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A New Concept Protecting Concrete Surfaces

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Abstract

1 Introduction

Over the last years the number of fairfaced concrete surfaces which need to be repaired has heavily increased. In most cases, damages are caused by insufficient care during concrete pouring or by the use of lower strength concrete. Two main standards exist in Germany for the appropriate repair of reinforced concrete:

1. “Richtlinie für Schutz und Instandsetzung von Betonbauteilen” by the German committee for reinforced concrete (Deutscher Ausschuss für Stahlbeton DAfStb) [1]
2. “Zusätzliche Technische Vorschriften und Richtlinie für Schutz und Instandsetzen von Betonbauteilen” (ZTV-SIB) by the German minister of transportation (Bundesminister für Verkehr) [2].

Except for two surface protection systems, OS 1 (DAfStb) and OS A (ZTV-SIB), which consist in a simple hydrophobization, all others rely on coatings which change the original exposed concrete surface. No surface protection system with the ability to protect and to preserve exposed concrete facades without changing its surface appearance is known as yet.

The aim of this investigation is to confirm whether the preservation of exposed concrete surfaces with protective substances developed for porous sandstone may bridge the gap in the field of concrete repair. The protective substances should fulfil the following requirements:

- Increase tensile strength of the surface.
- Leave optical appearance of the surface unchanged.
- Minimally reduce water vapour permeability.
- Protect against environmental influences.

In addition to these new protective substances for the protection of historic monuments other possible applications on concrete surfaces will be discussed.

2 Experimental

2.1 Protective substances

The protective substances SSS 219 and SSS 298 (SSS stands for <u>S</u>tein<u>s</u>chutz<u>s</u>toff / Stone Protecting Material) tested were developed within an large research project towards the preservation of porous sandstone at the Institute for Building Research of the Aachen Technical University (RWTH). The effect these protective substances exert is obtained by introducing a protecting and stabilising polymeric microlayer within the cell walls. As protective substances, only dissolved or emulsified components may be used since the evaporation of the solvent or emulsifier maintains permeability. The substances differ in polymer type, that identified by the number 219 is a polyurethane-based material, while the number 298 identifies a silicate ester based one [3].

More important than the polymer class itself are the polymeric chains between the linkages. The penetration depth of polyurethane substances is mainly influenced by the length of the chains. A major part of the development on the substances was the research on its molecular structure. The main problem of the ester silicate development was the shrinkage of the polymer film during solidification. In this case modifications in the arrangement of molecules were made by including elastic molecules within the silicate ester molecules in order to obtain a more elastic and resistant layer. Therefore the tested substances are not comparable to commercial protecting substances [4].

2.2 Specimens

The specimens were made to simulate a practically orientated low strength concrete surface with need of repair. During the preliminary tests a concrete with a the classification B 15 (compression strength of about 15N/mm²) was developed. The mixture is described in Table 1.

The aggregate was a gravel with a sieve-analysis-curve A/B 16, the cement a CEM I 32,5. The specimen were made in form of cubes with the length of 15 cm. They were first stored under water for two days adn subsequently at constant temperature (23°C) and relative humidity (50%) for 210 days.

The obtained concrete had a very low compressive strength and a high water absorption providing very good conditions for the absorption of the protecting substances. The concrete characteristics are shown in table 2.

After the storage of 210 days the protective substances were applied by spraying on a vertical surface. The absorbed quantity was about 1,4 kg/m². The penetration depth was about 16 mm. These results were achieved for both of the protecting substances. The curing time was four weeks. [4]

3 Testing Procedures

3.1 Remarks

The experimental tests were chosen according to standards used to assess the aim of the treatment.

The visual appearance was rated after treatment. So was the water vapor permeability by measuring the diffusion flow density. The surface stabilization of concrete after application of the protecting substances was verified by an abrasion-test on a grinding disk and by measuring the surface tensile strength with a tear-off-test. Additionally an attempt was made to induce surface damage by an extreme freeze-thaw-test.

Material	part [kg/m³]	mass ratio [–]	density [kg/m³]	volume [m³/m³]	weight [kg]
Cement	240,0	1,00	3150	0,0762	17,53
Water	180,0	0,75	1000	0,1800	13,15
Aggregate	1916,8	7,987	2630	0,7288	140,00
Air	0,0	0,0	0	0,0150	
Addition	2336,8	9,737			170,68

Table 1: Concrete mixture of the specimens

Concrete characteristics	age	unit	value
Compression strength	28 d	N/mm²	18,7
	90 d		21,0
	210 d		18,5
Water absorption after 1 h (1)	90 d	M-%	2,79
Water absorption after 24 h (1)	90 d		3,89
Water absorption coefficient (2)	210 d	$kg/(m^2 \cdot h^{0,5})$	2,67
Depth of carbonization	210 d	mm	11
(1): soaking under water (2): capillary suction			

Table 2: Concrete characteristics of the specimens

3.2 Abrasion Resistance

The experimental setup, using a grinding disk (Boehmescheibe), followed DIN-standard 52108. The abrasion of the specimen was determined by measuring the decrease in thickness after each of four test periods.

3.3 Surface Tensile Strength

The tear-off test was conducted following DIN 1048 part 2 chapter 6. Around the test area a radial groove of 10 mm depth was milled with a testing stamp of 50-mm diameter, so that the fractured surface was within the 16-mm penetration area of the protecting substances.

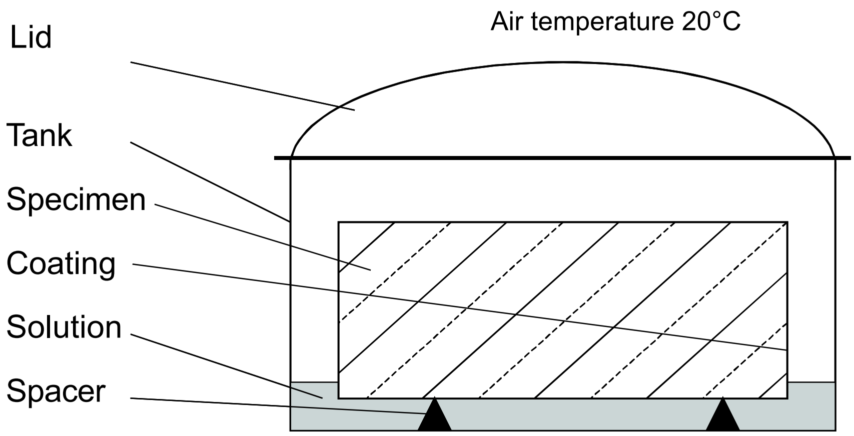

Figure 1: Storage of the specimen during the freeze-thaw-test

3.4 Freeze-thaw Test

The freeze-thaw-test was chosen in order to induce damage on the speciment surface. As the treated specimens did not absorb any water by capillary absorption, a vacuum was first pulled on them and then they were immersed in water. On the other thand, since the untreated specimen were able to absorb water, they were soaked by capillary absorption for 7 days. The freeze-thaw-stress used was based on the CIF-Test from Setzer [5]. During freezing the specimen were sitting 5 mm deep in distilled water.

3.5 Diffusion Flow Measurement

The diffusion flow was measured by the WDL-test (**W**asser**D**urch**L**assversuch) which was developed at the ibac in Aachen. In this test the mass of water evaporating from the surface of the specimen is measured. The specimen, in this case a drill core, stands in a plastic box and only the top surface, treated with the tested substance, is exposed through a hole in the lid having the same diameter as the drill-core. The core stands on gravel in water, so that capillary absorption is not disturbed. The vertical surface of the specimen as well as the whole box is sealed so that evaporation can only occur at the horizontal surface of the specimen. The mass of evaporated water can be measured easily by weighing the whole system. [6] Figure 2 shows the WDL-Test.

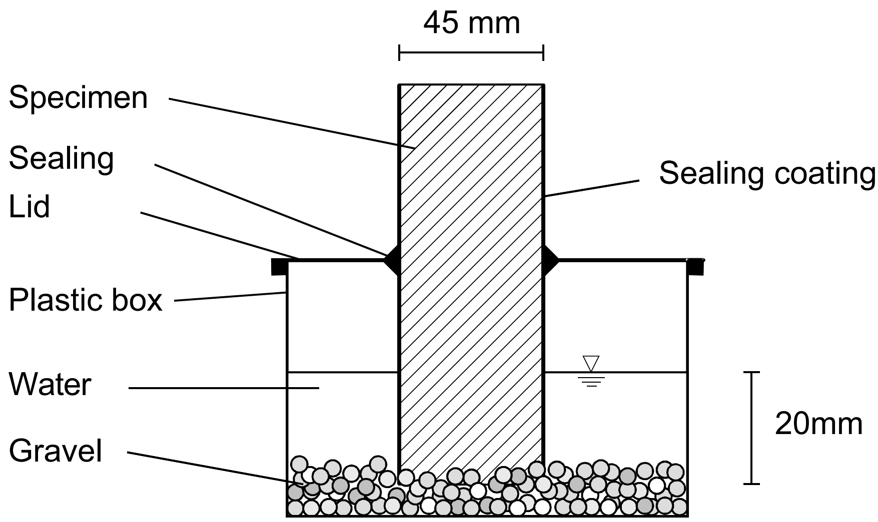

Figure 2: Principle of the WDL-Test

4 Test results and discussion

4.1 Concrete stabilisation in the surface area

4.1.1 Abrasion resistance

The abrasion test with the Böhmescheibe showed a significant increase in abrasion resistance for those specimens treated with the protecting substances.

To evaluate the effect of the substances the first four test periods are important because mainly the surface cement is abraded. In the following periods the influence of the aggregate, with its very high abrasion resistance, gets stronger so that the influence of the protecting substances on the cement matrix can no longer be detected as clearly with this method.

After the first four test periods, treatment with the protective substances reduced the abrasion by 28% for the SSS 219, and by 20 % for the SSS 298. In spite of the aggregate contribution, after 16 test periods a reduction of abrasion by 24 % (SSS 219) and 20% (SSS 298) was measured as compared to the results of the untreated specimens.

Fig. 3 shows the abrasion values as compared to the tolerated abrasion of the guideline RILI-SIB of the DAfStb for the old surface protection systems OS 3 and OS 12 for industrial floors.

Although both of the protection systems OS 3 and OS 12 do no longer exist, the comparison of the test results to the requirements of these old guidelines is very interesting as since the experimental setup is the same.

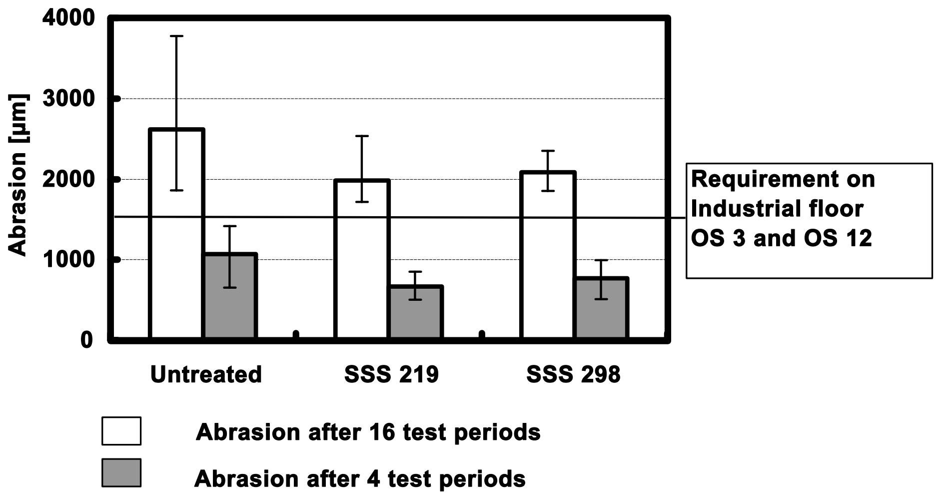

Figure 3: Abrasion with the Boehmescheibe. Average, minima and maxima of each 16 specimen. Concrete with water-cement ratio of 0.75, impregnated with protection agents

The OS 3 and OS 12 systems tolerated an abrasion of max. 8 cm³ and a 25% increase of abrasion resistance. An abrasion of 10.9 cm³ was obtained for the specimen treated with SSS 219, and of 11.5cm³ for that treated with SSS 298. The abrasion resistance increase was of 24 % (SSS 219) and 20 % (SSS 298).

4.1.2 Surface tensile strength

The treatment of the specimen with the protecting substances caused a high increase of the surface tensile strength. The strength increased by more than 100 % for both cases. The measured data are shown in fig. 4.

High surface tensile strength is required when the surface is to be coated. In the Rili SIB from the DAfStb and the ZTV-SIB from the German Minister for Transportation different requirements for the surface tensile strength are stated. Surfaces of lower strength concrete often do not fullfill the requested values. Although the surfaces of the untreated specimen did not fulfill the tensile strength requirements, the specimens treated with the protection substances did. In table 3 the test results are compared to the requirements of the Rili-SIB and the ZTV-SIB.

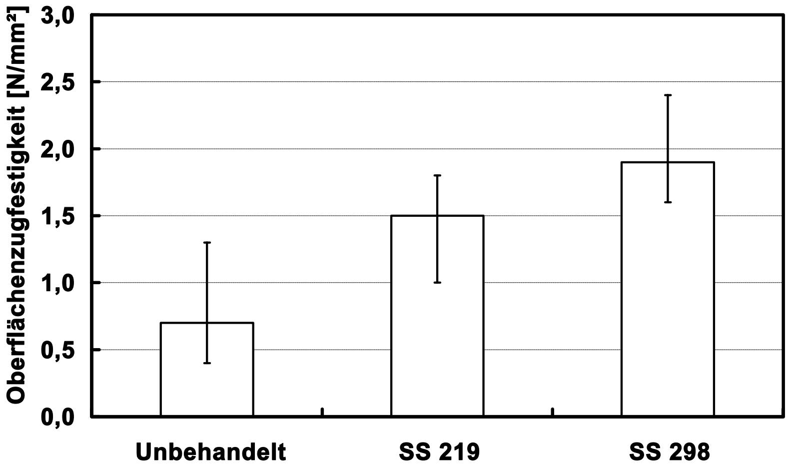

Figure 4: Surface tensile strength. Average, minima and maxima of each 6 single values. Requests of the Rili SIB and ZTV-SIB. Concrete with water-cement-ratio of 0,75.

4.2 Freeze-thaw-test

During the 22 frost periods of the test (11 days) there was no surface damage detected on the protected specimens. However, the unprotected concrete surface lost 1450 g/m² material from the surface in this same time span.

4.3 Measurement of the diffusion flow

The measurement of the diffusion flow showed that for both protection treatment a sufficient diffusion flow took place. Compared to the untreated specimen there is a small reduction of the flow, however, the diffusion flow is far over the known values of impermeable concrete, around 20 g/(m²d). Fig. 5 presents the test results.

5 Conclusions

The protective substances SSS 219 and SSS 298 were originally developed for porous sandstone. Applied to lower strength concrete they were able to effect a noticeable increase of strength throughout their range of penetration depth. The result is an increase of abrasion resistance of up to 37 % and an increase of the surface tensile strength of over 100 %. There is no change in the appearance of the original surface and a no significant loss of water vapour diffusion occurs. Both of

Protection system: Local repair/ Surface coating	Surface tensile strength [N/mm²]	
	average	Lowest single value
Test results		
Untreated specimen	0,5	0,7
SSS 219	1,5	1,0
SSS 298	1,9	1,5
Requirements of Rili SIB		
Concrete for not drivable surfaces	≥1,5	≥1,0
Polymerconcrete for not drivable surfaces	≥1,5	≥1,0
OS 2	≥0,8	≥0,5
OS 4, OS 5	≥0,8	≥0,5
OS 9	≥1,3	≥0,8
OS 11	≥1,5	≥1,0
OS 13	≥1,5	≥1,0
Requirements of ZTV-SIB		
Concrete repair system	≥1,5	≥1,0
OS A, OS B	-	≥0,6
OS D (without fine spackle)	≥1,0	≥0,6
Systems with fine spackle	≥1,3	≥0,8
OS-F	≥1,5	≥1,0

Table 3: Requirements on concrete surfaces for coatings

the protective substances cause a surface hydrophobization so that water absorption is reduced.

After the evaluation of the test program we can say that these protective substances can cause a strengthening protection of exposed concrete surfaces which reduces or stops damage from weathering.

Another practical area where these protective substances could be very useful is in the conventional field of concrete repair if a certain surface tension strength is needed in order to coat concrete.

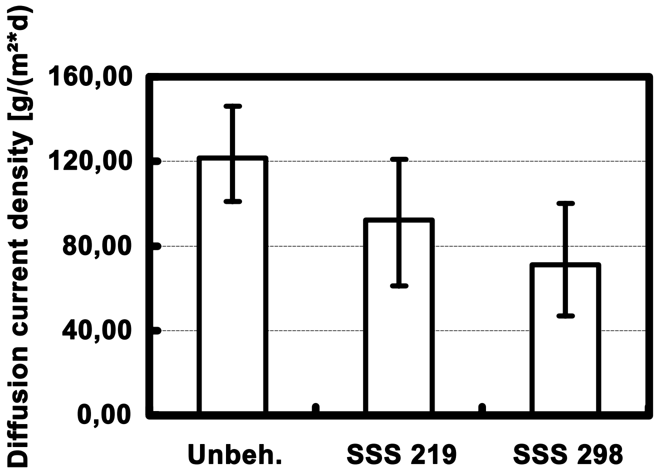

Figure 5: Diffusion flow at WDL-Test. Concrete surface treated with protective substances. Average, maxima and minima of 16 measurements each. Concrete with water-cement-ratio 0,75.

The fact that the treated surface still maintains its water vapour permeability allows treatment of even newly poured concrete so that different building procedures can be accelerated.

All in all the investigated protection substances provide many different new possibilities for protection and strengthening of concrete surfaces.

6 References

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