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**Testing of Effect of
Xypex Modified and Measures
to Increase Effectiveness of Xypex Admix**

Správa o výsledkoch
Test Results

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Content

| | | |
|-------|--|----|
| 1. | Introduction | 3 |
| 2. | Test Procedures, Methods and Materials | 3 |
| 3. | Test Results | 3 |
| 3.1 | Test Results on the Influence of Xypex Modified Coating on Rate of Carbonation and Re-alkalization of Mortar | 3 |
| 3.1.1 | Test Results on the Influence of Xypex Modified on Rate of Carbonation | 4 |
| 3.1.2 | Test Results on the Influence of Xypex Modified on Rate of Re-alkalization of Carbonated Mortar and its Repeated Carbonation | 6 |
| 3.2 | Results of Tests to Improve Effectiveness of Xypex Admix Additive | |
| | a) Stored in 55% Relative Humidity | 9 |
| | b) Stored in 95% Relative Humidity | 12 |
| 4. | Conclusions | 16 |
| | References | 17 |

1. Introduction

The report presents test results of effects of Xypex Modified and measures to increase effectiveness of Xypex Admix prepared for Hydrosan,s.r.o. in accordance with the Contract dated November 30, 2001.

The scope of testing was determined by the following requirements of the request:

- a. test the effectiveness of Xypex Modified coating as means to prevent carbonation of treated concrete
- b. test the ability of Xypex Modified coating to renew alkaline environment within carbonated concrete
- c. test measures to increase the ability of Xypex Admix (shown by previous tests to be relatively small) as means to slow down carbonation of concrete.

2. Test Procedures, Methods and Materials

The tests were carried out under identical conditions as previous tests described in reference (1).

For tests to increase the effectiveness of Xypex Admix two types of mortar mixes were used:

- mortar with cement to sand ratio of 1:5, w/c 0.5 (400 kg of cement/m³), - without additives, with 4% Xypex Admix, with 0.25% Berament N superplasticizer, and with a combination of these additives.
- mortar with cement to sand ratio of 1:4, w/c 0.6 (400 kg of cement/m³) - without additives, with 4% Xypex Admix, with 0.25% Berament N superplasticizer, and with a combination of these additives

Dosages of additives are expressed as % of weight of cement.

Two methods of curing were used:

- a. 24 hours hardening in forms in $20 \pm 2^{\circ}\text{C}$ and relative humidity 95%, after removal from forms 13 days in air of same temperature and relative humidity of 55%.
- b. curing under the same conditions but in relative humidity 95%.

3. Test Results

3.1. Test Results on the Influence of Xypex Modified Coating on Rate of Carbonation and Re-alkalization of Mortar

3.1.1 Test Results on the Influence of Xypex Modified on Rate of Carbonation

Tests were carried out using mortar with cement to sand ratio of 1:5 and w/c ratio of 0.5. Test samples 40x40x160 mm were prepared with one and two coats and for comparison without coating.

Results showing rate of carbonation are shown in Table 1 and Fig. 1.

Table 1 Test Results of Influence of Coating Xypex Modified on Rate of Carbonation of Mortar

| Time of Carbonation (in days) t | Depth of Carbonation d (mm) | | | | | |
|---------------------------------|-----------------------------|-------------------------|----------|-------------------------|----------|-------------------------|
| | No Coating | | 1 Coat | | 2 Coats | |
| | Measured | Calculated ¹ | Measured | Calculated ² | Measured | Calculated ³ |
| 3 | 4.8 | 5.4 | 3.5 | 4.2 | 1.0 | 2.4 |
| 5 | 6.1 | 7.0 | 4.6 | 5.4 | 2.5 | 3.1 |
| 7 | 8.3 | 8.3 | 6.1 | 6.4 | 3.8 | 3.7 |
| 10 | 10.8 | 10.2 | 7.6 | 7.9 | 4.0 | 4.5 |
| 12 | 12.0 | 11.1 | 8.5 | 8.6 | 4.6 | 5.0 |
| 14 | 13.2 | 11.8 | 10.6 | 9.1 | 6.1 | 5.3 |
| 17 | - | - | 13.0 | 10.1 | 8.3 | 5.8 |
| 21 | - | - | - | - | 13.0 | 9.0 |
| 360 | - | 60.4 | - | 46.9 | - | 27.0 |
| 3600 | - | 191.0 | - | 148.0 | - | 85.2 |

$$^1 d = 3,18\sqrt{t}$$

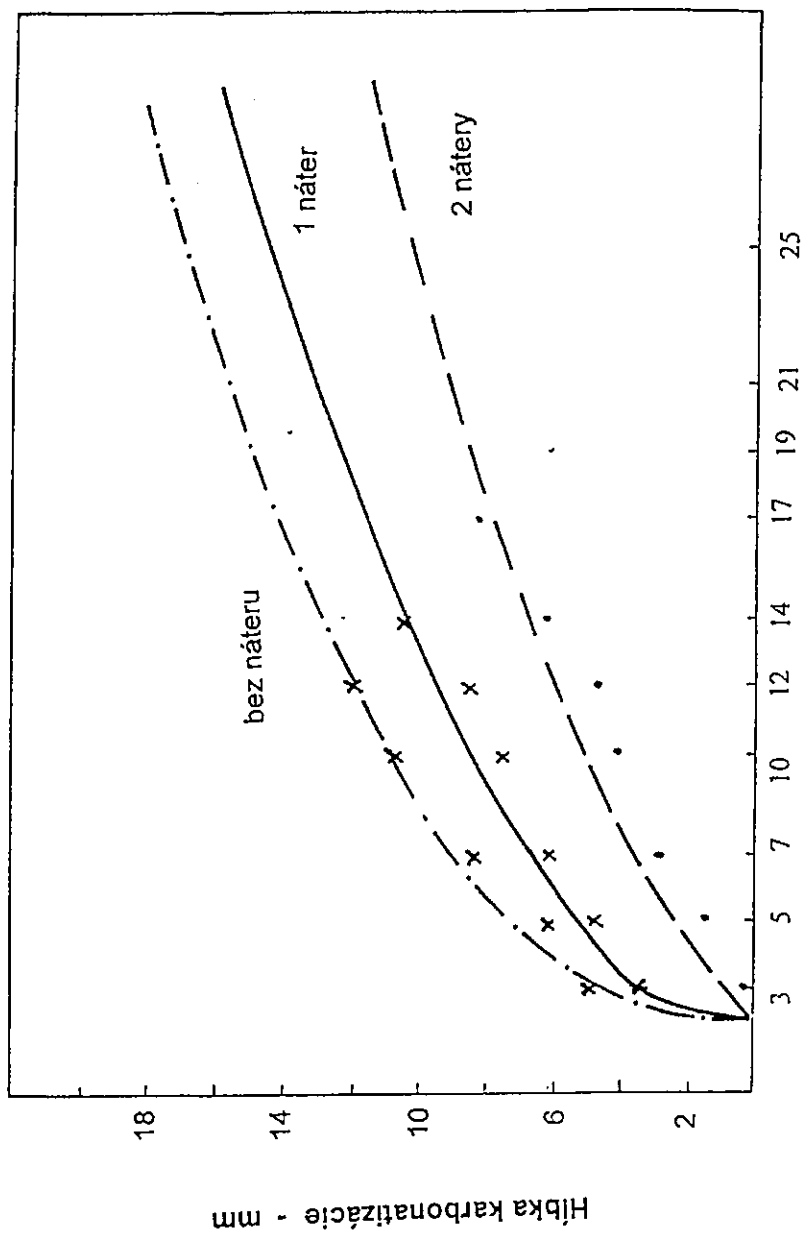
$$^2 d = 2,47\sqrt{t}$$

$$^3 d = 1,42\sqrt{t}$$

It is obvious that Xypex Modified slowed down the rate of carbonation. The effectiveness of the coating was higher with higher number of coats. The data regarding effectiveness of the number of coats is shown in Table 2.

Table 2 Rate of Carbonation of Mortar with Application of Coating XYPEX Modified

| Time of Carbonation In Days | Rate of Reduction of Carbonation with Application of Coating Compared to Plain Mortar (%) | |
|-----------------------------|---|-------------|
| | w/c 0.5 | |
| | 1 Coat | 2 Coats |
| 3 | 27.1 | 79.2 |
| 5 | 26.6 | 59.0 |
| 7 | 26.5 | 54.4 |
| 10 | 29.6 | 63.0 |
| 12 | 29.2 | 61.7 |
| 14 | 29.7 | 53.8 |
| Average | 27.2 | 61.9 |



Doba karbonatizácie - dni

Obr. 1 Vplyv počtu náterov XYPEX Modified na rýchlosť karbonatizácie malty

As shown, the rate of carbonation with one-coat application of Xypex Modified was slower on average by 27.2% and with the 2-coat application by 61.9% (compared to no coating). Refer to Fig. 2

3.1.2 Test Results on the Influence of Xypex Modified on Rate of Re-alkalization of Carbonated Mortar and its Repeated Carbonation.

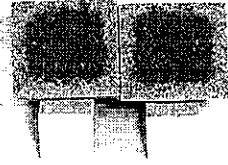
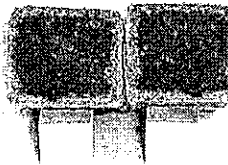
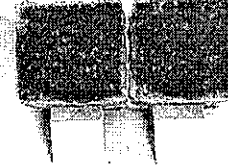
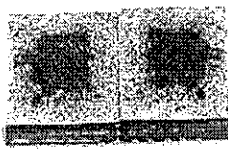
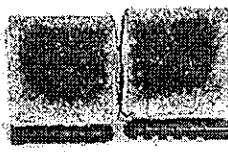
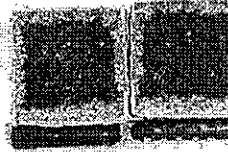
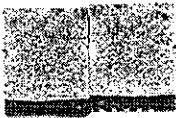
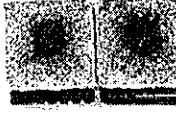
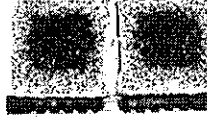
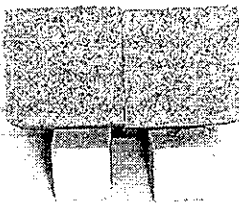
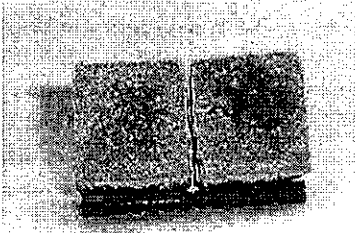
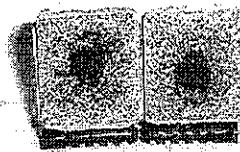
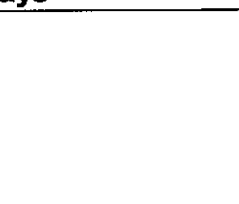
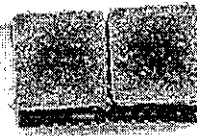
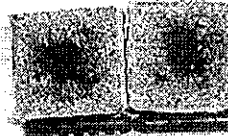
The test method was identical to the test method used for re-alkalization of the Xypex Concentrate coating application.

Test samples were made of mortar with w/c ratio of 0.5 that was completely carbonated and treated with one coat of Xypex Modified. Then the samples were exposed to re-alkalization which consisted of curing of samples in normal air with relative humidity 98% and temperature 20 to 25 °C. After complete re-alkalization the samples were exposed to carbonation. Both processes were measured by using phenolphthalein and documented on photographs (see Fig 3 and 4).

Table 3 Test Results of Carbonation of Re-alkalized Mortar.

| Time of Carbonation in Days | Depth of Carbonation (mm) | |
|--------------------------------|---------------------------|-----------------------------|
| | Re-alkalized Mortar | Original Mortar w/o Coating |
| 1 | 4.1 | - |
| 2 | 5.8 | - |
| 3 | 9.0 | 4.8 |
| 4 | 13.0 | - |
| 7 | ≥ 20 | 8.3 |
| 10 | | 10.8 |
| 14 | | 13.2 |

Fig 3 and 4 together with Table 3 document a high rate of repeated carbonation of re-alkalized mortar within 7 days of carbonation. For comparison, this time was 19 days for original non-re-alkalized mortar with application of one coat. That means that rate of carbonation was approx. 3 times faster for re-alkalized mortar than for non-re-alkalized mortar.

| Plain Mortar (51) | Mortar with 1 Coat (52) | Mortar with 2 Coats (53) |
|--|--|---|
|  <p>3 days</p> |  <p>3 days</p> |  <p>3 days</p> |
|  <p>7 days</p> |  <p>7 days</p> |  <p>7 days</p> |
|  <p>14 days</p> |  <p>14 days</p> |  <p>14 days</p> |
|  <p>19 days</p> |  <p>19 days</p> |  <p>19 days</p> |
|  <p>21 days</p> |  <p>21 days</p> |  <p>21 days</p> |

**Fig. 2 Cross Sections of Test Samples Tested with Phenolphthalein
(Mortar with w/c 0.5)**

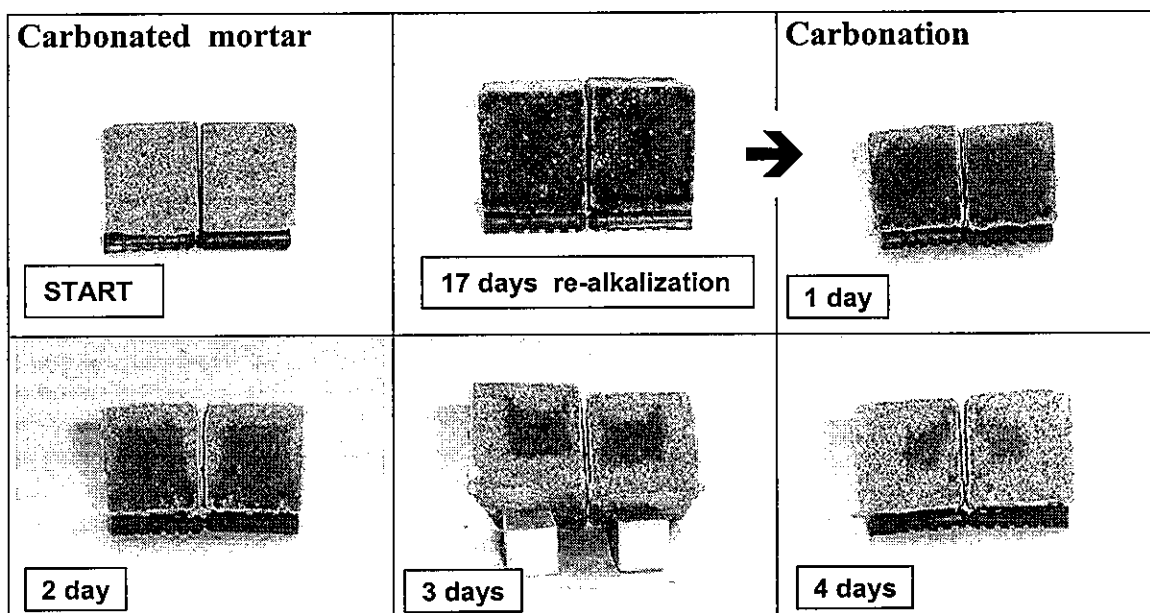


Fig. 3 Cross Sections of Carbonated Mortar after Re-alkalization and Repeated Carbonation

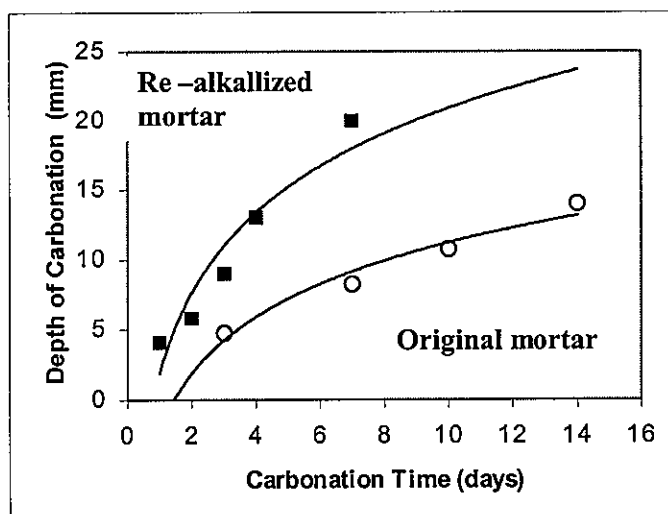


Fig. 4 Rate of Carbonation of Re-alkalized Mortar and Original Mortar without Coating

Table 7 Reduction (-) and Acceleration (+) of Carbonation in Mortars with
XYPEX Admix and BERAMENT N Superplasticizer – Moist Cured

| Time of Carbonation (days) | 4% XYPEX Admix | | 0.4% BERAMENT N | | 4% XYPEX Admix 0.4%BERAMENT N (*) | |
|----------------------------|----------------|---------------|-----------------|---------------|--------------------------------------|---------------|
| | w/c 0.5 | w/c 0.6 | w/c 0.5 | w/c 0.6 | w/c 0.5 | w/c 0.6 |
| 1 | -14.29 | -28.57 | -50.00 | -42.86 | -50.00 | -41.86 |
| 3 | -4.08 | -41.67 | -38.42 | -43.83 | -41.61 | -50.00 |
| 6 | +3.85 | -24.15 | -28.92 | -40.74 | -23.08 | -37.04 |
| 8 | -23.67 | -33.87 | -41.67 | -58.50 | -33.33 | -40.02 |
| 10 | -15.38 | -41.46 | -25.64 | -41.46 | -23.08 | -48.78 |
| 14 | -29.20 | -40.42 | -43.33 | -42.55 | -38.33 | -40.42 |
| 20 | -22.32 | -33.90 | -44.78 | -32.20 | -26.87 | -37.29 |
| 24 | -30.00 | -41.18 | -50.00 | -35.29 | -35.00 | -44.12 |
| 30 | | -32.81 | | -28.12 | | -37.50 |
| 38 | | -36.25 | | -35.00 | | -37.50 |
| Average | -17.27 | -36.19 | -39.00 | -39.74 | -31.61 | -41.41 |

(*)0.25% BERAMENT N in w/c 0.6

It can be expected that the reduction effects are the result of addition of superplasticizer and its influence on consistency of mortars and on the properties of hardening mortar. According to the results, fresh mixes of mortars with 0.5 w/c ratio showed consistently 10 cm *slump* and 0.6 w/c 13.5 to 14.2 cm. It is possible that reported differences in consistency of mortars were one of the reasons influencing the described differences in the rate of carbonation of samples with combine additives of Xypex Admix and Berament N superplasticizer.

Figure 9 shows the test results.

4. Conclusions

1. Test results unambiguously showed that both Xypex Concentrate and Xypex Modified reliably reduce the rate of carbonation in concrete. An illustration of inhibiting effect of Xypex Modified coating can be calculated from the data using experimentally derived relations. According to these calculations, in 10 years in unprotected material carbonation will reach 191 mm depth, in one coat application 148 mm, but in two coat application 85 mm.

For the one coat application this relates to approx. 1.3 times reduction in the rate of carbonation, and in two coat application a 2.2 times reduction in the rate of carbonation.

2. A very important finding of crucial importance is the adequate length of moist curing of fresh concrete with addition of Xypex Admix in order to show maximum effect of this additive on the reduction of carbonation rate of concrete. This was proven by tests where samples were cured in a dry environment (missing inhibiting effect) and in moist environment. The importance of moist curing was unambiguously proven. It would be beneficial to conduct more detailed research to determine more details of the influence of moist curing on effect of Xypex Admix. Calculations showed 1.4 times reduction in the rate of carbonation in mortar with 0.5 w/c ratio with addition of Xypex Admix, and 1.6 times in 0.6 w/c ratio. These values are comparable to the influence of one coat of Xypex Concentrate and Xypex Modified.
3. The results showed the possibility to influence effectiveness of Xypex Admix by application of other additives. Therefore, possible combined application of Xypex Admix additive with other additives should be further tested.

References:

1. V.Živica, L.Bágel', Testing of Effectiveness of Products XYPEX. Ústav stavebníctva a architektúry SAV Bratislava, odd. hmôt a reológie, 2001, 24 pages.