

Water storage parameters of plaster with inner hydrophobic additive

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Abstract: - In this paper water storage parameters of hydrophobic plasters are determined. This article is focus on hygric properties of lime-metakaolin plaster connected with hydrophobicity. Most physic-chemical deterioration of building materials related to the penetration of moisture into building structure. Therefore, the aim of the testing was in description of influence of inner hydrophobic additive, which was applied to the interior structure of the element. Higher resistance of penetration water into materials show samples with hydrophobic additive. Water storage parameters are slightly better for plaster without hydrophobisation. However from the quantitative point of view the difference was not so important. Measurement involves not only properties of hydrophobic plaster, but comparative measurements with pure lime-metakaolin plaster were done as well.

Key-Words: - Plaster, hydrophobic additive, hygric properties, storage, transport.

1 Introduction

Exterior layer of plaster should protect the building and load-bearing materials from the effects of external environment and prolong their service life. Most of the damage on building structures directly related to the infiltration of moisture into building structures and material. Porous building materials could absorb a lot of water due to its porous structure which may cause some negative effects on material. Important negative side effect is water as the carrier medium. Transport of ions in direction away from construction could lead to leaching of the compounds and their subsequent efflorescence on the surface [1]. In the opposite direction harmful substances such as chloride ions from de-icing salt may be carried into the material and therefore slightly damage its structure [2].

Important parts of lime plaster are hydrophobic additives, which can limit water absorption. If hydrophobic admixture is added to plaster, hydrophilic part of molecule is connected to mineral structure while hydrophobic part is oriented outside the structure and can repulse water. The hydrophobic principle is about to increase surface tension together with contact angle of water due to formed hydrophobic layer on the inside surface of pore. Hydrophobic admixtures have to reduce pore walls wettability and replace capillary suction by capillary depression. Addition of hydrophobisation

admixture to lime plaster leads to lower sorptivity and better resistance to water and aggressive solution penetration. Fatty acid salts are often used as a hydrophobisator, namely calcium or zinc stearate [3].

The principle of hydrophobicity as a function method for increases durability and service life of building materials is described in this paper [4]. The article is about influence of inner hydrophobic additive on hygric properties of lime-metakaolin plaster. Specifically, the main part of the article relates to the storage parameters for modified plaster in the form of sorption isotherm.

2 Problem Formulation

Mechanical destruction is most commonly caused by the action of water, withholding, running, rising ground water and condensation. For this reason, it is necessary to know the material ability to absorb moisture. For description water storage parameters, the sorption isotherm and water retention curve were measured. The sorption isotherms were measured employing desiccators with different salt solutions for simulation of specific relative humidities. The water retention curve was determined using an ordinary pressure plate device [5].

2.1 Materials and samples

In this paper, two lime-based plasters with metakaolin were studied. The first of them was with hydrophobic addition (denoted as HP) and the second one (denoted as P) was without for comparative purposes. Metakaolin, a highly active pozzolanic material, is used instead of lime as an alternative silicate binder. Metakaolin replace 15% of lime by weight. The reason for using it is the supposed increase of compressive and flexural strength. To improve high values of hydric properties was used zinc stearate $[\text{CH}_3(\text{CH}_2)_{16}\text{COO}]_2\text{Zn}$ as the hydrophobic admixture for the lime-pozzolana plaster. The water/binder ratio was modified according to mixture workability.

Both plaster (P and HP) were prepared in mass of ingredients: a binder (lime plus metakaolin) and standardized sand as 1:3. Plaster mixtures were prepared using laboratory mixing machine. Each mixture was cast into a standard prism form, after two days all prisms were taken out of forms and then cured for 28 days in high relative humidity environment.

Comparative measurements without any hydrophobic additives were done as well. The test has started 28 days after manufacture of specimen had been made, to give enough time for hardening samples.

2.1 Experimental measurement

The measurement of basic parameters took place in a conditioned laboratory at the temperature of 22 ± 1 °C and 25-30 % relative humidity. Each result represents the average value from three to five measured values.

Basic properties of material were measured at first. As fundamental physical material characteristics, bulk density ρ_b [kg m^{-3}], matrix density ρ_m [kg m^{-3}], mechanical properties [MPa] and open porosity ψ [%] were determined.

The main driving force transmission of moisture in hygroscopic area is transport of water vapor. Moisture accumulation curve is known as sorption isotherms. It expresses the dependence of the moisture content of material on the relative humidity of the surroundings [6]. Sorption isotherms were measured employing desiccators with different salt solutions to simulate different values of relative humidity. The initial state for all the measurements was dry material. The experiment was performed parallel in all desiccators in thermostatic chamber at 25 °C. The water adsorption and desorption in a porous material are

based on van der Waals forces between the surface of the porous matrix and water molecules. The dry material mass increases after a contact with moist air because of gradual bonding of water molecules from the air to the pore walls, in the case of adsorption. At the moment of achieving the equilibrium state between the water vapour pressure in the moist material and in the surrounding air this process is stopped. The mass of samples was measured in specified periods of time until steady state value of mass was achieved. Then, the water content by volume w [-] was calculated according to the equation 4.

$$w = \frac{m_s - m_0}{V \cdot \rho_w} \quad (1)$$

where m_s is the mass of the wet sample in steady state conditions [kg] and m_0 is the initial mass of the sample [kg], ρ_w is water density [kg m^{-3}].

In the overhygroscopic moisture range, where liquid water transport is the dominant mode of moisture transfer, the moisture storage function is called the water retention curve [7]. For the principle of determination of water retention curve is used classical methods of pressure plate device. A capillary saturated specimen of a porous material is placed on a semi-permeable plate covered by a fine kaolin layer and a fine meshed cloth and exposed to either underpressure under the plate or overpressure above the plate. Due to the pressure difference between the interior of the porous body and the surroundings, the porous plate either draws in water from the specimen or transfers water to it, until pressure equilibrium is achieved. At that moment, the pressure in the porous space (i.e. the capillary pressure) is equal to the pressure in the measuring device, which can be easily determined. The moisture content is measured by the gravimetric method, i.e. by weighing the specimen before and after the process, or by measuring the volume of the drained or supplied water. After the measurements were finished the water content by volume w of the specimen was calculated at each pressure level and a water retention curve was constructed as $w = w(p)$ function using the measured $[p_i, w_i]$ points.

The sorption isotherm and the water retention curve for the same material can be unified into a general moisture storage function using the Kelvin relation, the relationship between the relative humidity and the capillary pressure p_c in the pores at isothermal conditions:

$$\phi = \frac{P_v}{P_{vs}} = \exp\left(-\frac{P_c}{\rho_l R_v T}\right) \quad (2)$$

where p_v is water vapour pressure [Pa], p_{vs} is saturation vapour pressure [Pa], ρ_l is density of liquid water [kg m^{-3}], R_v is gas constant of water vapour [$\text{J mol}^{-1}\text{K}^{-1}$] and T is absolute temperature [K]. p_{vs} can be obtained from Clausius-Clapeyron equation, which links saturation vapour pressure with temperature, and p_c , which describes relation between capillary pressure and pore radius of the tube, can be calculated from the Young- Laplace law:

$$p_c = \frac{2\sigma}{r} \cos(\theta) \tag{3}$$

3 Problem Solution

First basic properties as bulk and matrix density, open porosity and flexural strength after 28 days were determined. Results are shown in Table 1. Introduced results are the average of three and more measured values.

Tab. 1 Basic materials properties

No.	ρ_b	ρ_{mat}	Ψ	f_{cf}
	[kg m^{-3}]	[kg m^{-3}]	[$\text{g/m}^2\text{h}^{0,5}$]	[MPa]
P	1695	2620	35.4	1.90
HP	1745	2615	33.2	1.26

Influence of hydrophobic additive on basic parameters was negligible. The difference was about few percent. Hydrophobic plaster HP achieved lower open porosity and thus higher bulk density.

The results of measuring storage water are shown in Fig 1. For the both studied plasters the obtained water storage parameters were almost similar taking into account the accuracy of measured method.

If we compare the behavior of all tested materials, the sorption curves clearly show that the HP is able to absorb more moisture than the P at the fully saturated state. However due to hydrophobic additive plaster HP has slower absorption on the beginning of sorption curve. Desorption curves are very similar. From the adsorption isotherms it is clear that the adsorption capacity of HP especially at relative humidity in range 75-95% is smaller. It is means that hysteresis of P is larger than HP. The adsorption isotherms, constructed from the measured points, were shown at Figure 1.

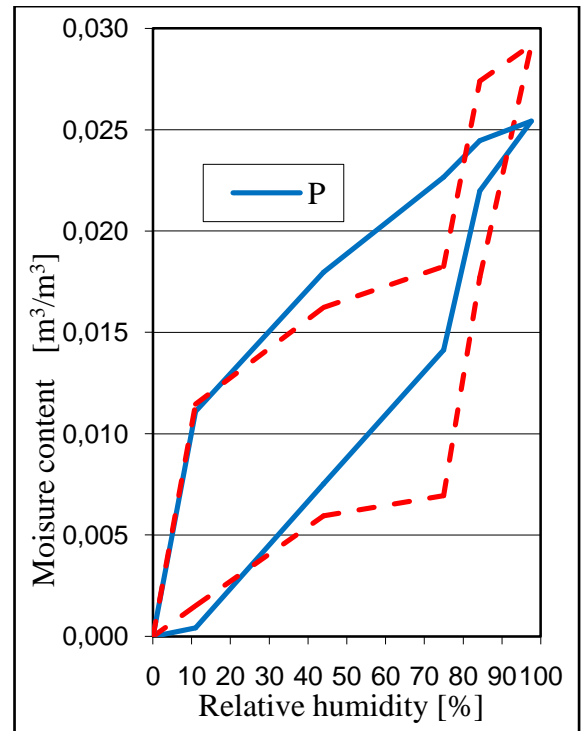


Fig.1 Sorption isotherm of tested materials

The steepest decline in moisture content with increasing pressure shows HP, which has characterized break by retention curve around 2-3 bars. The slower decline curve means the lower the relative amount of capillary pores in the material. However the open porosity of P is higher so plaster P must contend higher amount of larges pores. Figure 2 clearly shows that most water is able to absorb HP, which contains a large amount of capillary pores. Different amount of capillary pores in plaster was created due to hydrophobic additive.

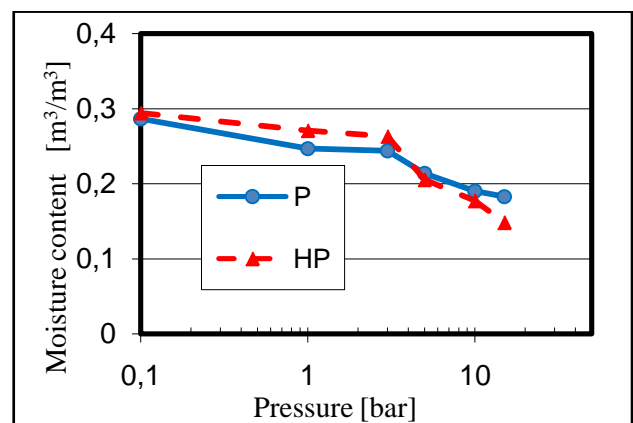


Fig.2 Retention curve

Using the Kelvin equation can be obtained from the measurement data retention adapted into the desorption curves. Fig. 3 shows a water retention

curves adapted into the desorption curves. Lower capacity has P, which has smaller number of small capillary pores.

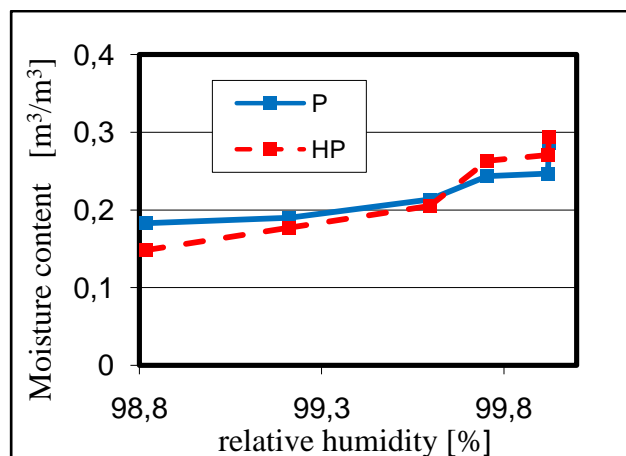


Fig.3 Retention curve adapted into the desorption curves

4 Conclusion

In this work were presented the hygric properties of hydro and non-hydrophobic plaster. In many cases causation of significant damage is moisture in the form of gaseous or liquid. Therefore water transport and storage parameters are necessary for basic assessment of the behavior of these materials in construction.

Basic properties such both plasters remained unchanged. Differences are within the variations in measurements.

Analysis of measured showed that open porosity decrease and more capillary pores created by adding hydrophobic admixture. This is a negative effect as a risk of damage due to ice formation (higher storage capacity). Open pore structures with large pores have enough free space for crystal growth so that crystallization does not lead to damage of internal structure. However, from the quantitative point of view the differences were not very high so that this is only a minor flaw on otherwise significantly improvement of hygric properties of tested material

In future work, measurement of salt transport and storage properties of the designed lime-metakaolin plaster with and without hydrophobic admixture will be done.

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