>
<tr>
<td>Honeycombed brick (37,5)</td>
<td>2,5</td>
<td>213</td>
<td>19,5</td>
</tr>
<tr>
<td>Cellular concrete (30)</td>
<td>2,31</td>
<td>112</td>
<td>12,2</td>
</tr>
<tr>
<td>Cellular concrete (37)</td>
<td>2,85</td>
<td>112</td>
<td>15</td>
</tr>
<tr>
<td>Light wood (9)</td>
<td>0,75</td>
<td>302</td>
<td>6,2</td>
</tr>
<tr>
<td>Mineral wool (8)</td>
<td>2</td>
<td>22</td>
<td>2,6</td>
</tr>
<tr>
<td>Expanded polystyrene (8)</td>
<td>2,05</td>
<td>7</td>
<td>1,5</td>
</tr>
<tr>
<td>Extruded polystyrene (8)</td>
<td>2,76</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Plaster (1)</td>
<td>0,03</td>
<td>234</td>
<td>0,4</td>
</tr>
<tr>
<td>Plaster sheet (1)</td>
<td>0,03</td>
<td>175</td>
<td>0,3</td>
</tr>
<tr>
<td>Wood wool (8)</td>
<td>1,95</td>
<td>113</td>
<td>5,8</td>
</tr>
</tbody>
</table>

4. **Comparison**

Three steps have been followed to obtain a comparison of various solutions:

i. To choose few common solutions and gather insulation + skeleton (except for blocks with shared insulation).
ii. Each value is converted to a mark on 20 by proportionality, the best value for each parameter have 20.
iii. The coefficients are applied to the previous values.

5. **Final choice**

With a mark of 17/20, the honeycombed brick with a thickness of 37,5 cm seems to be the best wall material for summer comfort. This solution is with shared insulation, so it does not need an extra insulating body. However, with a mark of 16/20, the wood solution could be preferred for an eco-conception.

![Fig. 5 Comparison of few solutions](image-url)

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CONCLUSION

This method to determine wall materials is efficient and easy to use. However, some hypothesis for the calculation, of the time lag for example, decreases the accuracy of the solution. Consequently the solution is a global approach of the walls quality and many parameters like the orientation of walls or colors are not taken into account. Also the choice of the coefficients is subjective.

REFERENCES


[2] K.J. Kontoleon *, D.K. Bikas; The effect of south wall’s outdoor absorption coefficient on time lag, decrement factor and temperature variations; Department of Civil Engineering, Aristotle University of Thessaloniki (A.U.Th.), Greece, accepted 20 November 2006


[5] Silvana Flores Larsen1, Celina Filippín2, Graciela Lesino1 ;

Thermal behavior of building walls in summer: Comparison of available analytical methods and experimental results for a case study. Available at: http://www.springerlink.com/content/78241u17g4665765/fulltext.pdf


[8] Course Material

All internet sites were available on 16/05/2010