THE EFFECT OF HYDROPHOBIZATION ON THE PROPERTIES OF FGD GYPSUM

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Abstract

The measurements of basic physical, thermal and hygric parameters of hardened gypsum modified by the addition of hydrophobization substances are carried out. Bulk density, open porosity, thermal conductivity, thermal diffusivity, volumetric heat capacity, water absorption coefficient and apparent moisture diffusivity are determined and compared to the properties of hardened gypsum without any admixtures.

Key words: calcined gypsum, modified gypsum, hydrophobization.

1 Introduction

The solid structure of calcined gypsum is created by reverse hydration from the flue waste gas desulfurization (FGD) gypsum $CaSO_4.2H_2O$ when gypsum $CaSO_4.2H_2O$ is formed according to the equation:

$$CaSO_4.1/2H_2O + 1\ 1/2H_2O \rightarrow CaSO_4.2H_2O \quad (1)$$

This compound is relatively soluble in water, its solubility is 256 mg in 100 g of water at 20°C. The resistance of hardened gypsum against water (relative humidity, rain etc.) is generally a serious problem. For the utilization of gypsum elements in the exterior, it is necessary to modify it so that it would exhibit more suitable properties and longer service life. Modifications of gypsum are usually performed using polymer materials. Possibilities of modification are in two different scopes. The first scope is using a hydrophobization admixture in the course of sample production. The second one is impregnation of specimen surfaces.

There are some examples in the literature of using hydrophobization admixtures to gypsum. For instance, Colak [1] impregnated the gypsum surface by various epoxy resins and studied the effect of impregnation on mechanical properties and water sorption. While the flexural strength was not changed due to the impregnation, some resins were found to protect gypsum completely from water penetration. However, generally it can be stated that the resistance of hardened gypsum against water is not yet resolved in a satisfactory way.

In this paper, the measurements of basic physical, thermal and hygric parameters of hardened gypsum modified by the addition of hydrophobization substances are carried out. Bulk density, matrix density, open porosity, thermal conductivity, volumetric heat capacity, water absorption koeficient, apperent moisture diffusivity and sorption isotherms are determined and compared to the properties of hardened gypsum without any admixtures.

2 Experimentals methods

Basic physical properties were measured by vacuum pump experiment. Sorption isotherms were measured by the classical desiccator method. The apparent moisture diffusivity was determined on the basis of a common water sorption experiment. The thermal conductivity was measured in laboratory conditions using the commercial device ISOMET 2104 (Applied Precision, Ltd.).

More detailed information about the methods used for measurement of basic physical, thermal and hygric properties can be found in [2], [3].

3 Material and samples

The material, which was used for reference measurements (non-hydrophobized material – denoted as S0) and the measurements of the effect of hydrophobization, was β-form of calcined gypsum with purity higher than 98 % of FGD gypsum, produced at the electric power station Počerady, CZ.

Hydrophobization admixtures used for our investigation were common commercially available materials. The first modification (the modified gypsum denoted as S3) contained the admixture IMESTA IBS 47 (an alloyed hydrophobization powder for gypsum compounds) produced by Imesta Inc., Dubá u České Lípy, CZ. Concentration of this admixture was 0.5% by mass. The second one (the modified gypsum denoted as S4) contained the admixture ZONYL 9027 (a fluorochemical solution that provides a durable, subsurface, transparent, protective barrier against oil and water on porous surfaces) produced by Du Pont, USA. This admixture was used as a 5 % solution in water.

The water/gypsum ratio, the hydrophobization admixture and the concentration of the admixture) of the measured materials are shown in Table 1.

Table 1 Composition of measured materials

Material	Water/gypsum ratio	Hydroph. admixtures	Concentration
S0	0.627	none	none
S3	0.627	Imesta IBS 47	0,5% by mass
S4	0.627	Zonyl 9027	5% solution

The samples were mixed according to the Czech standard ČSN 72 2301 [4]. For the measurements of particular physical, thermal and hygric parameters, we used the same specifications for the samples as for the reference measurements in [2], [3].

For the measurements of particular parameters, we used the following samples: apparent moisture diffusivity – 6 specimens 50 x 50 x 23-25 mm, thermal conductivity and volumetric heat capacity – 6 specimens 70 x 70 x 70 mm, sorption isotherm – 20 specimens 30 x 30 x 10 mm.

4 Experimental results and discussion

The basic properties – bulk density, matrix density and open porosity of the non-modified and modified gypsum are shown in Table 2.

Table 2 Basic physical properties of measured materials

Material	Bulk density [kgm^{-3}]	Matrix density [kgm^{-3}]	Open porosity [% by volume]
S0	1019 ± 1.5%	2530 ± 2.0%	60 ± 3.4%
S3	942 ± 1.5%	2534 ± 5.7%	63 ± 2.8%
S4	941 ± 1.5%	2741 ± 3.3%	66 ± 2.3%

The values of bulk density were very similar for all three studied materials. This can be explained by the fact that water/gypsum ratio was the same for all materials. The minor differences in open porosity corresponded to the differences in bulk density.

Table 3 Thermal properties of measured materials

Material	Thermal conductivity [Wm^{-1}K^{-1}]	Volumetric heat capacity [Jm^{-3}K^{-1}]	Thermal diffusivity [m^{2}s^{-1}]
S0	0.47 ± 10%	(1.60 ± 10%)E+6	(0.29 ± 10%)E-6
S3	0.41 ± 10%	(1.51 ± 10%)E+6	(0.28 ± 10%)E-6
S4	0.38 ± 9%	(1.50 ± 10%)E+6	(0.23 ± 10%)E-6

Table 3 shows basic thermal properties measured by ISOMET 2104 (Applied Precision, SK). The measured samples were in equilibrium with the following laboratory conditions: relative humidity 50% and temperature about 20 °C. The differences in thermal conductivity are in a good agreement with the differences in open porosity, so that the material S4 shows the best thermal properties.

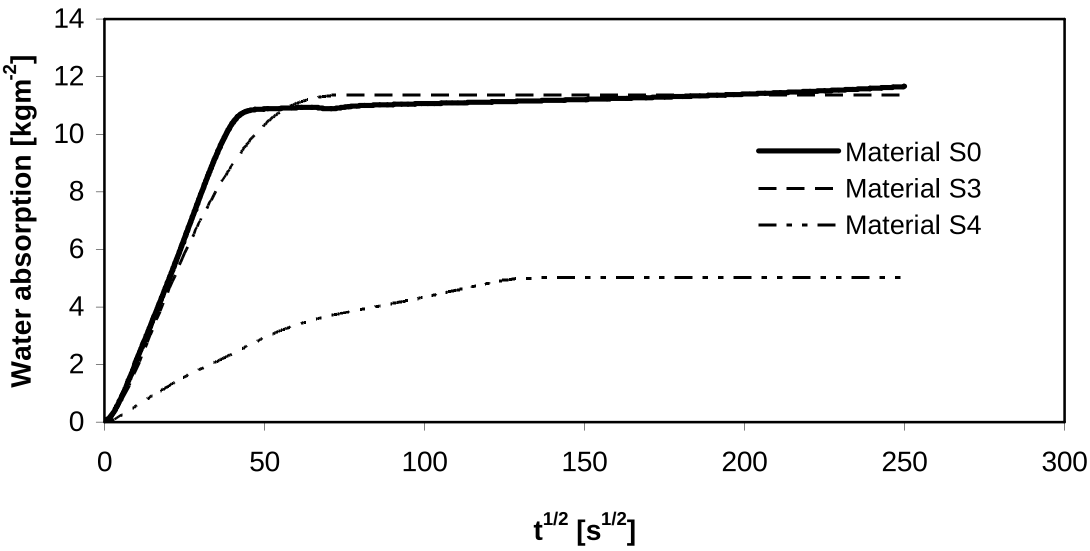

Fig.1 Results of the water absorption experiment

Table 4 Hygric properties of measured materials

Material	Water absorption coefficient [$kgm^{-2}s^{-1/2}$]	Apparent moisture diffusivity [m^2s^{-1}]
S0	0.31	2.63 E-7
S3	0.25	1.47 E-7
S4	0.06	7.32 E-9

Figure 1 shows the dependence of water absorption [kgm^{-2}] on the square root of time [$s^{1/2}$]. Clearly, the effect of hydrophobization was well remarkable in material S4 but for the material S3 no significant changes compared to the reference material S0 were observed.

Table 4 shows the quantification of experimental results of the water absorption experiment in the form of water absorption coefficient and apparent moisture diffusivity. We can see that for the material S4 the water absorption coefficient and the apparent moisture diffusivity are significantly lower that for the reference material S0 and the modified material S3.

Figure 2 shows a comparison of the sorption isotherms of non-modified and modified gypsum samples. In this case, the effect of hydrophobization was remarkable for both S3 and S4 modifications, particularly in the range of high relative humidity where a decrease as high as 20-30% was observed.

Summarizing the results of water transport and water storage properties, we can state that the hydrophobization of the material S4 (ZONYL 9027) was very successful for the studied gypsum. The modified gypsum S3 with the hydrophobization admixture IMESTA IBS 47 (S3) exhibited lower effect of hydrophobization particularly in a relation to liquid water transport.

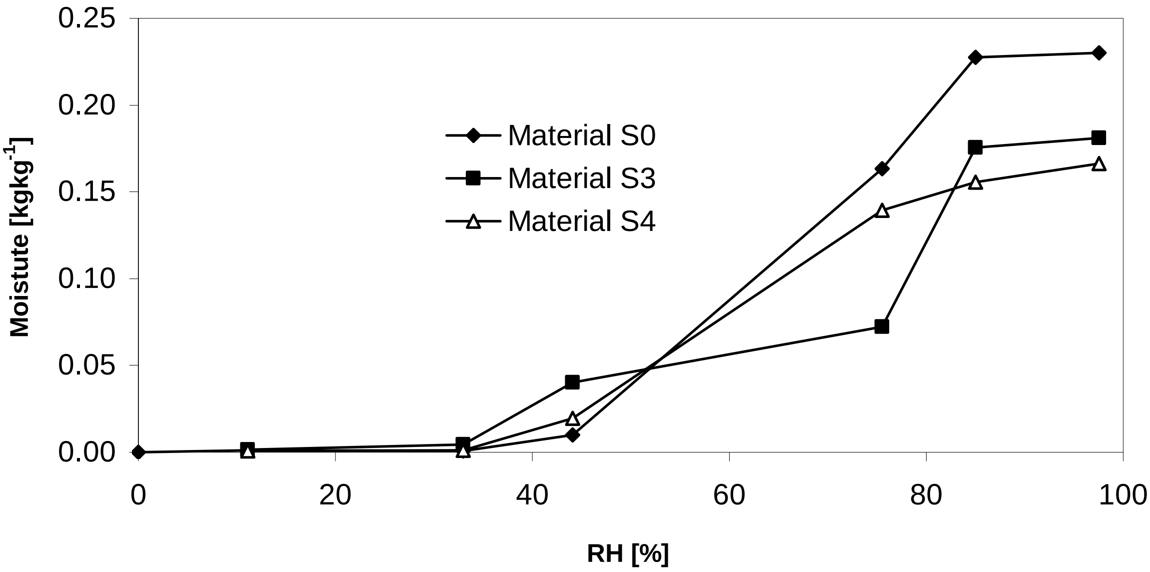

Fig.2 Sorption isotherm of the measured materials

5 Conclusions

The measurements of physical, hygric and thermal properties in this paper have shown that only the hydrophobization admixture ZONYL 9027 applied to the modification of FGD gypsum (material S4) can be used in further applications. This admixture decreased the apparent moisture diffusivity of FGD gypsum by about two orders of magnitude, which is a very good result. The modified material exhibited liquid water properties somewhere on the level of common cement based materials. Also, the hygroscopic behaviour of the material S4 was reduced and the material exhibited best thermal properties among the studied gypsum materials.

On the other hand, the hygric properties of the material S3 with the hydrophobization admixture IMESTA IBS 47 (concentration - 0.5% by mass) were improved in the hygroscopic range only. The liquid water transport in this material remained practically the same fast as in the reference gypsum material. This is not an acceptable result because any fast liquid water transport can lead to a fast increase in water content in the material and consequently to the worsening of mechanical properties.

Acknowledgement

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