An improved technique for measuring absorption coefficients of masonry building materials

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Abstract

Hygrothermal simulation is an important tool in the practice and policy of deep energy retrofit and other aspects of design. A key constraint on its use is availability of material data, in particular absorption coefficient. Practitioners must usually select data from databases with little or no useful information for historic materials. Improved automatic methods, such as those used here, have existed for over two decades; a further refinement is proposed. Data for two types of limestone from Lincolnshire, UK are presented, and the automatic method is compared with the manual method.

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Keywords: absorption coefficient; alpha value; hygrothermal; building material

1. Introduction and Aim

Hygrothermal simulation in accordance with [1] is an important technique to assess the moisture risk of build-ups. Reliable results require appropriate material properties, an important parameter being the absorption coefficient. Users of WUFI [2], for example, are advised to use methods specified in [3] to obtain liquid transfer coefficients. This standard calls for large samples such as whole bricks, and specifies the calculation of absorption coefficient in a way that is not suitable for smaller samples. This extended abstract demonstrates an alternative method which has advantages for samples of all sizes, particularly smaller samples with a mass less than 100g. Data for two types of English limestone are presented.

2. Literature

There are many methods in which to measure the absorption coefficient of a material including measuring electrical resistance and X-ray tomography [4], and gravimetric approaches [5,6,7,8]. The earliest proposal we know of for an automatic gravimetric method was in [9]. Feng and Janssen [8] discuss the way such experiments are carried out and codified, including the sensitivity to a variety of factors and the processing of results.

3. Methodology

The experimental techniques are similar to those described in [9] and recently elaborated in [6]. Cylindrical samples (~45mm diameter) are suspended a balance, with the bottom surface in contact with a water bath as shown in Figure 1 (to approximate 1D flow); the mass is recorded at suitable frequency e.g. every 5s. Other authors employ various complex arrangements for maintaining a constant water level. Instead, we propose that the surface area of the bath is large in relation to the sample, such that the volume of water absorbed has a negligible effect on the water depth. However this increases the rate of latent cooling discussed in [8]; this could be mitigated via heating of the bath, and/or completing the experiment within a chamber with high humidity. The slope of mass increase with the square root of time during initial wetting gives the ‘absorption coefficient’ although the precise definition varies [8].

Seven samples comprising two types of limestone were obtained from a building near Grantham, Lincolnshire. The type of stone and likely source was identified by visual inspection with reference to [10]. For practitioners it is helpful to provide positive identification or other meta data about samples to help select appropriate material data for particular situations. Unfortunately this meta data is often not provided or is insufficient, so it is impossible to select data on the basis of basic observations such as location, appearance, age of the building of interest and so on. As shown here, there can be significant variation in properties within broad categories or locations of material such as ‘Lincolnshire limestone’.

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Figure 1. Example of samples (left) and apparatus set-up for testing (right).

4. Results and Discussion

Table 1 presents the absorption values measured, as well as related properties of each of the samples. Figure 2 shows an example of the graph that is obtained from both the manual and automatic methods. One of each stone type is shown. The smaller points in each case show results from the automatic method, and the larger points are results obtained using the manual method. Sources of experimental error are discussed in [8]. Figure 2 shows the much greater volume of data points that can be collected using the automatic method, which reduces the uncertainty in fitting a slope. It also removes error associated with sample handling and wiping the sample as specified in [3].

Stone Type	Oolitic Limestone: Ancaster Ragstone				Ooidal Limestone: Hard White		
Sample Number	1	2	3	4	5	6	7
Bulk density [kg/m ³]	1800	2000	1900	1800	2600	2100	2300
Saturation water content [kg/m ³]	160	160	200	200	90	120	120
Absorption coefficient (BS 15148 'manual' method) [kg/m ² s ^{1/2}]	0.041	0.055	0.081	0.069	0.030	0.054	0.043
Absorption coefficient ('Automatic' method) [kg/m ² s ^{1/2}]	0.051	0.056	0.077	0.080	0.027	0.055	0.051

Table 1. Summary of key properties for each of the stone samples tested.

There is reasonable agreement between the results of the two methods; the linear regression between the manual and automatic methods has a slope of 0.96 and an intercept of 0.0055; the R² value is 0.88. Further work would be necessary to explore the variance within and between these methods, expanding on the work presented in [8].

For some types of error, in particular those associated with manual handling of the samples and temporarily removing them from the water, the margins do not scale linearly, such that smaller samples are more vulnerable to experimental error [8]. In the context of heritage buildings, where it is often impractical or unacceptable to remove larger samples, techniques better suited to small samples are useful.

For practitioners undertaking hygrothermal simulation, the accuracy and precision requirements are often less demanding because the values measured are not used directly, but rather to guide selection of appropriate material data from a database. On the other hand, an important benefit of the automatic method for both practitioners and researchers is the convenience offered by the automatic method over the manual [6].

5. Conclusions

Absorption coefficient is an important parameter in hygrothermal simulation. Values for two known, contrasting types of limestone are presented. Two different experimental techniques are compared. The automatic method allows the absorption coefficient of smaller samples be measured with less experimental error and is more convenient. A simple approach to maintaining water bath level is proposed. Further work is required to quantify (and mitigate or account for) the errors introduced by latent cooling and small changes in water level. Variance within and between methods warrants further investigation.

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