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Title: The Use of Pavix CCC100 as a Reinforced Concrete Impregnate and as an Alternative to Silane.

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Abstract

In the UK, protective impregnation of reinforced concrete bridges and marine structures is stipulated in Highway Authority (HA) regulations. These define performance criteria for concrete impregnates based on test results obtained for Silanes. In this context, a single option material type has existed in concrete impregnation for more than two decades. At the same time, in Europe and elsewhere we see an irreversible move towards deduced dependency on materials that are hazardous to humans and the ecosystem. Whilst measures that extend the useful life of the built infrastructure are consistent with this and the aspirations of 'sustainable construction', continuing use of toxic substances like Silanes is not. Pavix CCC1000 is a water based, alternative that has emerged out of this conflict. Tests show conclusively that it achieves the Saline criteria and delivers additional benefits for structures, construction workers and the environment.

Keywords

Concrete, deterioration, protection, impregnation, highways authority, bridges, Silane, health & safety, ecosystem, Pavix, departures, freeze-thaw testing, ancient monuments

INTRODUCTION

Concrete deterioration

The deterioration of reinforced concrete structures of all types is a major social and economic problem in the developed countries. Many causes have been identified, particularly under the headings of poor workmanship and environmental attack. Under the first, lack of reinforcement cover and low concrete strength are commonly sited. Carbonation, caused by exposure to acid rain is a principal consideration under the second. In consequence, reinforcement corrosion, rust staining, concrete spalling and exposed reinforcement have become the stereotyping features of older reinforced concrete structures. Impregnation can be effective in helping to sustain the durability of such structures.

Silane Impregnate

In the case of highway bridges and marine structures, which for more than two decades have fallen under the HA regulatory requirements for Silane impregnation, the track record is mixed. Doubtlessly, numerous valuable structures have benefited from this treatment. At the same time, problem structures are frequently observed when travelling on the highways. Whilst purely conjecture, there are grounds to believe that such structures may have been short measured in the protective impregnation process with Silane. Acknowledging the perverseness of English weather and putting aside tales of Silane being applied in the rain, it is likely that the required dry conditions [1] have not always been achieved. More understandable is the difficultly commonly experienced in achieving the specified two 300ml/m^2 applications, particularly on vertical and inclined surfaces. Not surprisingly, application of the first coat tends to refuse the second. Interestingly, competition has pushed down the contractual prices of applied Silane to the extent that they are frequently less than the cost of the material alone. Putting aside acts of charity, this phenomena points to under-dosing. Where there is a significant shortfall in the applied dosage, the regulatory performance criteria, which were derived using the full dosage, are unlikely to be attained.

Site application of Silane by spray method carries significant risks, particularly when working over rivers and good land where containment should be used. Furthermore, applicators, other workers and members of the public need to be protected from expose to it. Additionally, because of its aggressive solvent properties, asphaltic pavement and bridge bearings have to be protected.

Alternative Materials

In Europe and elsewhere we see an irreversible move towards deduced dependency on materials that are hazardous to humans and the ecosystem. Whilst measures that extend the useful life of the built infrastructure are consistent with this and the aspirations of ‘sustainable construction’, continuing use of toxic substances like Silanes is not. This has led to the formulation of ‘green’ concrete impregnates. To the best knowledge of the authors, table 1 provides a comparison of available water proofing and impregnation materials. Excluding Saline, a common characteristic of these materials is their crystallisation mechanism.

In respect to highway bridges and marine structures in the UK, Pavix is the only alternative impregnate that has been tested and found to comply with the requirements of the HA [1]. Mainly for this reason, the HA have granted departures for the use of Pavix instead of Silane on a growing number of highway bridges. Referring again to table 1, the unique features of Pavix are (i) single coat application (ii) treats heavy trafficked areas, (iii) deep penetration, (iv) permanent treatment, (v) very good water and chemical repellency. (vi) freeze thaw protection, (vii) protection against chloride ions and (viii) protection of substrate region. Of these, the first is a great benefit in managing the construction process, where flexibility is a key issue. Its applicability to heavy trafficked areas has led to large scale applications on roads and airports.

	WATER PROOFING-IMPREGNATION MATERIAL				
	Pavix	Silanes	Sodium Silicate	Xypex	Vandex
CHARACTERISTICS					
Product Appearance	Liquid	Liquid	Liquid	Powder	Powder
Base Material	Water	Solvent	Water	Cement	Cement
Single Component Product	Yes	Yes	Yes	Add Water	Add Water
Non-film Forming	Yes	Yes	Yes	No	No
Easy to Apply	Yes	Yes	Yes	No	No
Single Coat Application	Yes	No	No	No	No
Environmentally Friendly	Yes	No	Yes	Yes	Yes
Treats Heavy Trafficked Areas	Yes	No	No	No	No
Deep Treatment	Yes	No	No	No	No
PERFORMANCE					
Permanent Treatment	Yes	No	No	No	No
Water Repellency	Very Good	Good	No	No	No
Chemical Repellency	Very Good	Good	No	No	No
Enhances Adhesion	Yes	No	Yes	Yes	Yes
Curing Function	No	No	No	No	No
Crystallization Mechanism	Hydrophilic/ Hygroscopic	-	Hydrophilic	Hygroscopic	Hygroscopic
Crystal Growth Towards Moisture	Yes	-	-	Yes	Yes
High Freeze-Thaw Protection	Yes	No	No	No	No
High Protection Against Chloride Ions	Yes	No	No	No	No
Reduces ASR (New Concrete)	Yes	No	Yes	No	No
Reduces Efflorescence	Yes	No	Yes	No	No
Reduces Moisture Transmission	Yes	No	No	Yes	Yes
Substrate Region Protected	Internal	Surface	Surface	Surface	Surface

Table 1 [Based on Data Supplied by Int. Chem-Crete Corp]

This Paper

This paper focuses on the use of Pavix as an alternative impregnation for concrete. It continues with a review of tests carried out to evaluate importance aspects of performance. The results of testing to HA requirements [2] are included. This is followed by an account of a recently concluded freeze-thaw test programme conducted by the authors. The paper concludes with observations on the merits of Pavix impregnation.

TESTS CONDUCTED ON PAVIX

A large range of tests have been carried out to assess the influence of Pavix impregnation on various performance issues. These are summarized in table 2. This indicates that Pavix impregnation (i) improves resistance to scaling, (ii) reduces water vapour transmission through concrete, (iii) does not reduce the bonding ability of the concrete surface, (iv) enhances abrasion resistance of concrete surfaces, (v) does not adversely influence the skid or slip resistance of concrete surfaces and (vi) complies with drying rate, absorption and alkali resistance criteria set by testing Silanes. The last item in table 2 is relevant for site application, especially over rivers and good land. The scope of this paper does not allow all known tests to be reported, which include those carried out to Czech Republic and Russian Government Standards. These essentially support the results described in table 2.

Performance Issue	Test Conducted	Principal Outcome with Pavix Impregnation
Chloride Penetration	AASHTO T 259-00 Resistance of Concrete to Chloride Penetration	Reduced penetration of chloride into concrete [3]
Abrasion Resistance	ASTM C-944-99 Standard Test Method for Abrasion Resisatnce of Concrete or Mortar Surfaces by the Rotating-Cutter Method	Abrasion resistance of concrete is not adversely affected (possibly enhanced).[3]
Water Absorption	ASTM D 6489 Standard Test Method for Surface Water Absorption in Concrete.	Significant water sealing effect on concrete surface, (4 x uncoated) [4]
Water Vapour Transmission	ASTM E 96-95. Standard Test Method for Water Vapour Transmission Materials	Reduced water vapour transmission through concrete [3]
Pull Off Strength	ASTM D-4541-95 Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Tester	Does not appear to affect pull-off strength of concrete [3]
Scaling Resistance	ASTM 672-98 Standard Test Method for Scaling Resistance of Concrete surfaces Exposed to De-icing Chemicals	Reduced degree of scaling damage [3]
Slip & Skid Resistance	ASTM F 609 Standard Test method for Static Slip Resistance of Footwear, Sole, Heel or Elated Materials by Horizontal Pull Slip-meter (HPS). ASTM E 303 Standard Test Method for Measuring Surface Frictional Properties Using the British pendulum Tester	Does not impact on the slip or skid resistance of concrete surfaces (applies to wet roads or pedestrian pavement). [3]
Depth of Penetration	Stereomicroscope observation used. No Applicable Standard	2.5mm Min, 6.4mm Max and 4.4mm Ave penetration [3]
Resistance to Liquids	CSN EN ISO 2812-1 Painting Compounds-Determination of Resistance to Liquids.	Protects against Petroleum [5]
Silane Alternative	‘Drying Rate Coefficient’, Appendix 2, Design Manual for Road & Bridges BD43/03 (British Isles)	Mean ‘Drying rate Coefficient‘ determined to be > 30% [2]
Silane Alternative	‘Absorption Ratio & Alkali Resistance’, Appendix 2, Design Manual for Road & Bridges BD43/03 (British Isles)	‘Absorption Ratio’ determined to be < 7.5% before exposure to alkali and < 10% after exposure to alkali [2]
ASR Resistance	ASTM C 1260. (Modified) Standard Test Method for Alkali-Silica Reaction Assessment	Significant potential to control expansion at early stage. Further work needed to conclude effectiveness for older concrete. [6]
48 hr.Toxicity	EPA-821-R-02-012, Oct 2004: Methods for Measuring the Acute Toxicity and Receiving Waters to Freshwater & Marine Organisms.	Indicates that dilution by rainfall run-off or drift during application would not cause acute toxicity in the receiving water. [7]

Table 2: Previous tests conducted in Pavix impregnated concrete

FREEZE-THAW TESTING

The authors have conducted a freeze-thaw testing programme on Pavix impregnated concrete to quantify its contribution to freeze thaw resistance. This was done strictly in accordance with ASTM C 1262-98 [8]. The approach differs from ASTM 672-98 referred to in table 2, which assesses surface deterioration using a 0-5 visual rating scale. The adopted test specimens were twelve 6cm x 7cm x 35cm coupons cut as pairs from old and new factory made reinforced concrete. These were dense, well compacted grade 40 concrete with light reinforcement. Eightly freeze-thaw cycles were applied, sufficient to justify weight loss analysis. One specimen from each pair was impregnated with Pavix at a dosage rate of 200ml/m2. To access the permanency of the impregnation, button cores were extracted and absorption tested at the end of the programme.

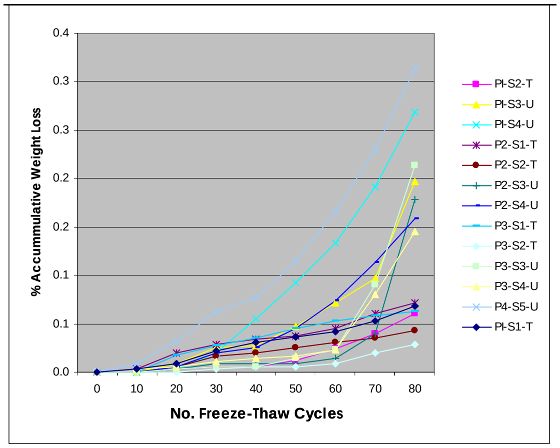
Following impregnation with Pavix and prior to commencement of freeze-thaw testing, the samples were condition. For this, each sample was placed in its own specially fabricated plastic container (figure 1) giving the surrounding clearances specified in ASTM C 1262-98.

Figure 1: Untreated sample in specially fabricated sealable Perspex box

The conditioning procedure, which takes about 24 hours, started by adding water at a temperature of 16-27 ^{0}C to the containers in order to achieve the required depth. Prior to finally sealing the containers and loading them into the freezer, the specimens were weighted to an accuracy of ± 0.1grams. At this stage bands of moisture were observed (figure 1) on the top faces of untreated specimens, these corresponding to through depth cracks. The fact that is did not occur in the treated specimens was attributed to the crack sealing properties of Pavix.

During the freezing cycle, the air temperature inside the chest freezer was maintained at –18 ± 5 ^{0}C for 4.5 hours excluding the temperature stabilising time which was typically 3.0 to 3.5 hours. The thawing cycle followed immediately after the freezing cycle. Sample containers were taken from the freezer and placed within a temperature controlled room, where the air temperature was maintained at 24 ± 5 ^{0}C. Using this facility, the duration of the thawing cycle proved to be about 16 hours.

At the completion of each 10th complete freeze-thaw cycle, the weight loss of each sample was determined. This process followed the standard’s strict procedure that ensures that finest particles are accounted for in the determination of weight losses. The specimen weights were also determined after drying at 100-115 ^{0}C for 24 ± 1 hours.



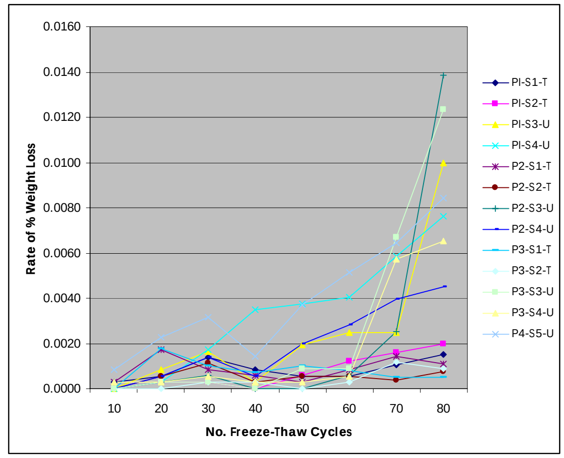


Figure 2: Percentage Accumulative of Weight Loss

Figure 3: Rate of % Weight Loss

Figure 2 shows the accumulative percentage weight loss for all specimens, treated specimens suffixed T and untreated U. From this, it is apparent that the treated specimens experience significantly less weight loss than their untreated counterparts. The results shown in figure 2 are reworked as first order loss rates in figure 3. Without exception, the untreated specimens have developed significantly higher rates of weight loss than their treated counterparts. All the treated specimens experience a similar low rate for weight loss without the notable increases experienced by the untreated samples.

To assess water absorption at the completion of the freeze thaw programme, extracted core buttons were soaked for 96 hours in a weak florescent sodium dye solution and dried for a further 48 hours before sectioning and light polishing. The cut sections shown in figure 4 were photographed under ultra-violet light. This was done by following a tried and tested procedure reported elsewhere [9].

Section from treated specimen

Section from untreated specimen

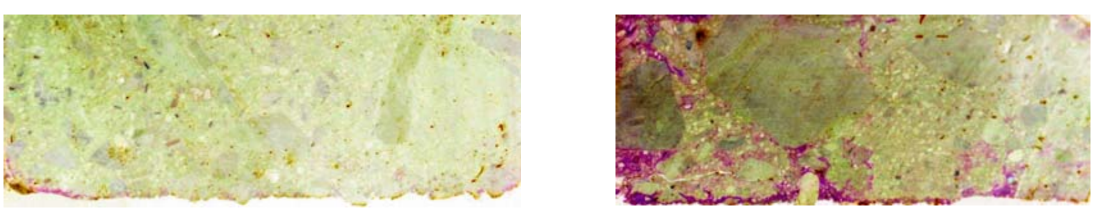


Figure 4: Absorption test for treated and untreated post samples

Comparing penetration in the two specimens, it is apparent that significantly more penetration has occurred in the untreated specimen (right in figure 4) than in the treated specimen (left in figure 4). The moisture blocking mechanism, claimed with Pavix impregnation, appears to be still active after subjecting the post samples to 80 freeze-thaw loading cycles.

OBSERVATIONS & CONCLUSIONS

A brief account has been given of the wide range of tests previously carried out on Pavix impregnated concrete. These address engineering performance, application and usage, and environmental protection issues. In all respect the contribution of Pavix impregnation is positive.

Further to the tests reviewed, the authors have reported a freeze-thaw testing programme undertaken in accordance with ASTM C 1262-98. The overall conclusions are that impregnation of reinforced concrete specimens with Chem-Cete Pavix CCC100 at a dosage of 200ml/m^2 (i) significantly reduces the rate of weight loss, (ii) opposes moisture transmission through cracks and (iii) resists water absorption on water soaked surfaces. Point (ii) supports the manufacturer's claim that Pavix has crack filling properties.

The water absorption test conducted following the completion of freeze-thaw loading indicates that Pavix's moisture blocking mechanism is not detectably degraded. It is reasonable to expect the impregnation to penetrate to a depth of 6mm-7mm and, on this basis, considerable weight loss would have to occur before the impregnation were no longer effective.

Future tests are planned which focus of the potential role of Pavix in the protection of ancient monuments. This involves a range of building materials other than concrete.

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