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UTILIZATION OF SUPERABSORBENT POLYMERS IN PLASTERS FOR MODERATION OF INDOOR RELATIVE HUMIDITY LEVEL

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Nowadays, the energy efficiency and moderation of indoor environment of buildings became important topic in the field of building physics. Moisture occurrence in building construction poses a significant task for building designers and material engineers. Among other factors, a high level of relative humidity has negative effect on the work efficiency and health of building inhabitants. The presented paper is aimed on the analysis of chosen superabsorbent polymers (SAPs) and its influence on properties of newly developed interior plasters. The identification of optimal ratio between superabsorbent polymers and plaster mixture from the point of view of the workability of fresh mixtures is done. Also, the effect of water/dry mixture ratio is studied according to enhanced absorption capability of SAPs. Specific attention is paid to hygric properties, the determination of apparent moisture diffusivity, water vapor resistance factor and estimation of sorption isotherms. Obtained results directly point to significant effect of SAP admixture on material properties of developed plasters. Namely, addition of up to 3 wt.% of SAPs shifts the water absorption coefficient almost ten-times, while the total open porosity is increased only about 20%. Such materials can be applied for the damped areas or places where increased water transport parameters play an important role for the efficient moisture removal.

Keywords: Indoor climate, Moisture moderation, Hygric properties.

1 INTRUDUCTION

Moisture level significantly affects durability of constructions, their thermal performance and quality of indoor air. Although modern advanced ventilation systems provide sufficient air exchange rate, their wider application conflicts with sustainability development principles due to high energy demands (Koffi *et al.* 2011). Moreover, according to the European legislation related to the Nearly Zero Energy Buildings, air tightness of building envelopes leads to large moisture loads in building interiors. Especially in case of passive and low energy houses, the water vapor from numerous moisture sources and as a natural consequence of the changing weather conditions represent substantial moisture loads and can induce undesirable indoor conditions (Johansson *et al.* 2012). On the other hand, the low relative humidity level of the indoor air poses a problem, which have been struggling mostly during winter when indoor relative humidity often drops below 30% as the response to the relatively dry continental climate (Toftum *et al.* 1998). In addition, some specific buildings such as museums or galleries require specific indoor humidity levels to secure appropriate indoor conditions for historical artifacts.

The extensive research comprising utilization of mortars for ambient control by the combination of vermiculite, perlite and super absorbent polymers was made by Gonçalves *et al.* 2014. Mixtures with SAP achieved the most promising results in the field of humidity control in comparison with the other materials. The addition of perlite and vermiculite brings an increase of the moisture buffering compared to reference sample, but not so significantly. On the other hand, according to the high demands of SAP containing mixtures on the amount of batch water, the highest unrestrained shrinkage, weight changes and strong reduction of mechanical properties was obtained. Further research of application of SAP and porogene additives (aluminum powder-AP, sodium olefin-sulphonate-SOS) in the mortars was conducted in a study of Yang *et al.* (2011), which was focused on finding compromise between moisture buffer capacity and in particular mechanical properties. Here, the mixture with AP and SOS additives did not significantly shifted the moisture buffer properties of studied mortars. The lower SAP dosage resulted in decrease of the unrestrained shrinkage but also drop of capability to absorb water molecules. Senff *et al.* (2015) investigated the influence of difference dosages of SAP on rheological and mechanical properties. The combined effect of various dosages of SAP and w/c ratios on workability revealed importance of rheometry tests which play relevant role on the final properties. Necessity to increase of w/c ratio in line with SAP addition did not cause increase of the capillary index of mortars but negative impact on the flexural strength was obtained.

The superabsorbent polymers can provide a suitable environment for organisms such as fungi, yeasts, algae, lichens, protozoas or mites thank these properties (Haas *et al.* 2014). However, the presence of these organisms in indoor environment may pose the health problems for buildings occupants. Spores and metabolic products as enzymes and toxins may again get into the environment and sensitive persons may suffer from allergies and other diseases. Moreover, microbes under conditions when fungal peroxidases or cellobiose dehydrogenase are produced could mineralize polymers after solubilisation (Stahl *et al.* 2000).

Based on the literature survey, several attempts in the field of moderation and description of the relationship between indoor climate conditions, building inhabitants, and moisture performance of building materials can be found. The presented study is aimed at evaluation of influence of SAP admixtures on the basic physical and especially moisture transport parameters of newly designed plaster mixtures to outline possible ways for development of new type of plasters.

2 MATERIAL AND METHODS

2.1 Used Materials

Commercially produced cement-lime core plaster WEBER MV1 was used as a reference material, which was further enriched by particular SAP admixtures.

Table 1. Mixture composition.

Mixture	Dry plaster mixture (kg)	Water (kg)	SAP (kg)
PR	5	0.8	-
PS1	5	1.1	0.05
PS2	5	1.3	0.1
PS3	5	1.5	0.15

Free flowing white granules of SAP Favor Pac 300 with diameter about 500 – 2,000 μm from Evonik Industries (Germany) were used. Such material was applied for modification of reference plaster mixture in three grades. The detail description of particular mixtures enriched by 1, 2 and 3 wt.% of SAP is given in Table 1. Higher dosage of SAP was not tested because of negative effect of SAPs on the workability of fresh mixtures.

2.2 Determination Methods

Basic physical properties of studied plasters were characterized by meaning of measurement of the bulk density, the matrix density and the total open porosity. Performed measurement of the bulk density was done on five cubic samples of 50 mm side and determined from the measurement of sample sizes (using digital caliper) and its dry mass. The matrix density was accessed by helium pycnometry using apparatus Pycnomatic ATC (Thermo Scientific). The accuracy of the gas volume measurement using this device is ±0.01% from the measured value, whereas the accuracy of used analytical balances is ±0.0001 g. The measurement of bulk density uncertainty was 5.3% and 3% for matrix density.

The cup method in dry-cup arrangement was employed in the characterization of water vapor transport. It was based on measuring the diffusion water vapor flux through the specimen and partial water vapor pressure in the air under and above specific specimen surface. Water vapor transmission properties of a studied material were found by placing a specimen of the material on the top of a stainless-steel cup, whereas the specimen was in contact with the cup sealed by technical plasticine. For the measurement 5 samples with dimensions of 100 x 100 mm and 50 mm thickness were used. The cup contained a sorption material, namely silica gel. Measuring cups were placed in a controlled climate chamber and weighed periodically. The steady state values of mass gain were utilized for the determination of water vapor transport properties.

The ability of designed plasters to transport liquid water was described by the measurement of water absorption coefficient, which was defined as:

$$i = A \cdot t^{1/2} \tag{1}$$

where i (kg/m^2) is the cumulative mass of water, A (kg/m^{2}s$^{1/2}$) the water absorption coefficient and t the time (s). The water sorptivity test was used in the experiments.

For measurement of sorption and desorption isotherms, dynamic vapor sorption device DVS-Advantage was used, whereas the measurements were done at 21 °C. Before the measurement, the sample of studied material was dried at first and maintained in desiccator during cooling. Then, the sample was put into the climatic chamber of the DVS-Advantage instrument and hung on the automatic balances in the special steel tube. The instrument measures the uptake and loss of vapor gravimetrically, using highly precise balances having the resolution of 1.0 μg. Such a high resolution is obtained by hanging samples on the end of a beam where the position of the beam is measured by an optical sensor. The particular samples were exposed to the following partial water vapor pressure profile: 0; 20; 40; 60; 80 and 95% of relative humidity (RH). Each step in RH during the DVS measurement is incremented either when a stable mass is achieved with mass change less than 0.00004% /min or a maximum time interval of 400 min is reached. Because reaching of sample mass equilibrium at high RH was problematic, the maximum time interval of samples exposure to RH of 80% was 4000 min, and for RH of 98% it was extended up to 7000 min. The sample mass was 5–10 g.

3 RESULTS AND DISSCUSION

3.1 Basic Physical Properties

The basic physical properties of studied mixtures are shown in Table 2. Here, the bulk density, matrix density and total open porosity are given to highlight differences between individual mixtures and allow more coherent comparison of material parameters. The incorporation of 1 wt.% of SAPs did not result in fundamental decrease of the bulk density and the total open porosity was increased only about 3% to almost 41%. However, further addition of SAPs in case of PS2 and PS3 mixture significantly affected bulk density and total open porosity, while the matrix density remained almost constant. Here as one can see, a significant drop of the bulk density was obtained when the amount of SAP admixture exceeded 2 wt.%. To be specific, incorporation of 2 and 3 wt.% of SAPs led to the decrease of the bulk density to 1,225 kg/m^3 and 1,203 kg/m^3 respectively. The most distinct changes are visible for the total open porosity, which was shifted to 52.4 % and 53.1 % respectively.

Table 2. Basic material properties of designed mixtures.

Mixture	**Bulk density (kg/m^3)**	**Matrix density (kg/m^3)**	**Total open porosity (%)**
PR	1593	2547.9	37.5
PS1	1511.3	2549.6	40.7
PS2	1224.8	2574.2	52.4
PS3	1203.3	2563.2	53.1

3.2 Hygric Properties

The outstanding hygric storage properties of the pure SAPs were partially transferred to the newly developed mixtures and thus, the hygric properties of developed plasters were affected in great extent. The detail results of the water absorption coefficient and the moisture diffusivity coefficient are given in Table 3.

Table 3. Hygric properties.

Mixture	**Moisture diffusivity (m^2/s)**	**Water absorption coefficient ($kg/m^2s^{1/2}$)**
PR	9.93E-08	0.0379
PS1	3.76E-07	0.0779
PS2	6.80E-07	0.2425
PS3	1.02E-06	0.3737

Here, the hygric transport properties obtained for reference plaster were strongly changed when SAP admixture was added. The incorporation of 1 wt.% of SAP resulted in the doubled water absorption coefficient as well as for the moisture diffusivity coefficient. Obtained shift cannot be assigned only to increase of the total open porosity as was described latter and this notable change is linked to the very high water absorption of incorporated SAP admixture. The fundamental impact of the SAP addition was further confirmed by achieved results for other mixtures. The water absorption coefficient was significantly increased when SAP admixture exceeded 2 wt.%. Here, for PS2 mixture was eight times higher, while for PS 3 exceeded more than ten times initial value achieved by the reference plaster. Similar results were obtained also for the coefficient of moisture diffusivity, which was improved almost about three orders of magnitude.

3.3 Water Vapor Properties

The effect of increased moisture uptake was also studied by meaning of sorption isotherms and water vapor transport. Results of the cup method used for the determination of water vapor properties are given in Table 4 together with data of equilibrium moisture content (EMC) calculated from measurement of sorption isotherms. Here, similar behavior as was described in previous section was noted also for the water vapor transport and storage parameters. Looking at results of the water vapor diffusion coefficient, is possible to distinguish very strong effect of incorporated SAPs on material response when is exposed to the elevated humidity level. Namely, water vapor resistance factor was more than two times lower compared to the reference plaster. This fact can be assigned to the coupled effect of the increased total open porosity and moisture storage ability of SAP particles. EMC values were affected to a far greater extent and modified plaster was able to store more than five times higher amount (PS3) of water vapor compared to the reference plaster.

Table 4. Water vapor properties.

Mixture	Water vapor resistance factor (-)	EMC (%)
PR	16.8	0.9399
PS1	12.3	1.4961
PS2	9.8	3.9842
PS3	7.3	6.1631

4 CONCLUSIONS

The performed experimental analysis of the basic physical and hygric properties of cement-lime plasters modified by SAP admixture revealed an interesting behavior of such materials. Dosages of the SAP admixture is limited according the increased swelling capability of SAP materials. However even for small amounts of applied SAP is possible to distinguish very significant changes in material behavior, especially in case when is exposed to increased moisture level. While the mixture PS1 with SAP admixture only about 1 wt.% did not modified structure and texture of material to a greater extent, increase of SAP admixture over 2wt.% led to substantial increase of the total open porosity. Notwithstanding, massive increase of the water transport properties cannot be assigned only to this phenomenon. Major cause of these changes is related to outstanding absorption capacity of SAP admixture, which resulted in a multiple increase of all water transport parameters. Such material parameters can be easily utilized for design of new type of plaster applicable for the damped areas or places where are increased demands on moisture removal (from air or walls).

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