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Hygrothermal properties relationships in historic bricks

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Abstract

As part of an ongoing research project to better understand the hygrothermal performance of solid masonry brick buildings, the material properties of dozens of historic fired clay bricks have been measured. This paper discusses the relationship between density, porosity, capillary and saturation moisture content as well as thermal conductivity. A clear relationship was found between bulk density and porosity, indicating a similar mineralogic basis for all fired clay bricks. Also capillary and saturation moisture content showed a clear dependency on the density. For the other material properties the dependency was less outspoken.

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Keywords: historic bricks, hygrothermal properties, density, thermal conductivity, capillary moisture content

1. Introduction and background

In most European countries the building stock predates the first energy crises. Many of those buildings have heritage value, but consist of poorly or non-insulated solid brick walls. To provide reliable estimates of the potential for energy savings, as well as the risks involved when thermally upgrading these facades, it is important to have a better view on the hygrothermal properties of the materials involved. In the framework of a research project subsidized by the Cultural Heritage Agency of the Netherlands [1], the hygrothermal material properties of dozens of historic fired clay bricks have been measured. The dataset has been extended with data from Flemish bricks, measured within the framework of a master thesis [2]. This paper presents the relationships of the most important hygrothermal properties as a function of the measured density of the fired clay bricks. Knowledge on a possible correlation between the brick's bulk density and its other properties can be extremely useful for the characterisation of historic bricks, as it allows a characterisation based on simple measurements, using less and smaller test samples.

2. Measurement campaign

All samples have been collected from conservation projects of historic buildings, mainly dwellings, dating from 18th till 20th century. In total 158 specimen have been collected. On all specimen a vacuum saturation test has been performed. The capillary moisture content was measured on 129 specimen and the thermal conductivity was determined for 70 specimen.

2.1. Porosity-density relationship

Density and open porosity have been measured using the gravimetric procedure based on Archimedes' law. For each sample the following relationship exists between bulk density ρ_b , porosity Ψ and solid density ρ_s :

$$\rho_b = (1 - \Psi) \cdot \rho_s \quad (1)$$

As shown in Figure 1(a) a strong correlation is found between porosity and bulk density, which illustrates the similar mineralogical composition of the fired clay bricks. Hence, equation (1) can also be used on the full set of samples, resulting in an averaged solid density of 2610 kg/m³ for historic fired clay bricks of the low countries. This value is in line with previously reported data which estimated the apparent solid density to be 2680 kg/m³ for a set of 63 UK production bricks [3].

2.2. Capillary uptake properties

Uptake experiments have been performed according to the procedure described in [4]. Capillary moisture content (kg/m³) and capillary absorption coefficient (kg/m²s^{0.5}) as a function of bulk density are presented in Figure 1(b) and Figure 1(c). A clear correlation is found between bulk density and both capillary and saturation moisture content. The correlation with the

absorption coefficient is, however, less outspoken. Overall, fired clay bricks with lower bulk density show a higher absorption coefficient, but the correlation is rather weak.

2.3. Thermal conductivity

The dry thermal conductivity (W/mK) of the brick samples has been measured via the guarded heat flow meter method. A specific set-up was created to deal with the small size of the samples. Figure 1(d) presents the obtained dry thermal conductivity as a function of the bulk density. As can be expected, the thermal conductivity rises with increasing bulk density. The exponential fit through the data is slightly higher, but in close agreement with one of the eldest (non-linear) relationships proposed for building materials [5].

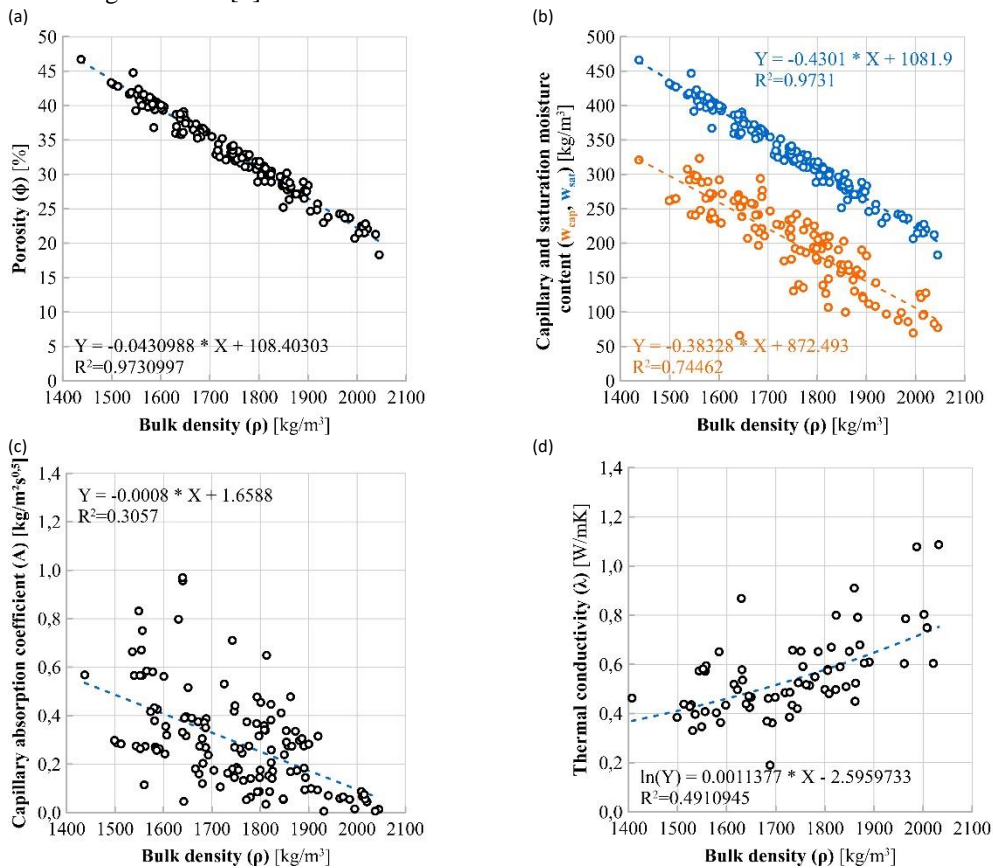


Figure 1. Hygrothermal material properties as a function of bulk density (a) open porosity; (b) capillary moisture content and saturation moisture content; (c) capillary absorption coefficient and (d) thermal conductivity

3. Conclusions

In the framework of an ongoing research project dozens of fired clay brick samples of historic buildings, mainly dwellings in Flanders and the Netherlands have been characterized by vacuum saturation tests, capillary uptake tests and heat flow meter measurements. A clear correlation was found between porosity and density, indicating that most of the brick samples have similar chemical composition. Also the capillary moisture content was strongly related to the density. A less strong correlation was found for the capillary absorption coefficient and thermal conductivity, though in both cases a higher bulk density on average correlates to a lower absorption coefficient and higher thermal conductivity.

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