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CRYSTALLINE ADMIXTURES AND THEIR EFFECT ON SELECTED PROPERTIES OF CONCRETE

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Abstract. There have been many experimental measurements of the waterproofing ability and durability of concrete with a crystalline admixture, but some other important properties have not been reliably tested yet. The results of the tests, carried out by the authors, showed that crystalline admixtures reduce the water vapor permeability of concrete by 16-20 %. The authors also carried out the water pressure test in different time intervals, during the initial phase of cement hydration. The test results have shown that the full waterproofing effect of concrete with a crystalline admixture is available approximately on the 12th day after the concrete creation. The crystalline admixture effect on the compressive strength of concrete was also the subject of the testing. The results have shown that the compressive strength of the concrete with a crystalline admixture (added in an amount of 2 %) and the compressive strength of the specimens from concrete without admixture were almost identical after 28 days.

Keywords: crystalline admixture; concrete; building envelope; water tightness; permeability.

1. Introduction

The protection of buildings against subsurface water and moisture is a significant part of the building design. Crystalline materials are often used to protect the underground parts of a building against moisture and subsurface water. There are several methods of the application of crystalline materials into the concrete structure: surface-applied coating or spraying, repairing and sealing mortars and integral waterproofing admixtures. The waterproofing admixture is designed for newly constructed buildings with the foundation structure from waterproof concrete. The crystalline admixture consists of Portland cement, specially treated quartz sand and a compound of „active chemicals". The chemical composition of active chemicals in the crystalline material is kept confidential by all producers. The crystalline material's waterproofing effect in concrete is achieved by the reaction of various chemical components, which are contained in the solution, when combined within the concrete matrix [1]. The process works only when the porous system of concrete reaches a sufficient level of moisture. Therefore, perfect moistening of the new concrete structure surface is very important. In the case of a shortage of moisture inside the concrete structure, the crystalline admixture's components lie dormant.

There were also many experimental laboratory measurements of the waterproofing ability of the crystalline admixture in the past, focused on verifying the waterproofing in various modifications [2–12] and the durability [13–15] of concrete with crystalline admixtures. The results of these tests are very convincing, thus the water impermeability and high durability of concrete with crystalline admixtures may be declared. Also, the results of its application to particular buildings and building constructions are, in most cases, conclusive [16–18]. The waterproofing effect of the crystalline admixture is conditioned on a strict technological discipline, especially the thorough curing of a fresh concrete [19].

The waterproofing ability and durability of the concrete with crystalline admixtures have been verified by many experimental measurements (as described above), but some other properties of crystalline admixtures have not been credibly described yet. There are uncertainties about the speed of the waterproofing effect, caused by the crystalline admixture in concrete. Furthermore, the changes in the water vapor permeability of concrete due to crystalline admixtures have not been credibly described yet. Water vapor permeability is a very important feature of each enveloping building structure, because a structure with low water vapor permeability is a potential risk in terms of surface condensation. All producers of crystalline admixtures declare that their admixtures do not reduce the water vapor permeability of concrete (some of them even present the water vapor permeability of concrete with their admixture). However, there is a missing comparison of these data with data for the same (reference) concrete without admixtures. Another problem is the fact that all available measured values of water vapor permeability were made on a commercial basis (presented by the producers of crystalline materials). For the comprehensive evaluation of crystalline admixtures, it is necessary to consider their effect on the compressive strength of concrete, not only their waterproofing ability (the compressive strength is the basic parameter of each bearing concrete structure).

The producers of crystalline admixtures declare

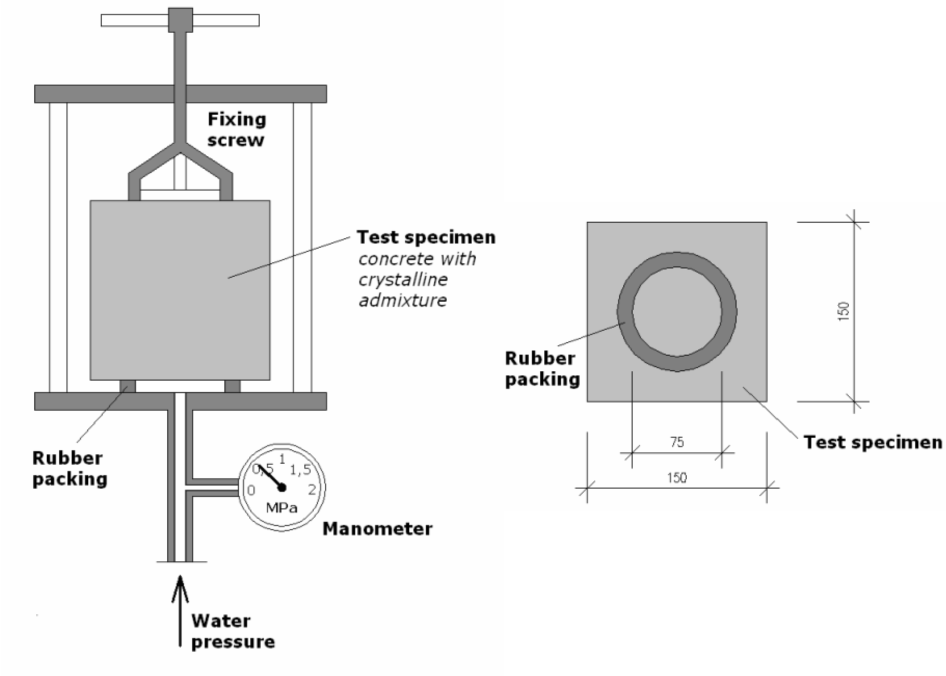

Figure 2. The test arrangement.

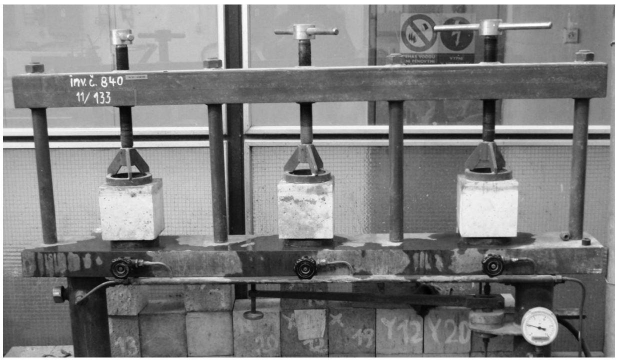

Figure 1. Specimens in the test apparatus.

that their admixtures do not reduce the compressive strength of concrete. Many of them even say that their admixture mildly increases the compressive strength of concrete, but a credible comparison of these affirmations with the compressive strength results of the same (reference) concrete without admixtures is missing (the results are only compared with the projected strength of concrete). The following article attempts to describe aforementioned unverified properties of crystalline admixtures.

2. The speed of the waterproofing effect

2.1. Materials and methods

There is different information regarding the time effect of crystalline admixtures from various producers. Each producer presents different data about the time of the beginning of the waterproofing effect (the time

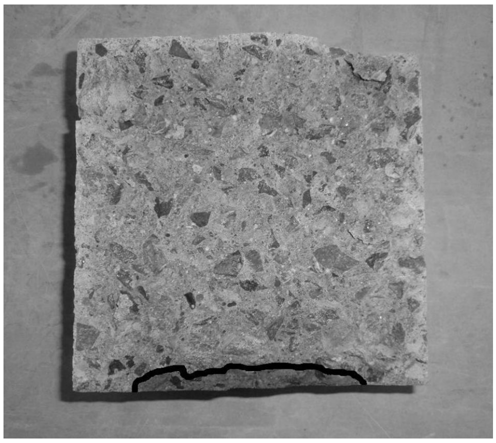

Figure 3. A broken test specimen with a visible boundary of seepage.

when the concrete is waterproof), without having exact measurements from a recognized laboratory. The aim of the experiment was to carry out the water pressure test in different time intervals during the initial phase of cement hydration. The water pressure test was conducted in accordance with the standard EN 12390-8 [20], taking into account open literature [21]. The test specimens had a size of 150x150x150mm and were made of C16/20 concrete with the Xypex Admix C-1000 NF crystalline admixture. 21 specimens were prepared for the test – 3 pieces for each tested time period. The crystalline admixture was added directly to the mixing water before mixing the other components in (in amount of 2 % of cement weight). The test specimens were prepared in accordance with the standard EN 12390-2 [22]. The measurements were

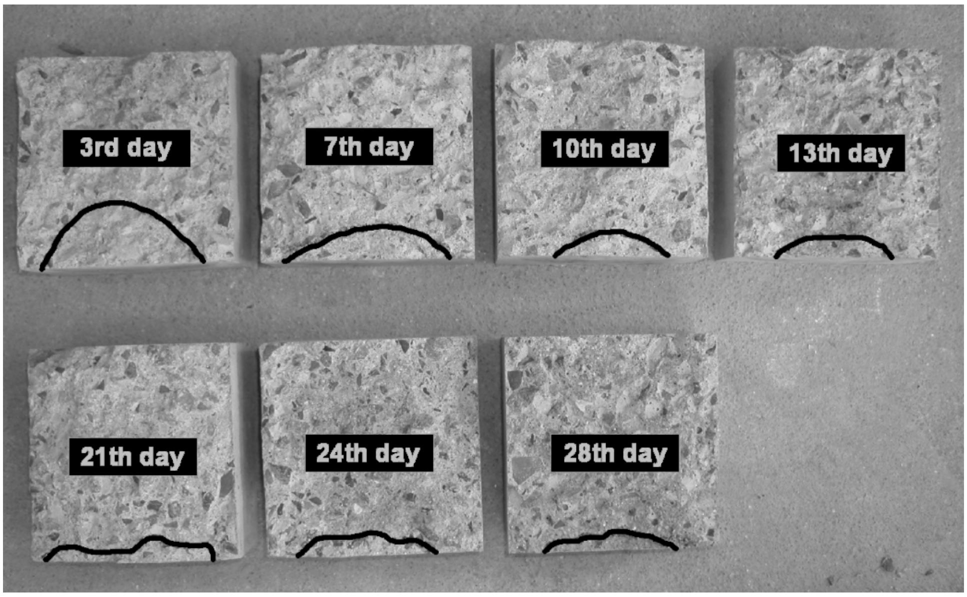

Figure 4. The seepage shape in various time periods after the creation of specimens.

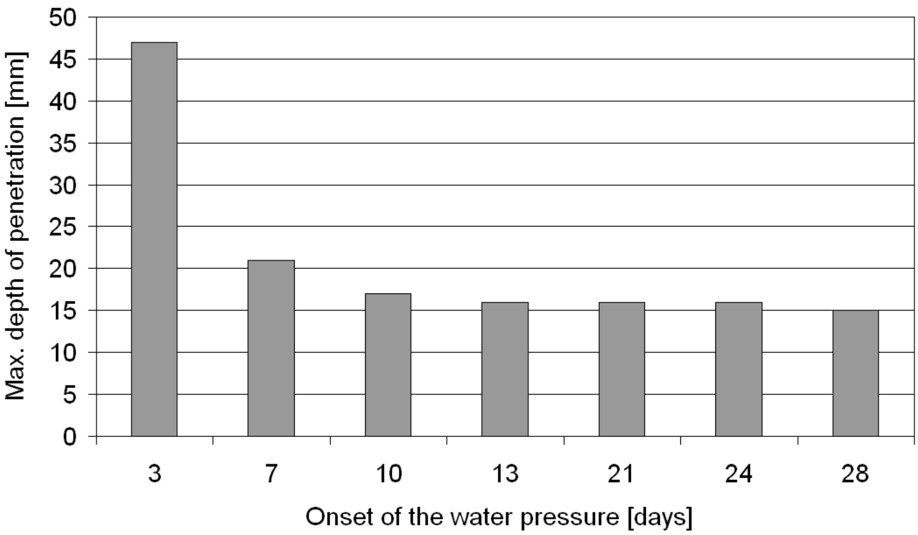

Figure 5. Relation between seepage and loading time.

carried out in various time periods after the creation of the specimens. Each test cube was loaded by a 0.5 MPa water pressure and stayed in the equipment for 72 hours (Figs. 1 and 2). After this time, the cubes were broken up and the seepage was measured (Fig. 3).

2.2. Results and discussion

The test results of the time-sequential water pressure tests (Figs. 4 and 5) have shown that the full waterproofing effect of concrete with a crystalline admixture is available approximately on the 12th day after the concrete (test specimen) creation. At that time, the seepage boundary is about 15mm away from the specimen's surface and the waterproofing effect is, therefore, guaranteed. The concrete structure with a crystalline admixture could be (theoretically) ready for water loading already on the 12th day after creation.

3. The uncertainty regarding the water vapor permeability

3.1. Materials and methods

The water vapor permeability of a building material in EN ISO 12572 [23] is defined by the water vapor resistance factor μ (–). There are 2 basic methods for the water vapor resistance factor measurement that are described in [23]: the „dry cap" method and the „wet cap" method. The „wet cap" method was chosen as appropriate in this case, because the presumed level of the surrounding air humidity was $\varphi \geq 60\,\%$. The principle of the „wet cap" method is the following: The test specimen is placed between two environments with different levels of air humidity: $\varphi_1 = 95\,\%$,

Type of specimen	Type of crystalline admixture	Water vapor resistance factor μ (–)	Water vapor permeability comparison
Concrete with admixture	Penetron Admix	85	120 %
Concrete with admixture	Xypex Admix C-1000	82	116 %
Concrete	–	71	100 %

Table 1. Results of the water vapor resistance factor μ (–).

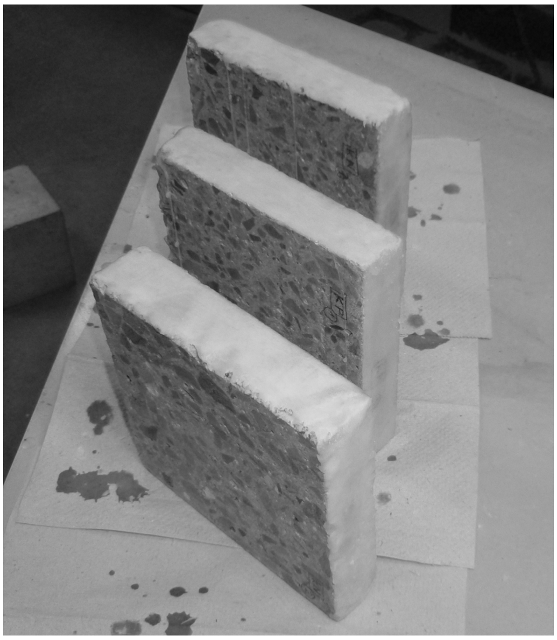

Figure 6. The test specimen (with paraffin).

Figure 7. The test set (specimen placed on the glass bowl).

$\varphi_2 = 50\,\%$. The laboratory measurement was carried out with concrete with crystalline admixture from 2 different variousvariousproducers: Penetron Admix and Xypex Admix C-1000 and, furthermore, with reference concrete without any admixture. 9 specimens were tested in total (3 for each aforementioned material). All the test specimens had sizes of 150 x 150 x 30 mm and were created by cutting from the standard test cube prepared in accordance with EN 12390-2 [22]. 4 sides (150 x 30) of the specimens were sealed with paraffin to ensure one-dimensional water vapor transmission (Fig. 6). After that, each specimen was placed in a glass bowl with Ba Cl2 + 2 H2O ($\varphi_1 = 95\,\%$) and deposited into the climatic chamber ($\varphi_2 = 50\,\%$). The airtight connection between the specimen and the glass bowl was secured through a silicone sealant (Fig. 7). The principle of the test was to measure the weight loss of the test set and find a steady quantity of the permeating water vapor per the time unit G (kg/h). The process of measuring is shown in Fig. 8.

3.2. Results and discussion

The water vapor resistance factor μ (–) of the tested concrete was calculated, according to EN ISO 12572 [23], from the values of the diffusion flow G (kg/h), the relative humidity of the environment on both sides of the specimen φ (%), the temperature during the test θ (°C), the dimensions of the specimens (mm) and the thickness of the air layer between the specimen and the surface of the solution inside the bowl. The resulting values of the water vapor resistance factor μ (–) are shown in Table 1. The results of experimental measurements have shown that the crystalline admixture reduces the water vapor permeability of concrete by 16 % (Xypex) 20 % (Penetron).

4. The crystalline admixture effect on the concrete's compressive strength

4.1. Materials and methods

For a deeper understanding of the crystalline admixture effect on the compressive strength of concrete, the strength test with two selected admixtures was performed according to EN 12390-3 [24]. The aim of the measurement was a compressive strength comparison between concrete with an admixture and the reference concrete. The measurement was carried out on cube-shaped specimens (150x150x150mm), which were prepared according to EN 12390-2 [22]. C20/25 concrete and crystalline admixtures Penetron Admix and Xypex Admix C-1000 NF were chosen for the test. 9 specimens were tested in total (3 for each aforementioned material). The compressive strength test EN 12390-3 [24] was carried out 28 days after the specimens creation (Fig. 9). The results of the compressive strength test are shown in Table 2.

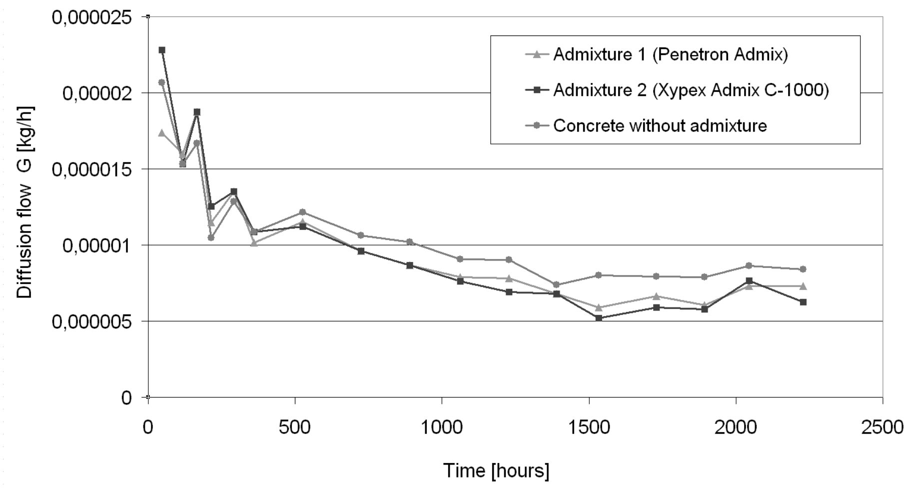

Figure 8. Diffusion flow of water vapor through the specimens during the test.

Concrete	Crystalline admixture	Compressive strength (MPa)			
		Specimen			Mean
		1	2	3	
C 20/25	Penetron Admix	35.6	35.8	37.1	36.2
C 20/25	Xypex Admix C-1000 NF	37.2	35.7	36.1	36.3
C 20/25	without admixture	37.6	36.9	36.0	36.8

Table 2. Results of the compressive strength test.

Figure 9. Loading of test specimen in a hydraulic press.

4.2. Results and discussion

The results have shown that the compressive strength of the concrete with a crystalline admixture (added in an amount of 2 %) and the compressive strength of the specimens from concrete without admixture were almost identical after 28 days. It was surprising, given the declaration of some crystalline materials producers that their admixtures mildly increase the compressive strength of concrete. After the evaluation of the results and their consultations with experts from practice, the following hypothesis (assumption) was derived: The crystalline admixture added in an amount of 2 % of the cement weight apparently caused a mild deceleration of the hardening of concrete. Even though the admixture increases the compressive strength, this effect occurs later than after 28 days. However, this hypothesis must be confirmed by subsequent testing.

5. Conclusions

The results of the laboratory testing of the speed of the waterproofing effect, caused by the crystalline admixture in concrete, have shown that the concrete structure with a crystalline admixture could be (theoretically) ready for water loading already on the 12th day after creation. For the practical use, it is possible to say that the concrete structure with a crystalline admixture has a guaranteed waterproofing ability after the standard hardening time of concrete (28 days), regardless of the fact that the tested concrete with admixture showed waterproofing effect after 12 days (worse conditions are expected on the actual building site, therefore, there is a risk of a slower onset of the waterproofing).

The laboratory measurement has shown that the crystalline admixture reduces the water vapor permeability of concrete by 16 % (Xypex) to 20 % (Penetron). However, these are relatively negligible values, which should not cause any failure of the structure due to moisture. Overall, it is possible to say that the effects of crystalline materials on the water vapor permeability of concrete are insignificant.

It is probable that a crystalline admixture, added in an amount of 2 % of the cement weight, caused a mild deceleration of the hardening of concrete (during the first 28 days). It was an interesting finding, given the declaration of crystalline materials producers that their admixtures mildly increase the compressive strength of concrete. It is, therefore, likely that even though the admixture increases the compressive strength, this effect occurs later than after 28 days. Based on these results, the crystalline admixture application in smaller amounts than the amount of 2 % of the cement weight can be recommended (depending on producer's documentation which determines the minimum amount of an admixture to ensure a waterproof ability of concrete).

All the aforementioned claims are absolutely valid only for tested crystalline admixtures (Xypex, Penetron), but due to the very similar substance of other crystalline admixtures (Vandex, Maxseal, Sikkaton, Masterseal, Krystol), it is possible to expect similar properties of concrete with these admixtures.

Acknowledgements

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