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Technical note

A discussion of "Characterization of hygrothermal properties of wood-based products – Impact of moisture content and temperature"

Hans Janssen *

KU Leuven, Department of Civil Engineering, Building Physics Section, Belgium

HIGHLIGHTS

- A prior paper in the journal studied vapour permeability of wood-fibre insulation.
- Mistakes in measuring, calculating and presenting this permeability were made.
- Actual permeabilities are most probably higher than widely adopted in literature.
- This deviation has led to dubious claims challenging the diffusion state-of-the-art.
- These challenges are partially contradicted by the investigation in this discussion.

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ABSTRACT

In 2014, this journal published the paper "Characterization of hygrothermal properties of wood-based products – Impact of moisture content and temperature", presenting among others the vapour permeability of wood-fibre insulation. This discussion demonstrates that the measurement, the calculation and the presentation of this vapour permeability has suffered from various errors, invalidating the obtained intrinsic vapour permeabilities of wood-fibre insulation. This discussion moreover demonstrates that several subsequent authors have furthermore misinterpreted their air-gap-corrected vapour permeabilities as intrinsic vapour permeabilities, which in turn invalidates, at least in part, these authors' challenges to the state-of-the-art on the measurement and simulation of hygroscopic moisture transport in porous materials.

1. Introduction

In 2014, this journal published the paper "Characterization of hygrothermal properties of wood-based products – Impact of moisture content and temperature" [1]. In that paper, hygrothermal properties of wood-based products were measured, including the sorption isotherm and vapour permeability of wood-fibre insulation. In the four years since that publication, these results have been referenced frequently [2–11]. The present author contends though that the study in [1] contains flaws in the measurement, calculation and presentation of the vapour permeability of wood-fibre insulation. These have led to the wider adoption of incorrect permeabilities [2–11], which in turn have resulted in debateable claims, on the inaptitude of stationary vapour diffusion experiments [8,10] and on the importance of advection in hygroscopic ad-/desorption [9,11]. The goal of this discussion is to reveal the erroneous measurements, calculations and presentations in [1] as well as to discuss the ramifications for the investigations [2–11] making use of [1]'s outcomes.

2. Flawed presentations and calculations in [1]

Please note that most results are given as pairs of values, for dry cup and wet cup respectively.

2.1. Air-gap-corrected vapour permeabilities

The vapour permeability of wood-fibre insulation was measured in [1] via cup tests. In such test, the top and bottom surfaces of a sample are exposed to two different environments at two different vapour pressures. Typically one environment is maintained by a saturated salt solution in a small metal or glass cup while the other environment is provided via a climate chamber [12]; but

* Address: Kasteelpark Arenberg 40, 3001 Leuven, Belgium.
E-mail address: hans.janssen@kuleuven.be

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alternatives exist. The vapour pressure difference between these two environments results in a vapour diffusion flow, which is measured via the mass change of the cup. This vapour flow then allows derivation of the intrinsic vapour permeability of the material. In this calculation however, one should correctly account for the additional diffusion resistances, between the cup's solution surface and the sample's bottom surface, and between the sample's top surface and the climate chamber [12], see also Eqs. (1)–(8) in [1]. The cup tests in [1] applied wood-fibre insulation at thicknesses of 2, 3 and 4 cm. The climate chamber was kept at 50 %RH, whereas 9 or 97 %RH was provided in the cups for dry cup and wet cup tests, respectively. The samples were preconditioned in two different ways: one series was dried in a ventilated oven at about 7% RH, the second series was kept in a humid room at 100% RH. In [1], these are dubbed 'dry' and 'wet', not to be confused with 'dry cup' and 'wet cup' tests.

The primary findings in relation to the vapour permeability of wood-fibre insulation are collected in Tables 4 and 6 in [1]. The primary results are vapour permeabilities of $3.6 \cdot 10^{-11}$ s to $4.6 \cdot 10^{-11}$ s and $7.4 \cdot 10^{-11}$ s to $8.3 \cdot 10^{-11}$ s and vapour resistance factors of 4 to 6 and 2 to 3 (Table 4), which are subsequently synthesised to 6 and 2 (Table 6). Unfortunately neither of these represent the intrinsic vapour permeability of the material: the tables present 'air-gap-corrected' permeabilities, corrected for the resistance between cup solution and sample surface, but not for the resistance between sample surface and climate chamber. The air-gap-corrected values are an unfortunate presentation choice. Because they still include the impact of the top surface transfer resistance, they are not generalizable, as that resistance is specific to the set-up used. They are moreover not the primary interest for researchers and practitioners, which (almost) always require intrinsic permeabilities. It will be demonstrated below that most researchers who use [1]'s permeabilities [2–11] did not distinguish between the provided air-gap-corrected values and the desired intrinsic values. This lack of distinction is probably also exacerbated by an additional presentation flaw: in Tables 4 and 6 in [1] these air-gap-corrected permeabilities are used for calculating the water vapour resistance factor μ, while EN ISO 12572 [12], and Eq. (8) in [1], prescribe its calculation from the intrinsic permeability instead. Despite Tables 4 and 6's explicit mention of air-gap-corrected permeabilities being presented, the use of the 'water vapour resistance factor μ' formulation evidently has misled most readers.

A similar flaw is present in the related [13], among others comprising the results of [1]. In [13]'s Fig. 16, dry cup and wet cup vapour permeabilities of wood-fibre insulation are shown. And while it is admittedly not evident in that figure, the first author of [1] (in charge of [13]'s LMDC results) has confirmed that these are not intrinsic but again air-gap-corrected vapour permeabilities [14].

2.2. Intrinsic vapour permeabilities

The only mention of intrinsic vapour permeabilities is given just above Fig. 12 in [1], where it is indicated that these range "between 10^{-10} s and 10^{-9} s". The reader needs to be alert to detect this statement, and even more so to note the implicit ringing of alarm bells. The range spanning one order of magnitude, with the upper limit 5 times larger than the vapour permeability of air, is a concern. Indeed, this range is incorrect due to an erroneous identification of the surface transfer resistances between the sample surface and the climate chamber. The values in Table 5 in [1] are $7 \cdot 10^8$ m/s and $2 \cdot 10^8$ m/s, but these are believed to be incorrect for several reasons.

Firstly, Fig. 1a repeats Fig. 12 of [1]. This indicates that the above-mentioned resistances were determined at the intersections of the average regression line with the vertical axis. However, this axis represents a sample thickness of 1.5 cm and the given resistance values include 1.5 cm of material. The intersections of the average regression lines with the origin gives resistances of $5.5 \cdot 10^8$ m/s and $-0.4 \cdot 10^8$ m/s instead. Secondly, it is unclear how the regression lines were determined. Fig. 1b overlays the excel-cloned average measurement results (markers), on which linear least-squares regressions are fitted (lines). It is evident that the slopes of these fits diverge from the original trendlines, the latter displaying a downward and upward bias. With these new regressions, the final resistances become $5.8 \cdot 10^8$ m/s and $-0.7 \cdot 10^8$ m/s.

The impact of such different surface transfer resistances is significant. Let us (illustratively) approximate the thickness/π_{agc} values for 4 cm samples as $9.5 \cdot 10^8$ m/s and $5.3 \cdot 10^8$ m/s. Applying [1]'s Eq. (7) with the original resistances yields intrinsic permeabilities $16 \cdot 10^{-11}$ s and $12 \cdot 10^{-11}$ s. On the other hand,

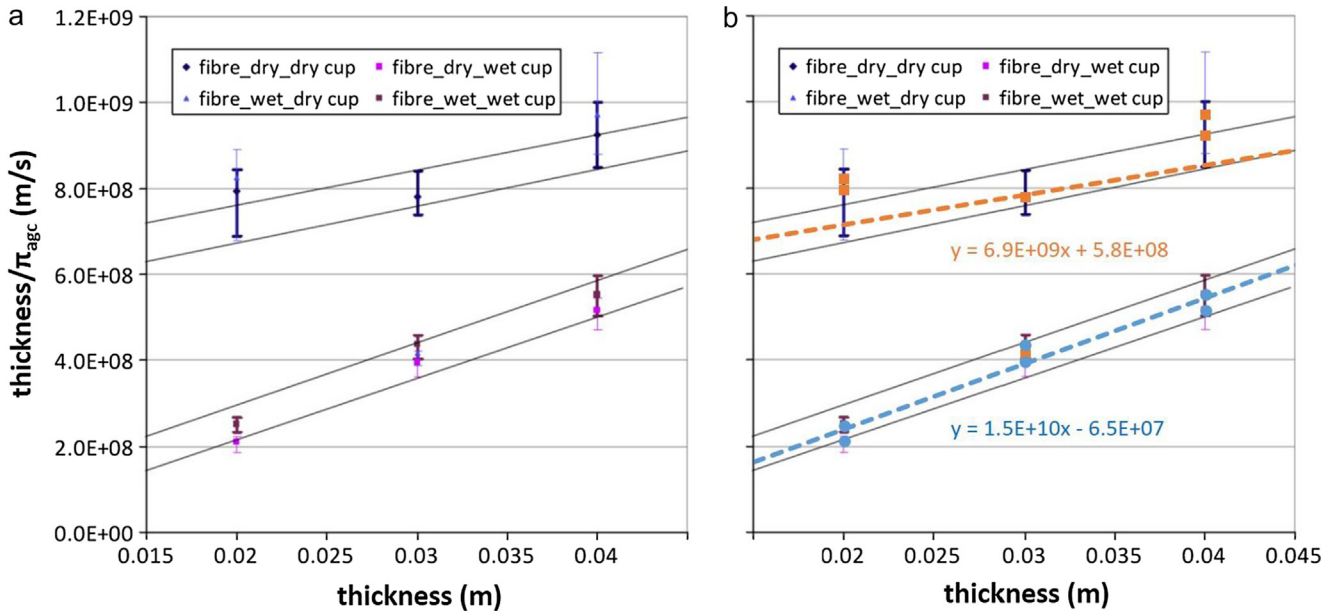

Fig. 1. (a) Original of Fig. 12 in [1], with π_{agc} [s] the air-gap-corrected vapour permeability; (b) Cloned version of Fig. 12 in [1], with regression lines for the dry cup and wet cup results respectively; in the expressions for the latter, x and y are thickness and thickness/π_{agc}, respectively.