HYDROPHOBING AGENTS, FOR PROTECTION OF LOW QUALITY CONCRETE

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ABSTRACT

An investigation has been made on the influence of hydrophobing agents on concrete´s moisture balance and resistance to freeze-thaw action. The investigation includes both laboratory experiments and full scale experiments on exterior walls of concrete houses.

Results show a substantial favorable effect on the freeze-thaw resistance of concrete with w/c-ratio over 0,55 and inadequate air entrainment, on water intrusion at varying hydrostatic pressure and on moisture content of exterior walls.

Key words: hydrophobing agents, freeze-thaw resistance, moisture content, moisture diffusion, alkali silica reaction.

1. Introduction

Concrete is the only domestic building material in Iceland. Its use for housing is therefore more common there than in most other countries, cast in place houses being the traditional type. Due to relatively high w/c-ratio, in the range 0,55-0,7, and often insufficient air entrainment, freeze-thaw damages of severely exposed building components are not uncommon. Damage caused by alkali-silica reactions are also a serious problem since some of the aggregates used are reactive sea dredged materials and the Icelandic portland cement contains high amount of alkalies, the Na_2O eq. being approx. 1.5%.

Since high moisture content is a key factor for both the above mentioned types of damage, remedial measures have been aimed at decreasing the moisture content in the concrete. For this purpose various methods have been investigated, one of them being impregnation with hydrophobing agents. Positive results obtained in full scale experiments on houses led to further tests in the laboratory. In this article results of these tests will be presented.

2. Hydrophobing agents

Hydrophobing agents have been used for many years for protection of mineral construction materials. Recently new alkali resistant types have been developed with less molecular size and greater penetration ability. Some of these new types were developed for protection of concrete. The main benefit of using these materials is claimed to be that they stop water absorption without preventing the escape of moisture, already in the concrete.

In (2) a classification system for hydrophobing agents is shown. The main types used for concrete are: silicone resins, oligomeric siloxanes and monosilanes. Silicone resin is the oldest product, with longest molecular chain and should be applied on dry concrete. Monosilane is the latest product. It has the smallest molecules, the greatest impregnation and can be applied on moist concrete. Compared with silicone resins it has both advantages and disadvantages. The advantages are:

- Since the molecule is smaller, it can penetrate the pores and capillaries more easily.
- Silanes can be applied to somewhat wet construction material.
- Silanes can be diluted with waterfree alcohol, which can be necessary in special cases.

The disadvantages of silanes are due to their volatility. As soon as a silane is applied to the construction material, there are two possibilities: the silane can be transformed into the active material due to its reaction with humidity or, being volatile, it can evaporate with the diluent. Evaporation, however, means loss of active material. This is increased if silane is applied to construction material heated by the sun or during windy weather conditions.

To utilize the advantages of the silanes without their disadvantages, oligomeric siloxanes have been developed. They are a mixture of almost non-volatile silanes and low-molecular siloxanes. The penetration capability is well comparable to that of the pure silanes. They also can be applied to a somewhat wet surface and, in special cases, they also can be diluted with alcohol. Due to the almost complete lack of evaporation, they will remain in the material once the solvent has evaporated. As for the pure silanes, the active substance will be formed in a reaction with humidity. Even with a low application concentration, the formation into active material is ensured so.

3. Experiments on houses

Included in the test program were eight houses. The cross section of the exterior walls were the same in all cases, see fig. 3.1. Moisture content in the concrete was measured by use of an electrical moisture meter of the type protimeter concretemaster. By this method conductivity of the concrete is measured between two holes drilled 150 mm apart and 25 mm deep. The conductivity is a function of moisture content and the scale of the apparatus has been calibrated for this relationship, showing directly moisture content of the concrete. Readings are corrected for temperature. This method shows well relative changes of moisture with time in the outer part of the wall but doesn´t necessarily show exact absolute moisture content. Fig. 3.2 shows the principle for this measurement.

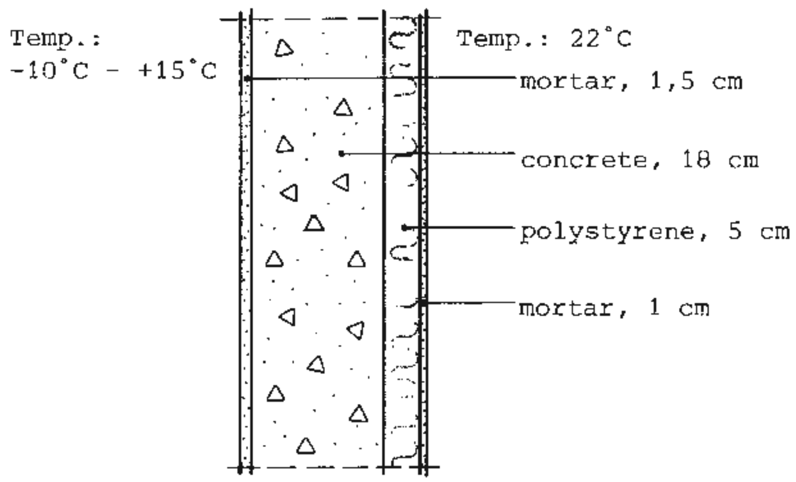


Fig. 3.1 Cross section of wall construction

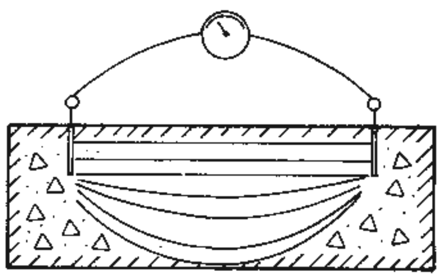


Fig. 3.2 Moisture meter (protimeter concretemaster)

The houses were treated with different types of hydrophobing agents, starting in 1980, and measurements were carried out from treatment through the year 1985. In all cases a subantial decrease in moisture content was observed. As an example, fig. 3.3 shows measurements carried out on the first house treated. Each point is average of measurements in three different places in the wall.

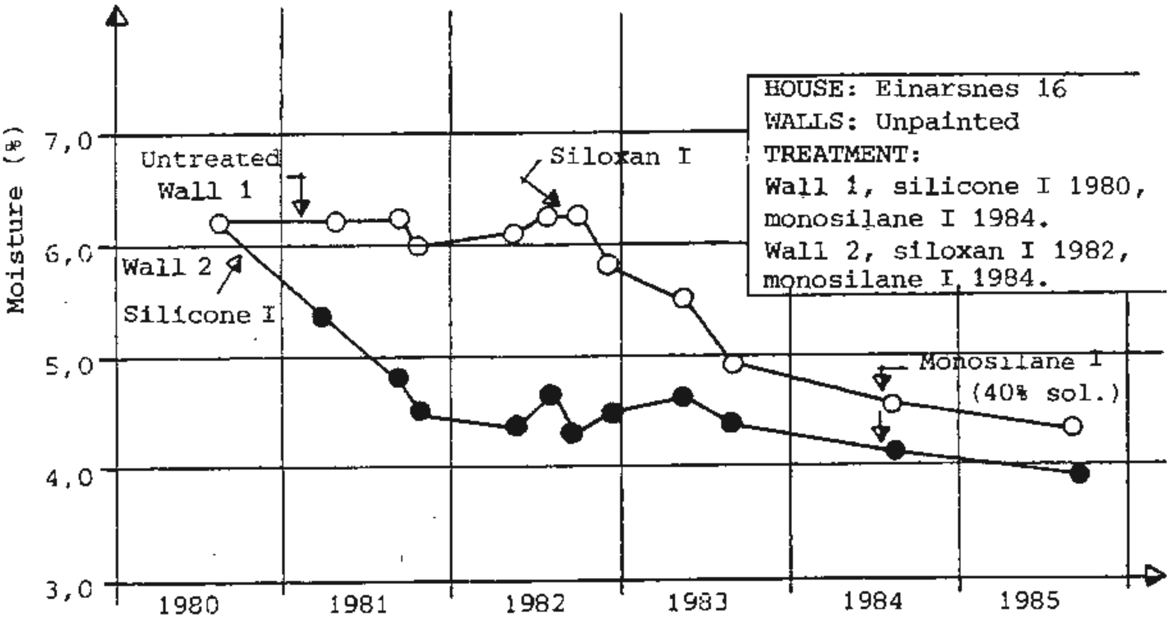


Fig. 3.3 Moisture change in concrete after impregnation with silicone, siloxan and later monosilane.

4. Laboratory experiments

4.1 The purpose of the experiments carried out in the laboratory was to provide information on the following:

- the effect of monosilanes on freeze-thaw resistance of concrete.
- the effect of different types of hydrophobing agents on the water absorbtion of concrete under different hydrostatic pressure.
- the penetration depth of monosilane in concrete with different moisture content.
- the effect of hydrophobing agents on the evaporation of moisture from concrete.
- the effect of hydrophobing agents on the bond strength to new concrete rendering.

In the following results from these experiments will be presented.

4.2 Freeze-thaw resistance

Trial mixes were made and cylinders cast with high- , medium- and low w/c-ratio and with no- , medium- and high air entrainment. The composition of these mixes are shown in table 4.1.

Table 4.1 Trial mixes for freeze-thaw tests

Mix no.	Type of aggregates	Cement content kg/m^3	w/c-ratio	Air content %	Compressive strength, 28 days MPa
A-1	Björgun	229	0,70	1,9	27,6
A-2	"	230	"	4,4	20,0
A-3	"	232	0,68	7,3	14,8
B-1	"	279	0,56	2,4	38,1
B-2	"	289	0,55	3,2	39,5
B-3	"	286	0,54	8,1	32,2
C-1	"	334	0,46	2,6	43,2
C-2	"	341	"	4,6	43,2
C-3	"	345	"	6,9	35,5

The method used for measuring freeze-thaw resistance was Nordtest NT-Build 209 with 3 mm thick layer of pure water instead of 3% NaCl solution on top of the sample. All samples were tested simultaneously.

Samples for testing were cut from the cylinders. The water repellent used for the tests was a 40% monosilane solution desolved in alcohol. For each trial mix tests were made on specimens without impregnation as well as on specimens impregnated for 15- and 30 sec. Tests were run for 100-150 cycles. After every 25 cycles, specimens were weighed, photographed and their scaling rated.

In fig. 4.1 results of scaling measurements are shown. One can see that after 100 cycles, only specimens without air-entrainment and with relatively high w/c-ratio show considerable scaling. In these specimens the effect of impregnation is most favorable, decreasing scaling to only a fraction, compared with specimens without impregnation. Impregnation for more than 15 sec. does though not consistantly give less scaling. The most probable explenation for this is that increased penetrations depth with longer impregnation time is relatively small and not outweighing the difference between individual samples caused by the heterogenity of concrete. In specimens with w/c-ratio 0,7 and 30 sec. impregnation time some not frostresistant aggregate particles were dissolved.

Tests on air-entrained specimens were continued and scaling after 150 cycles is shown in the same fig. Where scaling is considerable, one can clearly see the great beneficial effect of impregnation.

As a conclusion, the results indicate great beneficial effect of silane impregnation on freeze-thaw resistance of concrete, with high w/c-ratio and/or unsufficient air entrainment.

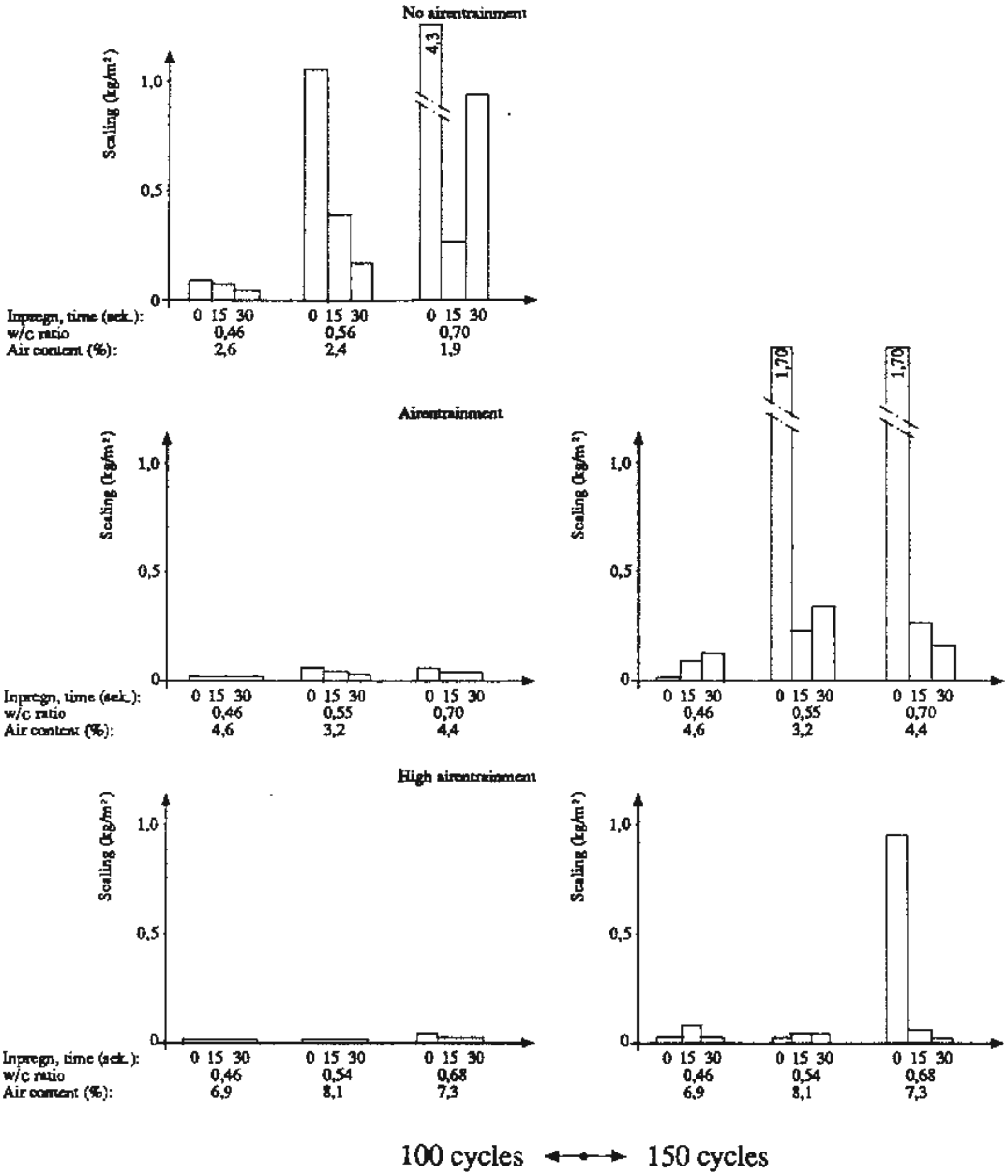


Fig. 4.1 Wethering resistance of concrete (Test method Nordtest NT-209 with water).

4.3 Water absorption

To distinguish between different types of silicones/silanes the following laboratory method was developed: Standard mortar bars, 40x40x160 mm, were oven-dried, then soaked in silicone/silane for 30 seconds, and placed under hydraulic pressure ranging from 0-800 mm depth in water. The moisture absorption was then measured after 24 hours. Typical results are shown in fig. 4.2 showing monosilanes to be most effective, even to considerable hydrostatic pressure.

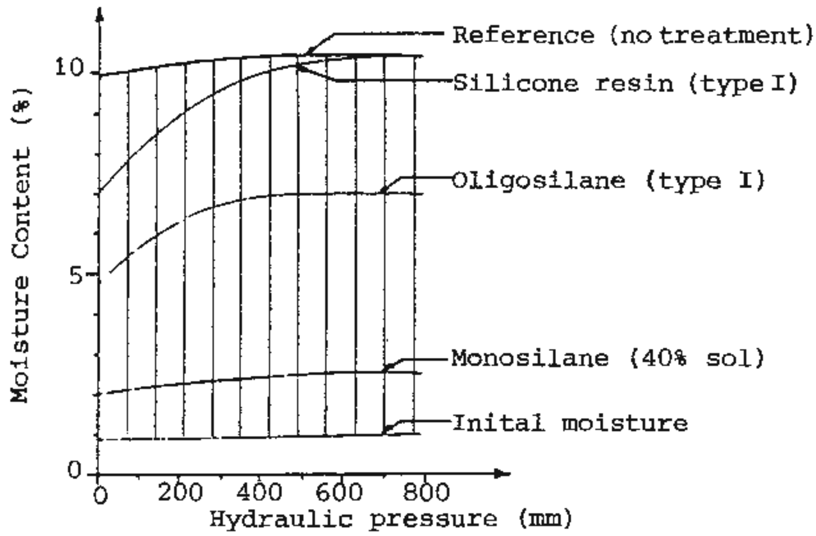


Fig. 4.2 Effect of some silanes/silicones on water absorption of mortar prisms under hydrostatic pressure in 24 hours.

4.4 Penetration depth

The depth of penetration was measured on standard mortar bars. Their moisture condition at impregnation were: oven dried at 105°C, saturated surface dry and saturated samples after two days of laboratory drying at 22°C and 30% RH.

The impregnation was performed by soaking them for different time periods in 40% monosilane solution, the solvent being alcohol. The following periods were used: 1x5-, 1x15- and 3x5 sec.

The impregnation depth was measured on broken bars by inspecting a cross-section of each bar after dipping it in water for a few seconds. The penetration depth was clearly indicated by a light coloured rim at the surface, in contrast to the darker inner area, due to water absorbtion. Results from these measurements are shown in fig. 4.3.

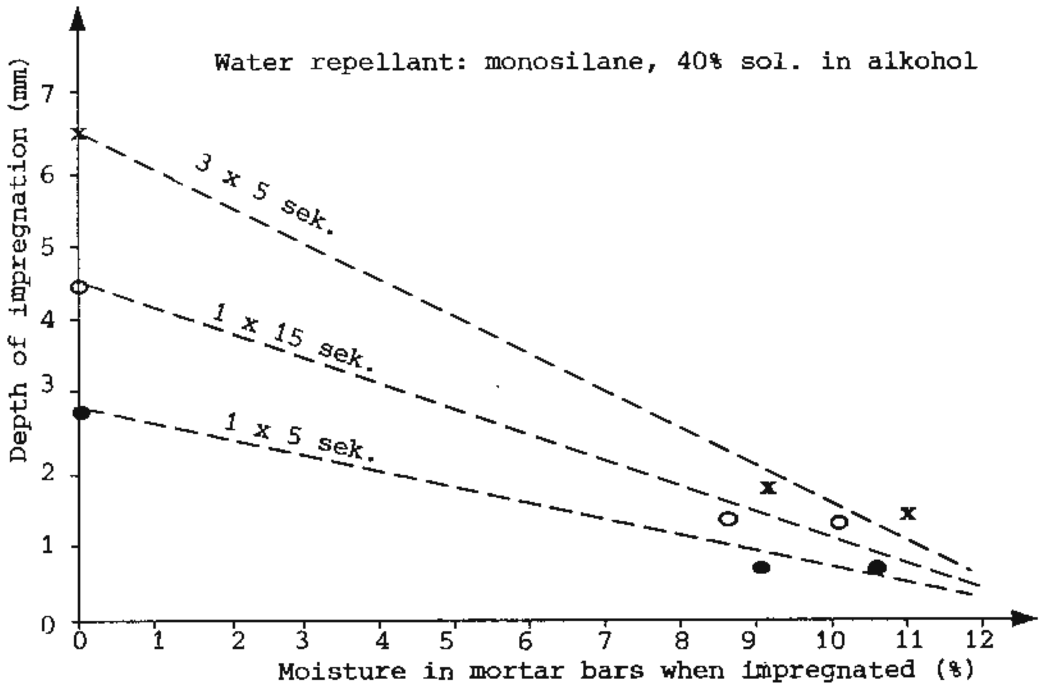
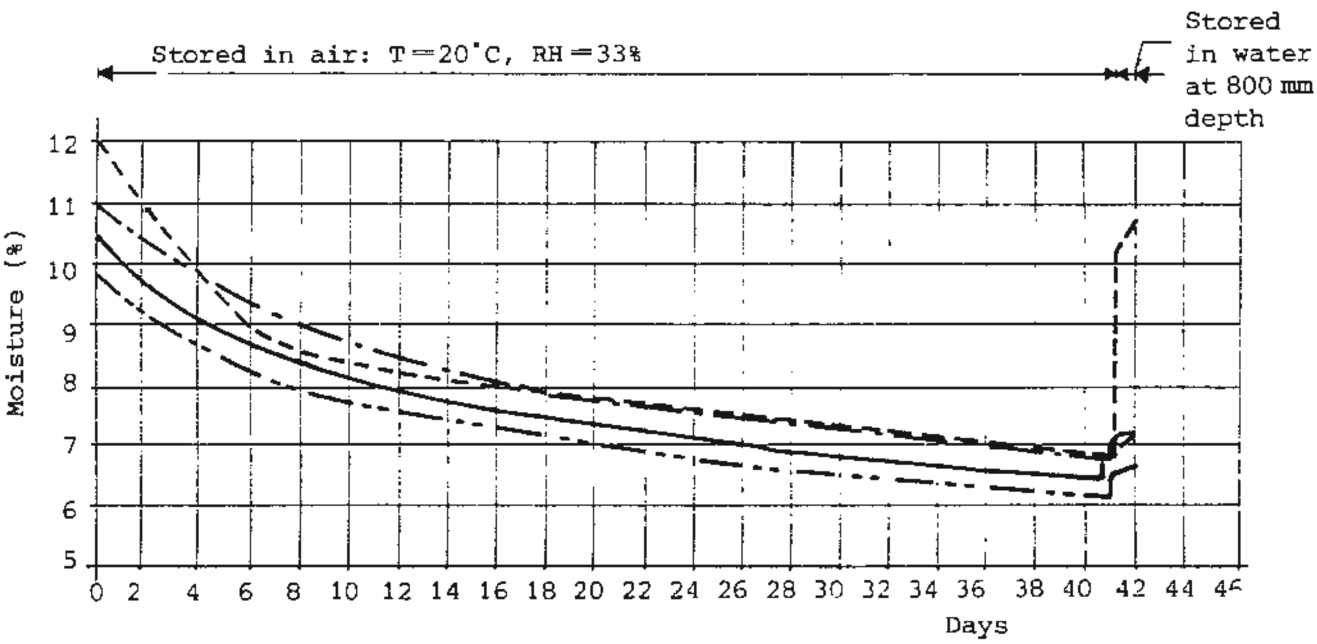


Fig. 4.3 Impregnation depth in mortar bars with different moisture content and impregnation time.

4.5 Evaporation of moisture

To investigate the effect of hydrophobing agents on evaporation of moisture, standard mortar bars were impregnated in moist condition, with various types of hydrophobing agents for periods as described in section 4.4. The mortarbars were stored at 20°C and 33% RH for 41 days, and weighed regularly. After 41 days the mortar bars were placed in water at 800 mm depth and the water absorbtion measured after 24 hours. As a reference saturated, untreated mortar bars were used.

The graph shown in fig. 4.4 indicates that the hydrophobing agents used (40% mono silanes) practically do not delay evaporation of moisture from the mortar bars, whilst they greatly decrease water absorbtion. Similar results were obtained for other types of hydrophobing agents regarding evaporation of moisture.



Impregnation with monosilane (40%) for 1x5 sec
" " " " " 3x5 sec
" " " " " 1x15 sec
Untreated

Fig. 4.4 Moisture change in mortar bars stored in air and water.

4.6 Bond between treated and untreated concrete

In order to obtain some indication of the effect of hydrophobing agents on the bond strength between old and new concrete the following experiment was carried out:

Standard concrete cylinders were treated with three different types of hydrophobing agents each for 15 sec. After three days, strong, cement based mortar rendering was cast on one end of some cylinders. The rest of the cylinders were stored outdoor for 1 1/2 months and then treated in the same way.

The bond strength between thorite and the cylinders was measured by applying tensile loads on each end of the cylinders and registering their tensile strengths. In all cases the break occured in the contact zone. In table 4.2 the measured tensile strengths are shown. The figures indicate that the bond strength of the former series decreases by 30-40%, while the latter series show reduction in bond strength of approx. 15%. No significant difference was registered between types of hydrophobing agents.

Table 4.2 Bond strength between impregnated concrete and cement based repair mortar.

Treatment of cylinders before applying mortar	3 day bond strength 3 days after impregnation (MPa)	3 day bond strength 1,5 months after imprengation (MPa)
Impregnation with siloxan, type 1, for 15 sec	0,42	0,55
Impregnation with siloxan, type 2, for 15 sec	0,42	0,55
Impregnation with monosilane (40% alcohol) for 15 sek	0,46	0,56
No impregnation	0,69	0,66

5. Summary of results and conclusions

5.1 Hydrophobing agents can be effective in decreasing the moisture content of concrete.

5.2 Monosilanes increase the freeze-thaw resistance of concrete with a relatively high w/c-ratio.

5.3 Hydrophobing agents decrease the water absorbtion of concrete. Monosilane is most effective, showing, contrary to silicone resins, high eficiency even under substantial hydrostatic pressure.

5.4 The penetration depth of monosilane depends greatly on the moisture content of concrete when applied, as well as, on the duration of treatment.

5.5 Hydrophobing agents do practically not effect the evaporation of moisture from concrete.

5.6 Hydrophobing agents can decrease the bond strength between treated concrete and new concrete.

5.7 The main conclusion of this project is that hydrophobing agents can have a beneficial effect on the durability of concrete that suffers from high moisture content and possible damages from freeze-thaw actions or alkali-aggregate reaction. Practical experience on concrete houses during the last 7 years seem to confirm this effect.

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