Internal thermal insulation with light weight autoclaved aerated concrete

Oliver Kreft, Berit Straube, Torsten Schoch

Xella Technology and Research, Department of Product- and Process Research, Gregor-von-Brück-Ring 9 A, D-14822 Brück, Germany & Hohes Steinfeld 1, D-14797 Kloster Lehnin, Germany

Abstract: According to their specific sorption capacities, building materials adsorb water vapour from ambient air and pass it back when the ambient humidity decreases. Condensation occurs when the temperature of the moisture falls below the dew point. Accumulated condensation water – i.e. at the interface between internal insulation and outer wall - involves damage emanating from physical, chemical or even microbial processes. For this reason, internal insulation is generally regarded as a problematic issue and, hence, compromise solution.

Aim of the present study was to investigate moisture transport processes in lightweight autoclaved aerated concrete (LW-AAC, dry density = 100 kg/m^3) in more detail. We examined water absorption properties of seven light weight AAC specimens with gradually modified degrees of hydrophilicity. The process of water absorption was determined according to standard EN 1609 for short-term absorption of water.

For the simulation of service conditions, selected specimens were fixed to test walls and exposed to a hygrothermic cycle using a climate chamber. During this test cycle, temperature and relative humidity inside the specimens were monitored continuously by integrated sensors. The spatial and temporal distribution of moisture content was determined on the basis of frequently taken drill cores. Water absorption capacities were compared to data collected from the climate simulation and are discussed with particular emphasis on basic requirements for internal insulation materials.

Keywords: autoclaved aerated concrete

1. INTRODUCTION

AAC consists of a fine nanometer-scale matrix porosity that results from the packing of tobermorite crystallites, and micro- to millimeter-sized aeration pores arising from the aluminum-driven foaming of the wet mix. Within micrometer-sized pores, water is held under the influence of capillary forces. When used for external insulation (i. e. in ETICS), organosilicone compounds can be used to implement water-repellency in *per se* hydrophilic LW-AAC. The class of organosilicones fulfils major prerequisites imposed on masonry protection: Strong reduction of capillary water uptake under maintenance of water vapour diffusion permeability [1, 2]. Internal thermal insulation offers several advantages i.e. uncomplicated and cost-effective mounting. Rooms can be heated comparably fast, as massive bearing walls do not have to be warmed. However, problems related to thermal bridges, condensation water and restraints to drying processes, in case materials with vapour-barriers are utilized, have to considered. Highly diffusion permeable materials (i.e. sheep wool, mineral wool, synthetic fibres) can involve severe condensate formation [3]. Materials with high diffusion resistance (i. e. EPS, XPS, VIPs) prevent formation of condensation water, but often involve relative humidities (RH) higher 80 % and, thus, bear the risk of mould formation [4].

With regard to vapour diffusion permeable, inorganic insulation materials (Calcium silicate, LW-AAC), elevated levels of capillary activity are discussed to be effective for counteracting condensation water formation at the interface between insulation and outer wall [5, 6]. Aim of the present study was to evaluate this assumption by means of LW-AAC samples of gradually altered capillary activity. Selected samples were tested under simulated seasonal hygrothermic cycles using a full-scale climatic test stand.

2. EXPERIMENTAL

The lightweight-AAC thermal insulation board YTONG Multipor® is a product of Xella Deutschland GmbH (Duisburg, Germany). It is manufactured from sand, cement, lime, gypsum, aluminium paste, water, inorganic fillers and organosilicone additives. Material parameters: Apparent density = 100-115 kg/m^3, compressive strength ≥ 300 kPa, thermal conductivity λ_R (23°C/50% RH) = 0,043 W/(mK), vapour diffusion resistance coefficient (μ) = 3) [7].

Highly capillary active LW-AAC was used as a base for comparison. Material parameters: Apparent density = 100-130 kg/m^3, λ_R (23°C/50% RH) = 0,042 W/(mK), vapour diffusion resistance coefficient (μ) = 3-7 [8].

Apparent densities were determined according to the standard EN 12068:1997-06. Short term water absorption by partial immersion was determined according to DIN EN 1609:1996+A1:2006, method B. The wall-scale climatic chamber can operate at temperatures between -20 and +80°C at 20 to 90 % relative humidity (RH). Two walls can be tested at the same time.

3. RESULTS AND DISCUSSION

3.1. Material properties

According to the European Technical Approval ETA-05/0093, short term water absorption by partial immersion (EN 1609:1996+A1:2006, method B) in YTONG Multipor is not allowed to exceed values of 2 kg/m^2. By varying the amount of a silicium-organic hydrophobing additive, a set of LW-AAC samples with gradually altered hydrophilicity and, thus, capillary suction was accomplished (Table 1).

Table 1. Results of the short term water absorption by partial immersion (DIN EN 1609:1996 + A1:2006, method B)

Sample name	Material type	Apparent density [kg/m^3]	Wp-value (B), DIN EN 1609 [kg/m^2]
MP-ORIG	YTONG Multipor, λ_D = 0,045 W/(mK)	108	1.8 ± 0.1
MP-TYPE 1	YTONG Multipor: Recipe # 1	109	3.1 ± 0.1
MP-TYPE 2	YTONG Multipor: Recipe # 2	104	4.1 ± 0.3
MP-TYPE 3	YTONG Multipor: Recipe # 3	105	6.6 ± 0.1
MP-TYPE 4	YTONG Multipor: Recipe # 4	105	7.8 ± 0.4
MP-TYPE 5	YTONG Multipor: Recipe # 5	104	10.6 ± 0.3
CP	Competitive product for indoor insulation	85-110	28.5 ± 0.5

Corresponding Wp-values were between 1.8 ± 0.1 kg/m^2 for the YTONG Multipor standard material (MP-ORIG) and 10.6 kg/m^2 for sample MP-TYPE 5 (Table 1). Samples were tested against a highly capillary active competitive product (CP, Wp = 28.5 kg/m^2) being merchandized with special emphasis on internal thermal insulation applications [8].

3.2. Full-scale climatic loading

Wall structures

Xella's full-scale climatic test stand (Figure 1) was employed to investigate the hygrothermal performance of two selected insulation materials. Wall systems were designed respective to internal thermal insulation applications. They are described in layers going from inside to outside as follows:

Wall system 1: 36.5 cm brick bearing wall. 140 mm insulation layer with CP-panels. For mounting and plastering, conditions and materials recommended by the manufacturer were strictly accommodated.

Wall system 2: 36.5 cm brick bearing wall. 140 mm insulation layer of MP-TYPE 5. Panels were primed with the standard "Xella-Grundierung" and mounted with "Multi-Leichtmörtel" (Xella/Fermacell). 5 mm plaster layer ("Multi-Leichtmörtel").

For bearing wall structures we used hollow bricks with an apparent density of 1,400 kg/m^3 and mortar MG III (10 N/mm^2) according to the German standard DIN 1053. Wall constructions were 1810 mm x 2500 mm (w x h) in size, each.

Boundary conditions

As given in table 2, a five-day stabilization phase at a temperature of -15°C (inside test stand, w/o RH-regulation) was followed by a 28-day humidification phase at -15°C (inside test stand, w/o RH-regulation). The cycle was completed by a drying phase at 20°C and 40 % RH. During both stabilization and humidification phase constant climate conditions of 40°C and 80% RH were maintained in the climate chamber adjacent to the test stand (Figure 1), whereas conditions were switched to 20°C and 40 % RH during the drying phase.

Table 2. Boundary conditions for the full-scale climatic test cycle

Phase	Duration [d]	Full-scale climatic test stand		Climate chamber	
		Temp. [°C]	RH [%]	Temp. [°C]	RH [%]
Stabilization	5	–15	w/o regulation	+40	80
Humidification	28	–15	w/o regulation	+40	80
Drying	> 28	+20	40	+20	40

Sampling and data collection

The spatial and temporal distribution of moisture (Figure 2) was monitored on the basis of frequently taken drill cores. Supplementary, temperature and RH were traced by data loggers placed at three positions in the constructions: At the interface between brick and insulation, in the centre of the insulation layer and at the interface between insulation and mortar.



Fig. 1. Full-scale climatic test stand with outer climate chamber.

Results

Water content profiles were retrieved over a period of 10 weeks, from July 31 to October 9 (Figure 2). We found initial moisture contents below 10 and 15 M.-%, respectively, for wall systems 1 and 2 (panels with high and intermediate capillary suction). During stabilization and humidification, the direction of the vapour diffusion flow was from the warm side (climate chamber) to the cold side (inside the full-scale climatic test stand). Under such "hibernal" conditions we found an equivalent formation of condensation water (~160 M.-%) in both structures (drill cores 1.2 and 2.2). The drying phase was characterized by two observations: A further increase of moisture content within the condensation area, followed by a back transport of water towards the evaporation area of the structure. Intermediate capillary suction values of the insulation layer resulted in a slightly higher accumulation of condensation water spread over a smaller thickness of insulation material (Figure 2. B). At the end of the drying phase, we observed approximately equivalent distributions of water in both insulation materials. Yet, water back transport provoked declining water contents in proximity to the bearing wall.

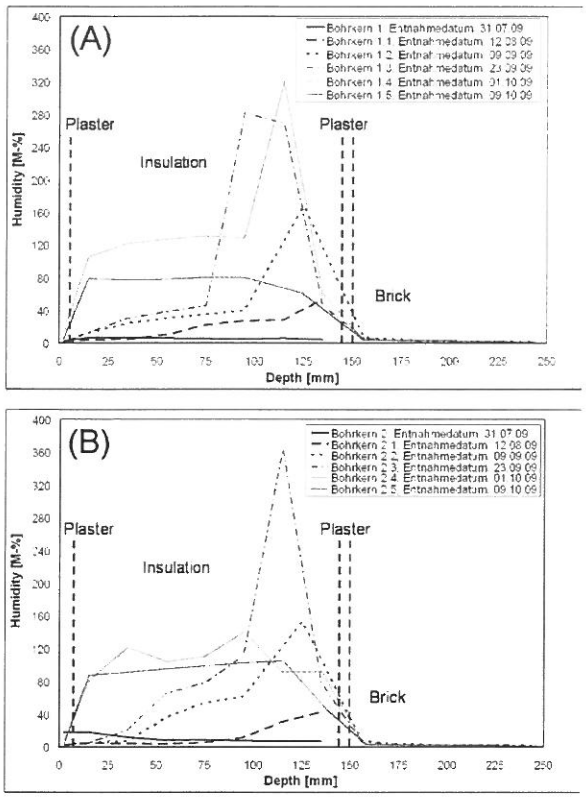


Fig. 2. Evolution of humidity profiles as measured from drill cores. (A) Wall system 1 with CP-panels (high capillary suction). (B) Wall system 2 with MP-V5 (intermediate capillary suction)

4. CONCLUSIONS

By varying the amount of organosilicone compounds during the production of lightweight-AAC YTONG Multipor it was possible to adjust the capillary suction of this insulation material on demand. Here, Wp-values (according to EN 1609:1996+A1:2006, method B) between < 2 kg/m^2 and 10.6 kg/m^2 were achieved. The most important result of the present study is that already a Wp-values of about 10 kg/m^2 facilitates a reduction of condensation water by 60 % within a reasonable timescale. This value was shown to be not amendable even at much higher capillary suction.

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