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The effect of hydrophobization on the properties of mortar mixtures

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Abstract. One of the possible methods to reduce degradation effects due to the influence of moisture on building structures and materials is the use of hydrophobic agents - hydrophobization. The article deals with the influence of the hydrophobic preparations use on the change of mortar mixtures properties, where not only the impact on capillary absorption, but also other key properties which can be influenced by the application of the hydrophobic agent, are monitored. By realizing a wide range of measurements, optimal concentrations were determined to achieve properties comparable with the rehabilitation materials without negative effect on other key properties of mortar mixtures, when is mainly a significant reduction of the capillary absorption factor of mortar mixtures only at tiny changing the thermal conductivity factor of the mortar mixtures and without proved changing the other monitored properties.

1. Introduction

One of the main factors that can significantly reduce the durability of the building is the influence effect of moisture [1]. In particular, this is a liquid form of moisture, which is primarily getting in construction due to a direct exposure of the construction to the moisture. In this case, the moisture in the construction spreads through the capillary system of materials - capillary absorption [2-3]. The most effective protection against this exposure of moisture is to prevent contact of moisture in the liquid form with the construction or the use of special materials for this purpose - waterproofing. In case of failure of these protection methods, either due to inappropriate design and use of the building, unprofessional application or mechanical damage of waterproofing, to reduce the impact of moisture degradation it is possible to use reducing capillary absorption of building materials. One of the possible measures is the hydrophobization of building materials and mortar mixtures from which the structures are made [4-5].

2. Tested materials

For the experimental part, four basic mortar mixtures were chosen - masonry mortars and plasters. This is a basic masonry mortar for all masonry works, rough coating plaster and masonry mortar applicable to masonry and coating plastering. A detailed description is given in table 1.

Table 1. Overview and description of the tested mortar mixtures [6].

	Description	Application
Baumit MM 50	Industrially manufactured dry mortar mixture for manual and machine processing.	Masonry mortar for all types of common masonry elements, for supporting walls, partitions and chimney bodies.
Baumit Manu 4	Industrially manufactured dry plaster mixture for manual processing in the exterior and interior.	Rough coating plaster for manual plastering, usable both in exterior and interior.
Baumit DuoDur	Industrially manufactured dry mixture suitable as masonry mortar as a universal plaster for manual processing.	Masonry mortar for all types of common masonry elements, for supporting walls and partitions. Coating plaster for manual plastering, usable both in exterior and interior.

The selected mixtures were mixed with water according to the manufacturer's recommendations and the individual consistencies were monitored by spill on a jogging table according to European standard
EN 1015-3 Testing methods for masonry mortars. Test specimens were prepared from individual mixtures, resp. from the pure reference mixture and subsequently with the addition of a hydrophobic agent. The hydrophobic agent was dosed to a total volume of mixture in an amount of 0.2 %, 0.6 % and 1.0 %. It was a silicone emulsion hydrophobic agent with a recommended dosage of 0.5 to 0.8 % of the finished mortar mixture volume. Silicone based hydrophobic agents work on principle of changing the physical-chemical properties of the material, in particular in a substantial increase of the wetting angle, which significantly reduces the absorption of moisture in the liquid form into the material.

3. Testing methodology

Test specimens were produced from individual mortar mixtures, namely 40 mm x 40 mm x 160 mm beam for the density in fresh and matured state and the capillary water absorption determining. Slabs 300 mm x 300 mm x 50 mm were also produced to determine the thermal conductivity factor and circular samples to determine the diffusion resistance factor.

3.1. Bulk density

The density in the fresh state was determined on 40 mm x 40 mm x 160 mm beams. By weighing the triple forms during production of the test specimens [7]. The density in the matured state was determined after 7 and 28 days of aging.

3.2. Adhesion

The effect of the hydrophobic agent on the adhesion both on the reference surface - concrete and ceramic masonry blocks was tested in the recipes. In case of adhesion to the concrete surface, the individual mixtures were applied in a uniform 10 mm thick layer to pre-moistened concrete slabs. In the case of adhesion to ceramic masonry fittings, the individual mixtures were also applied at a thickness of 10 mm in width of the ceramic wall fittings. In both cases, after 28 days of sample maturation, steel targets with a diameter of 50 mm by using two-component Sikadur glue were glued on the specimens. After curing, the targets were cut with the angle grinder in accordance with the relevant standard, always through the tested mixture to the subbase, and subsequently the adhesion by the DYNA Z 16 device was determined [8].

3.3. Capillary absorption
Determination of capillary absorption was performed on the beams made for this purpose. All of the longer surfaces must first be provided with a waterproofing coating so that water could then flow through only the lower square surface. After the waterproofing coat was matured, the beams were broken transversely into two halves. Each beam was weighed and with broken side down was put into a plastic container on a grid. The beams were watered up to a height of 5 to 10 mm from the bottom surface. At specified times, the weight gain of the test specimens was monitored as a result of water absorption. After the last weighing, each beam was longitudinally broken by a hammer and a steel chisel. On the fracture area of the sample was measured the height of the water rising [9].

3.4. Diffusion resistance
The principle of determining the diffusion resistance of mixtures consists of accurately monitoring the amount of moisture passing through by the material defined surface and the thickness of the material at fixed boundary environmental conditions. Prior to the start of testing, individual specimens were covered with silicone throughout their height to ensure a defined area. The specimens thus prepared were fixed by silicone on special testing vessels filled with dried silica gel. The vessels were placed in climate chamber with a defined environment of +23 °C and 80 % relative humidity. Approximately every 12 hours, the vessels with test specimens were weighed and the diffusion resistance factor was determined from the weight gain due to moisture passing through the silica gel [10].

3.5. Thermal conductivity
The thermal conductivity factor was determined on plates 300 mm x 300 mm x 50 mm by a stationary plate method on a Holometrix Lambda 2300 device based on a stationary plate method. Prior to the measurement, the flatness of the surface of each slab was checked and the slab was grounded if necessary. The determination of the thermal conductivity factor was performed in a steady state at an average temperature of +10 °C and a temperature gradient of 10 K. The measurement was always made on three test specimens (on each specimen was realized the determination of the thermal conductivity factor in total at 5 consecutive intervals) which were dried at a temperature of +75 °C to a constant weight. The final result presented is the arithmetic mean of these three measurements [11-12].

4. Influence of the hydrophobic agent on the properties of mortar mixtures
For mortar mixtures, the effect of the hydrophobic agent on the density was monitored both in the fresh state and at the maturation period after 7 and 28 days (table 2).

From referred values, it appears that by adding the hydrophobic agent to the mortar mixtures, in almost all of the specimens is density in the fresh state and during maturation reduced. There was no dependence between the size of the hydrophobic agent addition to the mixture and its density. In general, the addition of the hydrophobic agent to the mixtures does not have a significant effect on the density.

Table 2. Summary overview of densities of hydrophobic mortar mixtures.

	Addition of hydrophobic agent [%]	Baumit Manu 4	Baumit DuoDur	Baumit MM 50
Density fresh state ρ [kg/m^3]	0.0	1947	1950	2051
	0.2	1878	1953	1653
	0.6	1911	1924	1859
	1.0	1855	1979	1784
Density 7 days ρ [kg/m^3]	0.0	1721	1694	1854
	0.2	1631	1720	1748
	0.6	1656	1705	1643
	1.0	1638	1654	1594

Density 28 days ρ [kg/m^3]	0.0	1749	1724	1824
	0.2	1575	1696	1711
	0,6	1642	1688	1592
	1.0	1620	1601	1581

After 28 days of maturation, the hydrophobic agent effect on the properties of the mortar mixtures was monitored (table 3). Capillary absorption, adhesion, diffusion properties and thermal insulating properties were monitored.

Table 3. Summary overview of adhesions of hydrophobic mortar mixtures.

	Addition of hydrophobic agent [%]	Baumit Manu 4	Baumit DuoDur	Baumit MM 50
Adhesion strength on concrete f_t [MPa]	0.0	0.12	0.10	0.54
	0.2	0.14	0.11	0.10
	0.6	0.11	0.21	0.54
	1.0	0.13	0.11	0.34
Adhesion strength on brick f_t [MPa]	0.0	0.03	0.05	0.03
	0.2	0.06	0.03	0.12
	0.6	0.07	0.07	0.05
	1.0	0.03	0.05	0.12

From the resulting values, no effect of the hydrophobic agent on adhesion of mixtures to concrete or ceramic surfaces is apparent.

Table 4. Summary overview of changes in properties of mortar mixtures.

	Addition of hydrophobic agent [%]	Capillary absorption C [kg/m^2]	Thermal conductivity factor λ [W/(m.K)]	Diffusion resistance factor μ [-]
Baumit Manu 4	0.0	18.25	0.4651	4.26
	0.2	17.30	0.5251	4.06
	0.6	12.30	0.4313	4.49
	1.0	2.85	0.4060	4.75
Baumit DuoDur	0.0	17.95	0.4668	3.81
	0.2	16.05	0.5455	3.75
	0.6	14.00	0.4895	4.10
	1.0	2.55	0.4635	4.04
Baumit MM 50	0.0	14.45	0.6227	4.60
	0.2	14.20	0.6759	4.95
	0.6	5.75	0.6165	4.54
	1.0	1.50	0.5340	4.41

From the values of the capillary absorptions listed in table 4 the positive effect of the hydrophobic agent addition to the mortar mixtures clearly evident. There was an indirect proportionality between the increasing dose of the hydrophobic agent and the capillary absorption coefficients; therefore, the capillary absorption coefficients are reduced by increasing the hydrophobic agent dosage in all test mixtures.

With Manu 4, DuoDur and MM 50 mortar mixtures, the same effect of the addition of the hydrophobic agent on the thermal insulation properties is evident. Adding a small amount, namely 0.2 % will increase the thermal conductivity factor. On the contrary, with increasing amounts of added hydrophobic agent in plaster mixtures, the factor of thermal conductivity decreases, at a concentration of 1.0 % will be reached lower values than to plaster mixtures without the use of a hydrophobic agent.

No dependence of the diffusion resistance factor due to the addition of the hydrophobic agent to the mixture has been proved for the tested mortar mixtures. The addition of the hydrophobic agent has always had a different effect on the diffusion resistance factor.

5. Conclusion

The results of the previous chapter clearly confirm the positive effect of the hydrophobic agent on mortar mixtures. This is mainly a significant reduction of the capillary absorption factor of mortar mixtures, when similar properties of capillary absorption as achieved by rehabilitation mixtures were achieved by adding 1.0% hydrophobic agent to the Baumit Manu 4, Baumit DuoDur and Baumit MM 50 tested mortar mixtures. The addition of hydrophobic agent in an amount of 1.0 % also seems optimal in terms of the change in thermal insulation properties, when by the addition is slightly reduced the thermal conductivity factor of the mortar mixtures. The effect of the hydrophobic agent has not been proved for the other monitored properties, which is also positive, especially in terms of adhesion, which did not show a significant decrease with the addition of 1.0% hydrophobic agent.

In case it is desired to achieve capillary absorption values of mortar mixtures comparable to rehabilitation plaster values, without effect on changes in other properties of mortar mixtures, the optimal dosing of the hydrophobic agent was proved to be 1.0%.

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