

# An approved alternative to silane

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**The Design Manual for Roads and Bridges (DMRB) BD 43/03<sup>(1)</sup>, published by the Highways Agency, prescribes measures by which bridges and marine structures may be protected. The publication specifies impregnation by hydrophobic, pore-lining materials to protect reinforced and prestressed concrete structures. While the Highways Authority has a policy of not endorsing or approving specific materials or products, silane has been the only material approved for this purpose.**

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This is unsurprising as the compliance criteria stated in the DMRB were determined using silane formulations. This is unfortunate because silane is now recognised to be a highly toxic material, prompting investigations into ‘worker-safe’, environmentally-friendly alternatives. As a consequence, it is proving necessary to establish a safe, environmentally sensitive alternative. Fortunately, the DMRB recognises the possible emergence of other impregnation materials.

While there are a number of other compliance considerations, such as weight loss under freeze/thaw cycles, the silane-derived compliance criteria currently prevails. Therefore, to promote interest in other impregnation solutions, the testing methods specified in BD 43/03 have been applied to Pavix CCC100, a water-based concrete impregnate. This was selected for evaluation because it is safe to use and does not pollute the environment. It is safe for use over rivers and may be disposed of in storm or foul water sewers. The material has only recently been introduced into the UK, but has a track record in the USA, Czech Republic, Russia and elsewhere. The tests, conducted on three separate batches of concrete, suggest that Pavix CCC100 complies with the BD 43/03 criteria for concrete impregnation<sup>(2)</sup>. Furthermore, a departure from the Specification for Highway Works: Clause 1709 has approved the use of Pavix CCC100 as an alternative material to silane<sup>(3)</sup>. It is understood that many similar departures have been granted for major highway projects across the UK. An example of a motorway

bridge recently treated with Pavix CCC100 is shown in Figure 1. This is situated on the A1 (M) between junctions 60 and 61 on the northbound climbing lane.

## Pavix CCC100

The material is a hygroscopic solution that applies hydrophilic and hydrophobic actions. It seeks water and combines with it to grow crystals that resist water. The crystals, which adhere tightly to the concrete pores, grow and shrink according to the amount of available moisture. Consequently, the impregnate provides water-resistance and reduced vapour permeability according to the prevailing conditions. A major innovation is that the material is formulated as a stable liquid. Unlike silane, it is not necessary to use special equipment to detect fraudulent dilution.

## Compliance criteria

The criteria stated in Appendix 2 of BD 43/03 is summarised in Table 1, together with the results for Pavix CCC100. The criteria used are the drying rate coefficient and absorption ratio before and after alkali exposure. The former initially appears to be unusual as impregnation using only water gives an apparently acceptable result, in excess of 30%. At the same time, a lower limit is needed because the structure must be allowed to ‘breathe’. The rationale for the absorption ratio is clear because water intake must be combated. Although an acceptable zero value would be achieved using an impermeable coating, this would not simultaneously achieve the specified drying rate requirement. The coefficients combine to achieve the necessary water resistance and vapour permeability. Absorption testing following exposure to potassium hydroxide gives an indication of expected performance under prolonged operational conditions.

## Compliance testing

Three separate batches of nine test cubes of Type C (0.45 water/cement ratio) were prepared in accordance with BS EN 1766: 2000 *Products and systems for the protection and repair of concrete structures. Test methods. Reference concretes for testing*<sup>(4)</sup>. The 28-day strength requirement is 50±5MPa. Following discussions with the material manufacturer, impregnated cubes received a minimum Pavix CCC100 dosage of 200g/m<sup>2</sup>. The soak time required to achieve this minimum dosage was previously determined using spare cubes cast together with batches of test cubes. Following the BD 43/03<sup>(1)</sup> testing procedure, cube impregnation was undertaken by dipping each of the six cube faces

**Figure 1: A motorway bridge situated on the A1(M) between junctions 60 and 61 which has been recently treated with Pavix CCC100.**



(Photo: Denis Chamberlain.)

**Table 1: BD 43/03 criteria and results for Pavix CCC100.**

Issue	Criteria (silanes)	Pavix CCC100	Result
Drying rate coefficient	>30%	30.7%	Pass
Absorption ratio	<7.5%	6.0%	Pass
Absorption ratio (after alkali treatment)	<10%	7.8%	Pass

into the material.

The testing equipment included weighing scales calibrated to  $\pm 0.01$  gm, temperature- and humidity-controlled chambers, a forced air circulation oven and fume cupboard. While use of the latter is specified, this is more appropriate for silanes than Pavix CCC100, which is both odourless and fumeless. It was important to avoid cross-contamination during testing. Mould release agents could not be used in the casting process. The total testing period was just over four months, with up to 21 days between individual stages.

#### Drying rate coefficient testing

Drying rate coefficient testing, as specified under Part A of BD 43/03 Appendix 2, focuses on the effect of moisture transmission through the near-surface region of the concrete. In the test, three cubes were impregnated and three were left untreated. The untreated cubes were used to provide a basis for estimating the oven-dry weight of other test cubes. The drying rates of the treated and untreated cubes were determined to establish the drying coefficient, following environmentally controlled conditioning. The actual coefficient is defined as the percentage ratio of the treated cube drying rate (24 hrs) against the untreated cubes (18 hrs).

#### Absorption tests

Subject to suitable storage, the absorption tests under BD 43/03 Part B permit reuse of the six test cubes from the drying test under Part A. Both the untreated and treated cubes are weighed before and after immersion in demineralised water. The absorption ratio is then established as the percentage ratio of the weight gain rate in the treated cubes over that of the untreated cubes. For alkali-resistance testing, treated cubes are totally immersed in potassium hydroxide solution for a period of 21 days and air-dried to achieve their weight prior to the absorption test. A second water absorption test follows for the treated cubes, giving an absorption rate ratio after alkali contamination.

#### Other tests

There are several relevant tests to establish the performance of impregnates for structures and pavements. These relate to the pull-off strength of coatings and resistance to freeze-thaw, chemical, surface abrasion, surface skid and scaling under exposure to de-icing salts. Pavix CCC100 has been tested according to tests formulated by the American Society for Testing and Materials (ASTM) and other international Codes and Standards. While detailed coverage of test results is beyond the scope of this article, the results are favourable. For example, impregnation has a negligible effect on surface skid resistance and pull-off strength. Other than the structures directly covered by BD 43/03, there are numerous situations where these broader performance characteristics are relevant.

#### Safety issues

A comparison of the health and safety characteristics for silane and Pavix CCC100 is given in Table 2. It is clear that the latter presents a more manageable risk control problem. The use of silane on highway bridges, for example, fre-

**Table 2: The comparative safety characteristics of silane and Pavix CCC100.**

Characteristic	Silane	Pavix CCC100
Appearance	Colourless	Colourless
Water repellence	Yes	Yes
Vapour permeability	Yes	Yes
Toxicity	Acute, affecting humans, animals and vegetation	None
Odour	Fruity, often objectionable	None
Fumes	Yes	None
Irritation	Skin irritating	Non-irritant
Environmental hazards	High-risk	None
Water-contamination	High-risk	None
Flammability	High-risk	None
Explosive with air	Possible	No
Flashpoint	39°C	None
Boiling point	150°C	100°C
Workplace containment	Yes, depending on site conditions	Unnecessary
Waste hazard	Hazardous	Non-hazardous
Stability	Hazardous decomposition products (inc. methanol)	Non-hazardous

quently poses numerous health and safety considerations, particularly for 'live bridge' renovation projects. BD 43/03 specifies the maximum acceptable windspeeds during spraying. However, the wind environment around bridges is frequently unpredictable, with gusts and rapid direction changes. As a consequence, operatives, other workers and members of the public are at risk. In lane closure projects, passing vehicles are vulnerable to wind-blown spray. In the case of bridges over rivers and land, effective measures need to be taken to avoid harming fish, animals and vegetation. While there is a strong case for full containment during impregnation, this is frequently difficult, costly and particularly unwelcome at the closing stages of contracts when time constraints are most apparent.

#### Concluding remarks

Silane is a highly toxic impregnation material will probably be banned by legislation in the near future. Pavix CCC100, an alternative, has been tested according to the strict procedures specified in BD 43/03 Appendix 2<sup>(1)</sup>. Tests on three independent batches of cubes prove compliance with BD 43/03, thereby clearing the way towards adoption by the industry. The characteristics of this water-based material are favourable to the management of health and safety and environmental pollution control. Departures from the *Specification for Highway Works: Clause 1709* have now been approved, permitting the use of Pavix CCC1000 as a silane alternative. This will affect new and existing structures in numerous major projects across the UK. ■

#### References:

1. THE HIGHWAYS AGENCY. Design Manual for Roads and Bridges Volume 2, Section 4, BD 43/03 *Highway structures: design (substructures and special structures), materials, paints and other protective coatings*, Her Majesty's Stationery Office, 2003.
2. CHAMBERLAIN, D. *Pavix CCC100: Impregnation of reinforced and prestressed concrete highway structures*, Test Report ESRC/2003/CP/01, Structures Research Centre, City University, London, October 2003.
3. UK HIGHWAYS AUTHORITY. *Departure from Specification for Highway Works: Clause 1709 to use 'Pavix CCC100' as an alternative to silane for the impregnation of concrete surfaces*, Departure ID 38974, June 2004.
4. BRITISH STANDARDS INSTITUTION. BS EN 1766: *Products and systems for the protection and repair of concrete structures. Test methods. Reference concretes for testing*. 2000.

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