ASSESSMENT OF THERMAL SENSATION OF CERAMIC TILES AND OTHER FLOOR COVERINGS

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1. ABSTRACT

The excellent technical performance and aesthetics of ceramic tiles compared to other products such as wood or terrazzo have created interest in reproducing the finishes of these other products in ceramic materials. However, the thermal sensation that ceramic products transmit when they come into direct contact with skin (feet, hands, etc.) is very different compared to those of other materials, mainly when compared to wood.

This study has determined the thermal effusivity of different materials (including different types of ceramic tiles) and, besides that, a device has been designed which enables us to imitate contact between skin and the object and which assesses the influence of its roughness on thermal sensation.

Once the method was validated, a large number of products of various kinds and with different textures have been characterized. The results confirmed expectations, that is, organic materials (wood and other products) provide lower effusivity values compared to ceramic materials. Furthermore, for these latter materials we observed a dependence both on porosity (as a result of the relationship between effusivity and porosity) and roughness on thermal effusivity.

2. INTRODUCTION

The excellent technical performance and aesthetics of ceramic tiles compared to other products such as wood or terrazzo have created interest in reproducing the finishes of these other products in ceramic materials. However, the thermal sensation that ceramic products transmit when they come into direct contact with skin (feet, hands, etc.) is very different compared to those other materials, mainly when compared to wood [1].

The thermal sensation of a material depends mainly on its effusivity [2]. Effusivity (sometimes called the heat penetration coefficient) is the speed that a material can absorb heat. It is the property that determines the temperature of the contact interface of two bodies at different temperatures. Effusivity (e) combines thermal conductivity (k), density (ρ) and heat capacity (C_p):

$$e = \sqrt{k \cdot \rho \cdot C_p}$$

The higher the thermal effusivity of a material, the quicker its storage capacity will be. Thus, the greater the effusivity level is materials will present a colder thermal sensation (ceramics and stone) whilst if effusivity is lower the thermal sensation is more comfortable (or more neutral) as is the case of wood. On the other hand, a material's roughness also affects thermal sensation by modifying the area of contact between the material and the skin.

3. COMPARISON OF THERMAL PROPERTIES OF CERAMIC TILES AND OTHER NON-CERAMIC PRODUCTS

The following table shows the effusivity, conductivity and density values of the different types of ceramic tiles and of other non-ceramic products.

Material	Density	Conductivity (K)	Effusivity
	kg/m^3	W/mK	Ws$^{1/2}$/m^{2}K
WOOD	400-900	0.1-0.2	350-650
CERAMIC TILES			
Tile	1870	1.1	1345
Glazed stoneware	2270	1.3	1570
Glazed porcelain stoneware	2380	1.5	1725
Extruded rustic stoneware	2160	1.1	1420
Fired clay	1780	0.7	1090
Catalonian floor tile	2070	0.9	1235
CONCRETE	1000-2500	0.5-1.8	750-2200
FLOORS AND STONES	2600-2700	2.8-3.5	2400-2850
CORK PANELS	120	0.04	88
SYNTHETIC MATERIALS	900-1500	0.1-0.2	400-550
GLASS	2500-3000	0.7-0.8	1100-1300

Table 1.*Thermal properties (conductivity and effusivity) and density of different ceramic and non-ceramic products.*

Figure 1 represents effusivity in terms of conductivity of some of these materials. Irrespective of the type of material, there is a close link between both thermal properties, therefore it is not necessary to analyse both properties to establish the thermal performance of ceramic tiles compared to the rest of the materials.

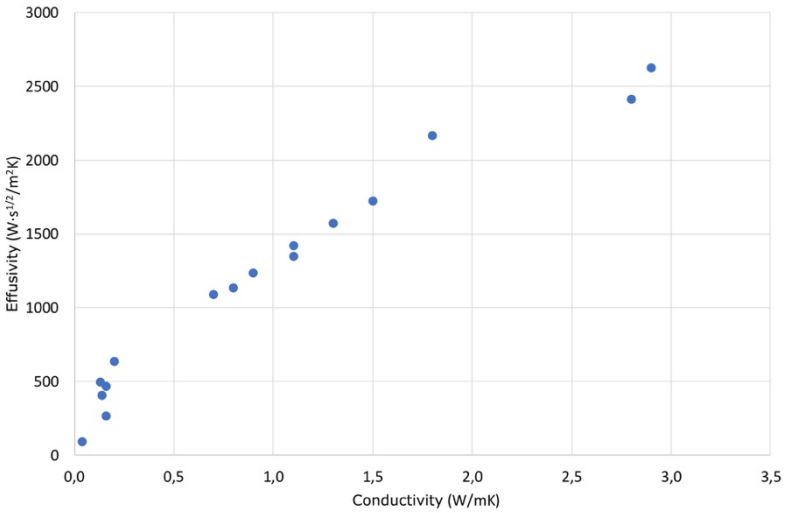

Figure 1. *Variation in effusivity with thermal conductivity of various materials.*

In order to compare the thermal properties of ceramic tiles with the rest of the materials, the following figure has been obtained, in which effusivity has been selected as the property to be analysed.

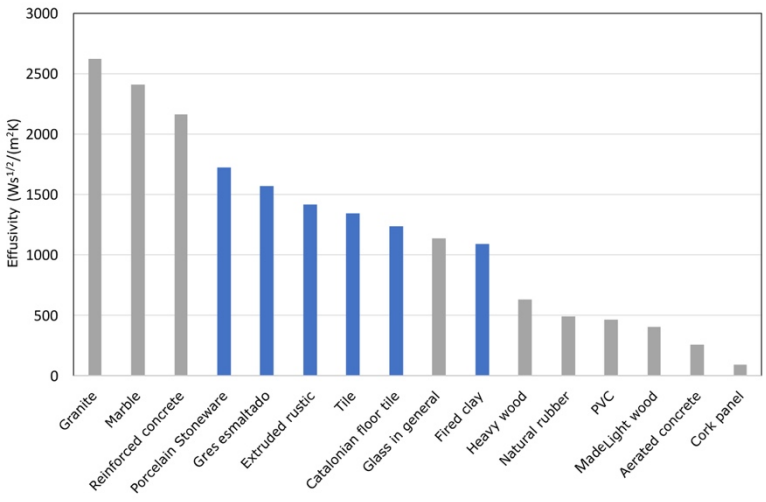

Figure 2. *Effusivity of various materials (ceramic tiles in blue).*

From these values it can be clearly seen that ceramic tiles present lower effusivity than other inorganic materials such as some natural stones or concrete, but a lot higher than "organic" materials such as wood, rubber, etc. A second analysis shows that in general porosity considerably affects thermal properties (Figure 3). Thus, we can see in Figure 2 that more porous products such as tiles, Catalonian floor tiles and fired clay and especially, aerated concrete, provide effusivity values lower than the densest products (concrete, porcelain stoneware, etc.).

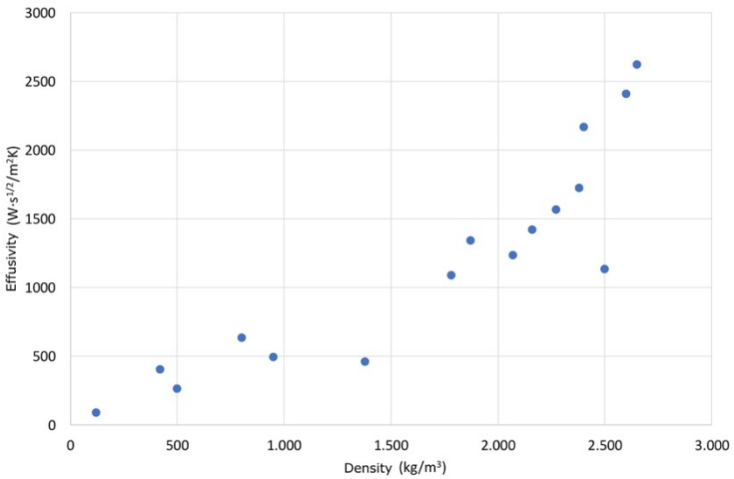

Figure 3. *Variation in effusivity with density in various materials.*

4. ANALYSIS OF THE THERMAL SENSATION OF CERAMIC AND NON-CERAMIC PRODUCTS. DESIGN OF A MEASURING DEVICE

This study has designed a device which enables the contact between skin and an object to be imitated. Basically, the method consists of putting in contact the material to be characterized (previously prepared at a temperature of 23ºC, representing ambient temperature) and metal (previously prepared at a temperature of 37ºC, representing human body heat). Once the two materials are put in contact, the evolution of the temperature of the metal is determined. Figure 4 shows the scheme of the device. In all the materials the same tendency was observed (Figure 5), a drop in temperature more marked at the beginning and less so as contact time increased.

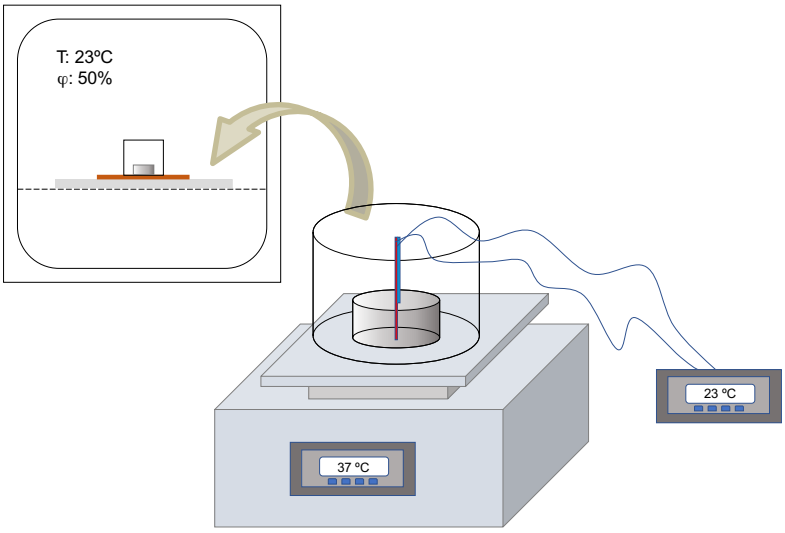

Figure 4. *Scheme of test performance.*

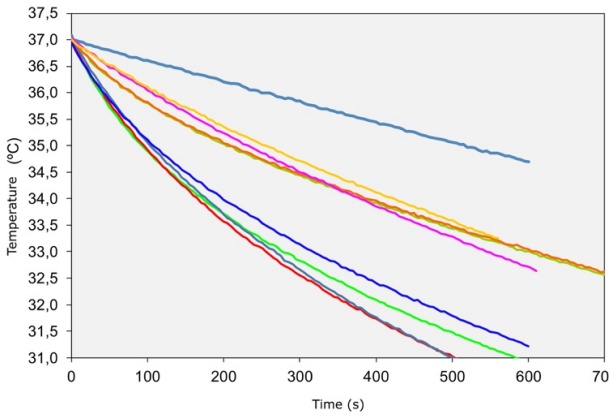

Figure 5. *Temperature evolution over time for various materials.*

Based on the curves obtained, the time that it takes the surface of the metal to diminish its temperature by 2ºC has been established as the parameter for being able to compare various materials. On attempting to correlate this parameter with effusivity (Figure 6) the tendency that was expected was obtained: products with lower effusivity are the ones that require longer times to reduce the temperature of the metal. Conversely, the validity of the method for establishing the influence of roughness on thermal sensation has also been determined, since products with similar effusivity levels have provided different time values (greater times for rough products and lesser ones for polished ones).

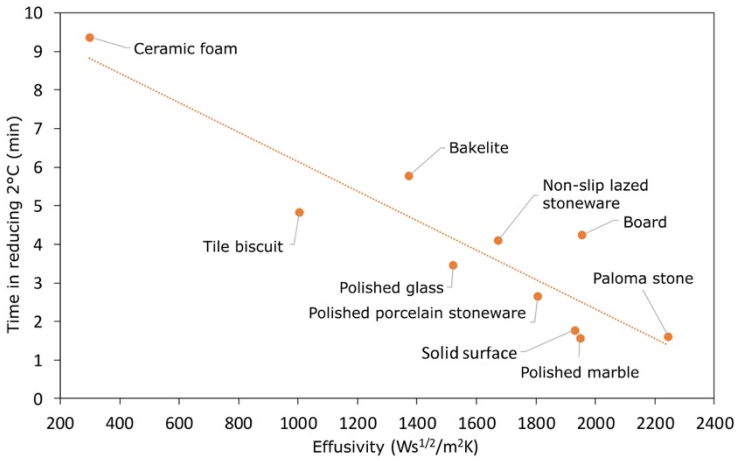

Figure 6. *Time needed to reduce the temperature 2º in terms of the effusivity of various materials.*

Once the method was validated, a large number of products with different textures and of different kinds have been characterized. The results, Figure 7, confirm expectations, that is, organic materials (wood and other products) provide better results than ceramics except for ceramic foam. Evidently, ceramic foam is not a product than can be used as flooring or covering, but it confirms that porosity is an important parameter for regulating thermal properties. On the other hand, if observed in greater detail ceramic products, besides the influence of porosity, we can see that texture is also an influence, since different porcelain stoneware tiles provide different values. Thus, it is worth highlighting two porcelain stoneware tiles (wood 3 and wood 4) which, as a result of their surface texture, provide similar values to tiles.

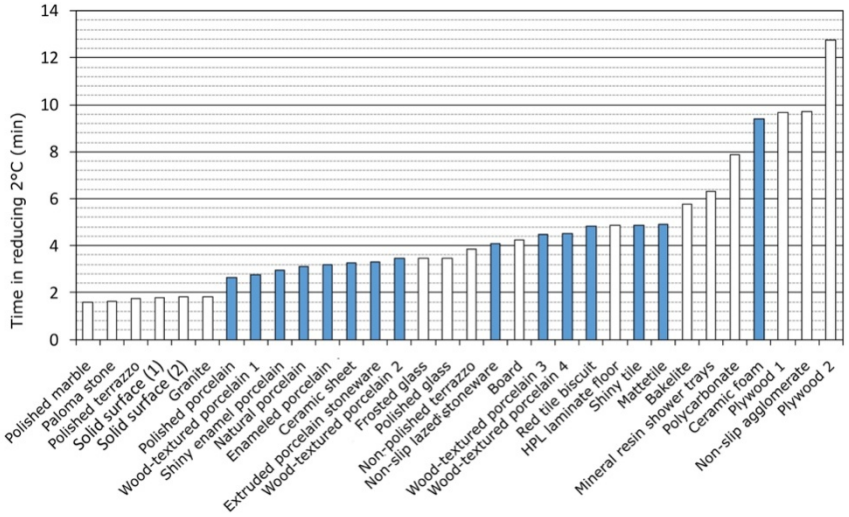

Figure 7. *Time in reducing the temperature 2ºC for different materials.*

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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