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Application of Silane-based Compounds for the Production of Integral Water Repellent Concrete

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Abstract

It has been shown that a durable and reliable chloride barrier can be established by surface impregnation of cement-based materials with silane or silane-based products. By means of this advanced technology service life of reinforced concrete structures built in aggressive environment can be extended significantly. Comparatively few experimental results can be found in the literature, however, on capillary absorption and on chloride penetration into integral water repellent cement-based materials. In this contribution different commercially available silane based compounds have been applied to produce integral water repellent concrete. The integral water repellent concrete and untreated reference samples have been exposed to seawater. Capillary absorption has been determined. Chloride profiles, which have been established in the exposed concrete, have been determined. The rate of chloride penetration into concrete can be slowed down considerably by addition of silane-based compounds to the fresh mix. Based on these results the extension of service life of reinforced concrete structures in aggressive environment built with integral water repellent concrete instead of a conventional high performance concrete can be estimated.

Keywords: integral water repellent concrete, capillary water absorption, chloride penetration, service life

1 Introduction

By now it has been shown in a convincing way, both by laboratory testing and in practice, that the rate of chloride penetration into cement-based materials can be slowed down significantly by surface impregnation with silane or silane based products such as silane gel or silane cream [1-3]. Service life of reinforced concrete structures in marine environment or in contact with de-icing salt can be extended considerably by means of this protective surface technology. Comparatively few results have been published, however, on the effectiveness of integral water repellent concrete with respect to chloride penetration [4, 5].

Surface impregnation can be applied only after hardening of concrete. A minimum period of drying is also necessary to open the pore space for capillary absorption of liquid silane. In practice there are situations where these requirements are difficult or even impossible to be fulfilled. In all these cases use of integral water repellent concrete would be an interesting alternative if the efficiency with respect to resistance to chloride penetration can be shown to be as good or at least comparable to the resistance obtained by surface impregnation.

The aim of the project described in this contribution was to study chloride penetration into different types of concrete with water-cement ratio varying from 0.4 to 0.5. Chloride penetration has been determined on plain concrete and integral water repellent concrete, which has been produced by adding silane-based products to the fresh mix. The essential question to be answered is, can the same resistance with respect to chloride penetration of reinforced concrete structures be reached with integral water repellent concrete as compared to surface impregnated concrete.

2 Experimental

Four different types of concrete have been produced. The composition is given in Table 1. Ordinary Portland type 42.5, broken gravel with a maximum diameter of 25 mm, river sand with a maximum diameter of 5 mm have been mixed with tap water. A super plasticizer has been added to the fresh mix of concrete type A to achieve necessary workability. In concrete type D 30 % of the Portland cement has been replaced by fly ash.

The fresh concrete has been cast into steel forms to produce cubes with an edge length of 100 mm. After 24 hours curing under wet burlap the forms were removed and the concrete cubes were placed in a humid room (T=20 °C; RH>95 %) until they reached an age of 28 days. Then the cubes were cut into two halves parallel to the direction of casting. The half cubes were then allowed to dry in laboratory atmosphere (T=20 °C; RH=65 %) for another 28 days. By then the side surfaces (50 x 100 mm) were sealed with wax and the formed surface was put in contact with a 5 % aqueous NaCl solution for 28 days.

Neat concrete cubes of all four types of concrete were produced and capillary absorption of salt water has been determined, they served as reference. In addition cubes of all four types of concrete have been produced but in this case 2 % and 4 % of silane based compounds have been added. The following three silane compounds have been applied to prepare integral water repellent concrete: Potectosil MH50, Protectosil WS600, and Protectosil 851. Finally thin layers have been removed by milling from the surface of the chloride contaminated specimens. The obtained powder has been collected and the chloride content has been determined by ion chromatography.

Table 1: Composition of the four types of concrete

Concrete Type	Cement	Gravel	Sand	Water	Fly Ash	W/C, W/B
A	380	1269	579	152	-	0.4
B	320	1267	653	160	-	0.5
C	300	1210	710	180	-	0.6
D	256	1267	653	160	64	0.5

3 Results and discussion

3.1 Compressive strength

In order to characterize mechanical properties of the four types of concrete and the influence of addition of silane, compressive strength of neat concrete and of concrete which has been prepared with an addition of 2 % and 4 % of Protectosil MH 50, 851, and WS 600 has been determined at an age of 28 days. The obtained strength values are compiled in Table 2. It can be seen that addition of 4 % of silane decreases compressive strength considerably. On an average compressive strength is decreased by one third. The presence of silane in the pore solution most probably slows down hydration of cement. But the interaction of the surface of unhydrated cement with water in the presence of silane has yet to be studied in detail. In practice the reduction of strength can be compensated at least partly by reduction of the water-cement ratio.

Table 2: Compressive strength [N/mm^2] of neat concrete and of concrete made with 2 % and 4 % of protectosil MH50, 851, and WS600 respectively

Type of silane added	Amount of silane added, %	Type of concrete			
		A	B	C	D
---	0	63.3	54.2	20.7	36.6
Protectosil MH 50	2	46.9	41.6	26.4	31.9
	4	47.9	46.5	20.5	30.1
Protectosil 851	2	56.9	40.5	18.5	35.2
	4	53.2	34.8	21.9	32.1
Protectosil WS 600	2	54.5	29.8	18.7	32.6
	4	41.7	25.1	14.1	23.8

3.2 Capillary absorption

Capillary absorption of a simple porous system can be described by a simple relation:

$$\Delta W(t) = A\sqrt{t} \qquad (1)$$

In real concrete this relation is only valid for limited time intervals. There are several reasons for this such as gravity, evaporation, and the well-known skin effect. We have chosen the initial coefficient of capillary absorption A_i, which describes the capillary absorption in the first few hours as characteristic parameter.

Capillary absorption of the integral water repellent concrete has been measured on half cubes. Results are compiled in Table 3. Capillary absorption is significantly reduced by the addition of silane compounds. As shown earlier 2 % is not yet the optimum and capillary absorption is further reduced by the addition of 4 % of silane. But the reduction of deep surface impregnation is still more efficient.

Table 3: Initial coefficient of capillary absorption for all four types of concrete with silane compounds added [g/m^2 h$^{0.5}$]

Type of Silane compound	Amount of silane added, %	Concrete A	Concrete B	Concrete C	Concrete D
MH 50	2	101	134	132	94.3
	4	38.2	75	103	66
851	2	82	78.1	98	83
	4	55	57	79	65
WS 600	2	77	55	110	133
	4	35	54	92	66

3.3 Chloride penetration

Chloride profiles as determined on concrete type A, B, C, and D without and with silane compounds added are shown in Figures 1 to 4. Results shown in Fig. 1 are characteristic for concrete with a water-cement ratio of 0.4. A comparatively small amount of chloride penetrated in this case the rather dense porous structure of the neat concrete. But it can also be seen that addition of protectosil has a minor effect on the penetration of chloride with the exception of 4 % MH50 and 4 % WS 600.

The protective function of protectosil becomes more obvious on concretes type B and C with a water-cement ratio of 0.5 and 0.6 respectively. In both cases the service life of reinforced concrete structures in marine environment will be significantly extended if integral water repellent concrete is used. This effect must be taken into consideration in any realistic durability design. If concrete C (W/C=0.6) is prepared with an addition of 4 % protectosil WS600 or with 4 % protectosil MH50, less chloride will enter than into untreated concrete type A (W/C=0.4).

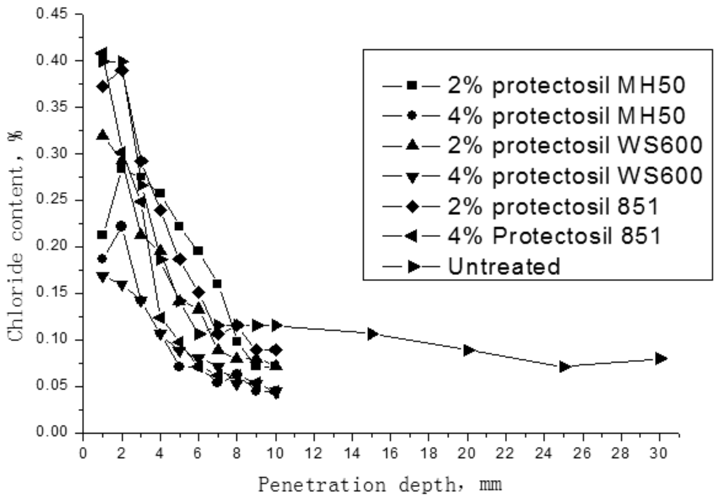

Figure 1: Chloride profiles as established in neat and in integral water repellent concrete type A (W/C=0.4) after 28 days of contact with 5 % NaCl solution

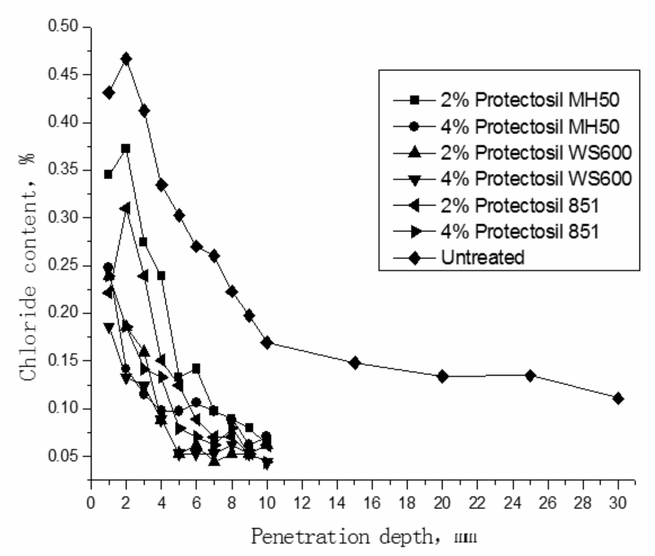

Figure 2: Chloride profiles as established in neat and in integral water repellent concrete type B (W/C=0.5) after 28 days of contact with 5 % NaCl solution

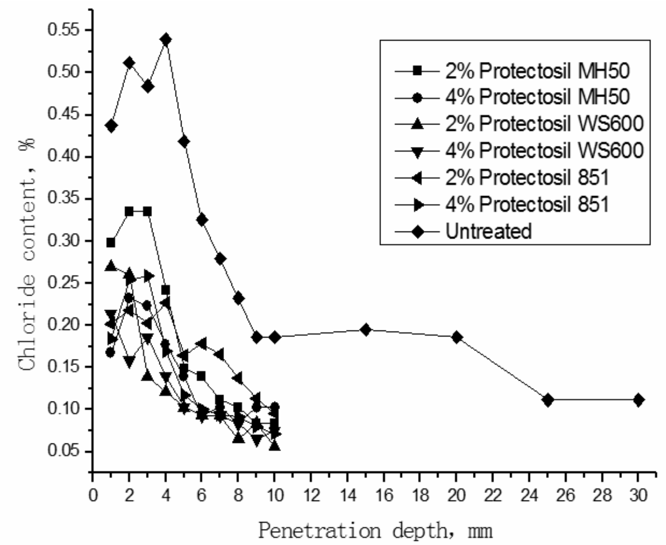

Figure 3: Chloride profiles as established in neat and in integral water repellent concrete type C (W/C=0.6) after 28 days of contact with 5 % NaCl solution

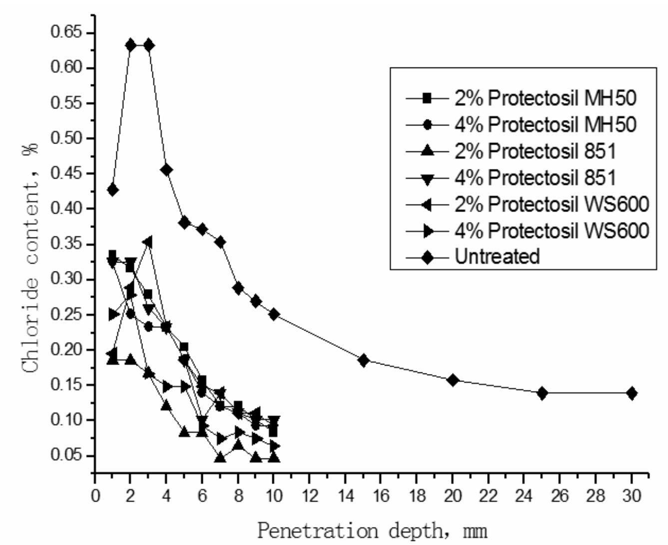

Figure 4: Chloride profiles as established in neat and integral water repellent concrete type D (W/C=0.6 + Fly ash) after 28 days of contact with 5 % NaCl solution

Neat concrete type D absorbs most salt water and as a consequence the chloride profiles show the highest chloride content and deepest penetration of the four tested types of concrete. But the protective function of integral water repellent treatment is most obvious in this type of concrete. If 2% of protectosil 851 are added to the fresh mix the chloride barrier is most efficient. Despite the high porosity of this concrete the integral water repellent concrete type D is still more durable than the neat high strength concrete type A. As a consequence we may conclude that durability of concrete and reinforced concrete structures may be increased by reduction of the water-cement ratio but addition of silane is more efficient and leads to longer service life.

4 Conclusions

Absorption of water and salt solution can be significantly reduced by adding silane compounds to the fresh mix. This technology results in an integral water repellent concrete. For prediction of service life of reinforced concrete structures in marine environment it is mandatory to take the protective function of integral water repellent concrete into consideration. Otherwise the prediction is unrealistic. Use of integral water repellent concrete is more efficient than lowering the water-cement ratio within the practical limits.

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Metal Soaps for the Production of Integral Water Repellent Concrete

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Abstract

It has been shown and verified in practice that surface impregnation of cement-based materials with silane prevents capillary uptake of water and aqueous salt solutions such as seawater. Integral water repellent concrete can also be manufactured by adding silane-based compounds to the fresh mix of concrete or mortar. Service life of concrete structures in aggressive environment can be significantly extended by water repellent treatment. In this contribution the influence of metal soaps to fresh concrete on water repellency of the hardened material has been investigated. The chloride penetration of integral water repellent concrete has been determined after exposure to seawater. The distribution of the metal salts in the treated concrete has also been studied. It has been found that chloride penetration into integral water repellent concrete after adding metal salts to the fresh mix has been slowed down considerably. Although a complete chloride barrier could not be achieved by the addition of metal soaps the service life of reinforced concrete structures can certainly be extended considerable by means of this technology.

Keywords: metal soaps, integral water repellent concrete, chloride penetration