Sorption scanning curves for hardened cementitious materials

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Abstract

Drying of screeded floor slabs is an important issue for the building industry. However, virtually no attention is paid in prediction models to the hysteresis of sorption isotherms, mainly because of lack of data. Disregarding the hysteresis in prediction models will generate inaccurate predictions of future moisture distribution and remaining drying time. This paper presents a method for fast determination of scanning sorption isotherms and sorption isotherms by using a gravimetric vapour sorption balance. A sorption balance continuously determines the mass of a small sample subjected to a sequence of predefined vapour pressures and temperatures. Sorption isotherms and two examples of sorption scanning curves at 20 °C are presented. Results from three materials commonly used in screeded slabs are included, *viz* concrete W/C 0.65, concrete W/C 0.55, and a screed, Floor 4310 Fibre Flow. Absorption scanning curves obtained for concrete show a significant moisture history dependence as a consequence of the hysteresis of the desorption isotherm itself. Desorption scanning curves originating from the absorption isotherms indicate little influence of the moisture history.
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1. Introduction

Drying of residual moisture and moisture distribution in screeded floor slabs are important concerns for today's building industry. Residual moisture is here defined as water in a material above a threshold known to cause damage to an adjacent material. Moisture coming from different sources, *e.g.* mixing, screeds, adhesives, and air, influences the vertical moisture distribution in the floor slab. Estimations of moisture distribution therefore require, apart from initial and boundary conditions, determination of various moisture related properties. The amount of water physically bound in the pore system corresponding to the relative humidity, RH, in the surrounding air, the sorption isotherm, plays a significant role in estimations of moisture distribution. However, the moisture history dependence of sorption isotherms, hysteresis, is often overlooked when such estimations are performed.

Sorption isotherms are indeed central to estimating residual moisture and later drying–wetting processes, *e.g.* when screed and flooring are applied.

Moisture distribution in single layer concrete floor slabs [1] can be estimated with a fair degree of certainty. However, further research is needed to evaluate moisture distribution in two-layer slabs with a comparable accuracy. This lack of knowledge may result in moisture related damage to materials and combinations of materials where residual moisture may be the key factor indirectly responsible for health problems. For example, degradation of adhesive in a moist and high alkali environment may release volatile organic compounds, VOCs, such as 1-butanol and 2-ethyl-hexanol. High concentrations of VOCs are suspected to cause health related problems including runny noses and eyes [2]. The residual moisture may also cause visual damage to the flooring such as axial deformations, discolouration, and blisters.

Prediction models currently used to estimate drying and moisture distribution do not take into account the hysteresis phenomenon of the sorption isotherm [3–5]. Disregarding

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hysteresis will lead to inaccurate moisture distribution estimations, *e.g.* the RH level in the screed top layer adjacent to PVC-flooring. When screed and flooring are applied, small amounts of water coming from the adhesive will substantially increase the RH in the upper part of the floor slab. Underestimating this increase in RH will, in turn, amplify the risk of moisture damage. An increased awareness of this problem is needed, especially since a prolonged concrete drying time is unattractive to building contractors.

For modelling of two-layer combinations, it is particularly important to recognize the hysteresis phenomena of the sorption isotherm, since sorption scanning curves profoundly affect the moisture redistribution. Prediction is straightforward for initial drying of a concrete slab when the moisture content at all depths of the first slab is determined from the desorption isotherm. However, when a second layer is applied to the slab, predictions of the future moisture distribution become more complex since hysteresis needs to be taken into account. As moisture penetrates the dry slab, moisture content is determined from a sorption scanning curve, commencing from the desorption isotherm. These sorption scanning curves will start from low moisture content levels on the desorption isotherm (Fig. 1, curves 1 and 3) and end up at successively higher moisture content levels. When the screed eventually dries and moisture load in turn decreases, moisture content is determined from sorption scanning curves, (Fig. 1, curves 2 and 4) commencing from the endpoint of the previous sorption scanning curves.

There is little previous research into determining sorption scanning curves in cementitious materials [6–8]. Research by Ahlgren [8] was not systematically carried out and variations within a material were never investigated. In addition, the experimental setup using climate boxes was time-consuming, with one year needed to determine a complete isotherm. As a consequence of the long testing period significant hydration took place during the experiment and had to be considered. A detailed description of the climate box method is published in [9]. Sorption balances have been widely used in other research areas such as the pharmaceutical and food industries [10–12]. Johannesson and Janz used a sorption balance on porous glass and sedimentary calcareous sandstone [13]. Additionally, Anderberg and Wadsö [6] used a sorption balance to determine both sorption isotherms and scanning curves of self-levelling flooring compounds. An inkbottle pore-method to predict sorption scanning curves on cement based materials was recently published [14].

This research has focused on experimental determination of isothermal sorption scanning isotherms for three different cement based materials: concrete W/C 0.65, concrete W/C 0.55, and a screed Floor 4310 Fibre Flow, SFC. A description of the method used and the investigated materials is presented as well as an estimation of the obtained accuracy of the performed measurements. Sorption isotherms have been obtained as well as two scanning sorption isotherms for each sample by using a sorption balance [15].

2. Materials

Three cement-based materials were used in this study, two concrete mixes with a W/C 0.65 and W/C 0.55, and a screed Floor 4310 Fibre Flow, SFC. Ordinary Portland cement, CEM II/A-LL 42,5 R according to 197-1 European Standard, was used in the two concretes tested. The basic binder of the SFC was alumina cement. For a detailed material description, see Table 1.

All samples were obtained from a full scale floor construction at different stages of drying in a room at 60% RH and 20 °C. The samples were never subjected to levels below 60% RH. To avoid effects of carbonation, at least 5 mm of the surface layer was chiselled off immediately prior to sampling. Samples were chiselled out from the floor construction at a specific time after casting, about 1–7 days prior to testing. The actual RH level of the samples was not determined at sampling. However, the RH lev-
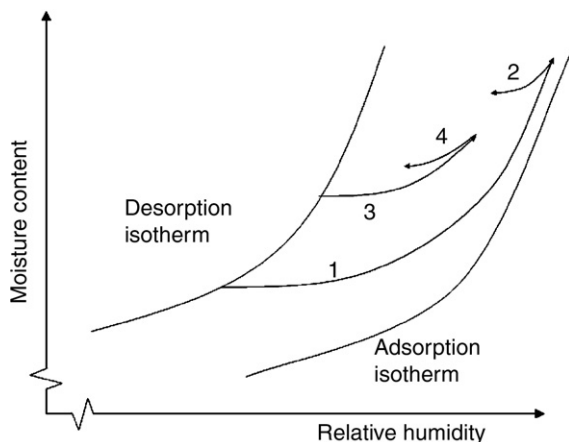

Fig. 1. Illustration of sorption scanning curves. Absorption scanning curves are marked 1 and 3 and desorption scanning curves are marked 2 and 4.

Table 1
Mixture description for each material

Material	W/C 0.65	W/C 0.55	SFC[a]
CEM II/A-LL 42,5 R	250	400	
Water	162	220	320
Sand 0–8 mm	976	1672	
Sand 8–12 mm	489		
Gravel 8–16 mm	489		
Portland cement			15–80
Alumina cement			80–320
Gypsum			30–160
Dolomite 0.002–0.1 mm			490
Sand 0.1–1 mm			740
Polymer			15–80
Glenium 51	1.5	2.9	

Quantities are in kg/m³.
[a] Mixture according to manufacturer.