

**The Concrete Testing Laboratory
School of Engineering
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LONDON EC1 VOHB
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**An investigation sponsored by the
Engineering Structures Research Centre**

**TEST REPORT ESRC/2003/CP/01
PAVIX CCC100: Impregnation of Reinforced
and Pre-stressed Concrete Highway Structures**

**Testing In Accordance With the Procedures of
Appendix 2, Design Manual for Roads and Bridges
BD 43/03***

[*The Highway Agency, Scottish Executive Development Department, Welsh Assembly Government Llywodraeth Cynulliad Cymru and The Department for Regional Development Northern Ireland]

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Preface

This report gives the results of testing the concrete impregnate, Chem Crete Pavix CCC100 according to the procedures specified in Appendix 2 of the Design Manual for Roads & Bridges, BD 43/03. To date, the most commonly specified material has been Epichem Silane, the generic material used to derive the Highways Agency acceptability criteria.

The motivation for the report is the possibility for improving the health & safety climate of those employed in the application of impregnates. A further driver is the possibility of reducing the risk of environmental pollution that arises in the use of toxic substances. In this context, it is interesting to compare some of the characteristics of Silane and Pavix CCC100 given in the table below.

Characteristic	<i>Silane</i>	<i>Pavix CCC100</i>
Appearance	<i>Colourless</i>	<i>Colourless</i>
Water repellent result	<i>Yes</i>	<i>Yes</i>
Vapour permeable result	<i>Yes</i>	<i>Yes</i>
Toxicity	<i>Acute, affecting humans, animals and vegetation</i>	<i>None</i>
Odour	<i>Fruity, often objectionable</i>	<i>None</i>
Fumes	<i>Yes</i>	<i>None</i>
Irritant	<i>Skin irritating</i>	<i>Non irritant</i>
Environmental hazards	<i>High Risk</i>	<i>None</i>
Water contaminate	<i>High Risk</i>	<i>None</i>
Flammability	<i>High Risk</i>	<i>None</i>
Explosive with air	<i>Possible</i>	<i>Not possible</i>
Flashpoint	<i>39°C</i>	<i>None</i>
Boiling point	<i>150°C</i>	<i>100°C</i>
Workplace containment	<i>Yes, depending on site conditions</i>	<i>Not needed</i>
Waste hazard	<i>Hazardous</i>	<i>Non Hazardous</i>
Stability	<i>Hazardous decomposition products (inc. methanol)</i>	<i>Non Hazardous</i>

In comparing Silane and Pavix CCC100, it is interesting to note that they deliver different mechanisms. According to its manufacturer, Silane is a hydrophobic pore lining material which reacts with silicates and moisture to produce a water-repellent but vapour-permeable layer. Pavix CCC100 on the other hand, lines pores with strong, tightly adhering crystals that deliver a combination of hygroscopic, hydrophilic and hydrophobic actions. In this case, gas permeability is given by the deduction in crystal size under drying conditions. The crystals shrink and grow according to moisture availability.

From the accompanying test results, Pavix CCC100 is proven to comply with the acceptance criteria set by the Highways Agency. Furthermore, noting the observations of section 8.4 Vol 2, Section 4, Part 2 BD 43/03, there appears to

be nothing preventing the specification of Paxiv CCC100 as an alternative to Silane.

Those interested in the wider performance issues with Paxiv may be interested to note that favourable outcomes have been determined for the range of tests summarised in the table below.

STANDARD	Property Aspect
ASTM C666	<i>Resistance of Concrete to Rapid Freezing and Thawing</i>
ASTM C672	<i>Scaling Resistance of Concrete Surfaces Exposed to De-Icing Chemicals</i>
ASTM C1218	<i>Water-Soluble Chloride in Mortar and Concrete and Mortar</i>
ASTM C944	<i>Abrasion Resistance of Concrete or Mortar Surfaces</i>
ASTM D4541	<i>Pull Off Strength of Coating</i>
CSN 73 1326	<i>Surface Corrosion Resistance Test of Cycle Freezing in Salt Solution</i>
CSN EN IOS 2821-1	<i>Chemical Resistance Test</i>
CSN 73 6177	<i>Surface Skid Resistance Test</i>
CSN 73 2578	<i>Water-Proofing Test of Concrete</i>
CSN EN 1062-3	<i>Water Absorption Test of Concrete</i>
GOST 12730.5-84, GOST 22690-88, GOST 10060-95, GOST12730.1-78, GOST 12780.1-78 and GOST 10180-90. These Russian tests address all the above aspects of testing.	

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Introduction

The laboratory work has been conducted according to the strict procedures set out in Appendix 2 of BD 43/03. This gives test methods that evaluate the effectiveness of impregnation in terms of (i) the 'drying rate coefficient' and (ii) the 'absorption ratio' before and after exposure to alkali. The purpose of the work is to determine whether or not Chem Crete Pavix CCC100 is an acceptable impregnant for use on Highway Agency structures.

The requirements for acceptance by the Highways Authority are summarised in the table below:

Criteria	Value(Silanes)
Drying Rate Coefficient	> 30%
Absorption Ratio	<7.5%
Absorption Ratio (after alkali treatment)	<10%

European Standards

This laboratory investigation is based on the following European Standards:

- prEN 13579 (Pre-normative) Test 1: Drying test for surface impregnants
- EN 1766:2000 Products and systems for the protection and repair of concrete structures - Test methods - Reference concretes for testing.
- EN 13580, Products and systems for the protection and repair of concrete structures - Test methods - Water absorption and resistance

Testing Laboratory

Details of the testing laboratory are as follows:

The Concrete Laboratory
Tait Building
School of Engineering
City University
Northampton Square
London EC1 VOHB

Report reference

This report designation is: TEST REPORT ESRC/2003/CP/01: PAVIX CCC100 Impregnation of Reinforced and Pre-stressed Concrete Highway Structures.

Manufacturer of impregnation material

The manufacturer and supplier of PAVIX CCC100 is:

International Chem-Crete Corp.
800 Security Row
Richardson, TX 75081

Batch identification

The product's 55 gallon container bares the identification as follows:

Chem Crete Pavix CCC100
 Batch ID: 101/3

Supply date

The product was supplied as a 55 gallon (US) sealed drum dated 6th April 2003

Date of test

The preparation of test specimens commenced on 12th June 2003. There was no deviation from the specified test procedures. In accordance with section A2.7 the dipping time for impregnation was increased from 120 ± 5 secs. to 200 ± 5 secs. This was necessary to achieve the manufacturer's minimum specified dosage of 200g/m^2 . Prior to commencing the main tests, a trial batch of cubes was produced to determination the required dipping time.

Test cube numbering

Three separate batches of test cubes were prepared, as sets of nine cubes for the purposes of impregnation testing and six cubes for strength determination by crushing. The mix production dates, cube numbering and the purpose of each cube in the impregnation testing are given in the table below:

Mix date: 5 th May for 12 th June 2003		
Batch No.	Cube No.	Purpose
B	7-PB1	Untreated
B	8-PB2	Untreated
B	9-PB3	Untreated
B	10-PB4	Treated
B	11-PB5	Treated
B	12-PB6	Treated
B	13-PB7	Oven dried
B	14-PB8	Oven dried
B	15-PB9	Oven dried

Mix date: 9 th June for 7 th July 2003		
Batch No.	Cube No.	Purpose
C	16-PC1	Untreated
C	17-PC2	Untreated
C	18-PC3	Untreated
C	19-PC4	Treated
C	20-PC5	Treated
C	21-PC6	Treated
C	22-PC7	Oven dried
C	23-PC8	Oven dried
C	24-PC9	Oven dried

Mix date: 21 th July 8 th for 18 th August 2003		
Batch No.	Cube No.	Purpose
D	25-PD1	Untreated
D	26-PD2	Untreated
D	27-PD3	Untreated
D	28-PD4	Treated
D	29-PD5	Treated
D	30-PD6	Treated
D	31-PD7	Oven dried
D	32-PD8	Oven dried
D	33-PD9	Oven dried

In the text only the last digit is referenced e.g. Batch B, Cube No. 4 means 10-PB4

Concrete mix design

The concrete mix design used for all three batches of test cubes was Type C (0.45) in accordance with EN1766:2000 section 6.2.1.2. This mix requires 360 kg/m³ cement, and 0.45 water/cement ratio. The cubes are also required to have an average 28 day compressive strength of (50 ± 5) N/mm². Compression testing conducted in accordance with prEN 12390 proved all three batches to be within the required strength limits.

The materials and masses used for the production of all three batches are given in the table below:

Constituent Material	Wt (Kg)
Cement	5.8
Sand	10.2
10mm Aggregate	6.6
20mm Aggregate	13.2
Water	2.6
Total Mix*	38.4

* This mix volume allowed additional cubes to the nine required in each batch for testing, to be cast. These were used for compression testing at 28 days after casting.

Further details of the concrete constituents are given in the following table.

Constituent: Cement	
Type	Supplier
Blue Circle (Lafarge) Ordinary Portland Cement (OPC) conforming to BS EN 197-1 CEM 1 42.5N	PJ Johnson & Co (Timber) LMD, Johnsons Quay, 166-168 Shepherdess Walk LONDON NI 7JL
Constituent: Fine Aggregate	
Type	Supplier
Coarse sharp sand	PJ Johnson & Co (Timber) LMD, Johnsons Quay, 166-168 Shepherdess Walk LONDON NI 7JL
Constituent: Coarse Aggregate	
Type	Supplier
Type: Uncrushed (gravel), max. coarse size: 20mm	PJ Johnson & Co (Timber) LMD, Johnsons Quay, 166-168 Shepherdess Walk LONDON NI 7JL

Laboratory Testing Part A

Tests for drying rate

Test Procedure

The principle of the test method is to compare the 'rate of drying' and 'water absorption' of treated and untreated test cubes from the same batch of concrete. The ratios of the rates are defined as the 'drying rate coefficient', and the 'absorption ratio'. Testing has been conducted on three different batches of concrete, denoted B, C and D. A trial batch denoted 'A', not reported, was produced to determine the dosage time and generally familiarise oneself with the testing procedures.

The notation employed in this report is the same as that defined in BD 43/03. For convenience, this is reproduced in the Appendix of this report. Reference to an item of equipment is indicated as (E7), for example

Cube conditioning

The three separate batches of 100mm concrete test cubes were all cast (E1) to Type C (0.45) specification with 28 day curing in accordance with EN1766. The dates of the three batches are given in the 'laboratory log' included in the Appendix of this report.

No oil or releasing agent was used (E1). After removal from the curing tank, the cubes were cleaned with tap water using a soft brush (E2) to remove loose material. The test cubes were surface dried using absorbent paper towel (E3) and then weighed (giving W_{ssd}) using the precise balance (E4). Six test cubes (No. 1-6) were placed on a laboratory bench for conditioning. These cubes were supported to enable air to circulate around each of their 6 faces (E5). They were left in this environment for 7 days, with the temperature and humidity automatically monitored at 1 hour intervals, to confirm that the temperature remained within 21 ± 2 °C and Relative Humidity within $60 \pm 10\%$ (E6). Following conditioning, the cubes were reweighed (giving W_t). The remaining three cubes were dried in an oven maintained automatically at (105 ± 5) °C (E7) for 7 days, and then cooled in a desiccator cabinet containing silica gel (E8), and reweighed (W_{od}). In addition, test cubes (No. 1 - 6) were weighed daily during conditioning until their weight, W_t , was equivalent to a moisture content of (5 ± 0.5) %.

Cube treatment

Three test cubes (No. 4 - 6) were treated in a fume cupboard (E9) with the fan on immediately after conditioning.

A cube was treated by dipping each face in Pavix CCC100, with reweighing for each dipped face (giving W_{t1}). For each face, 60ml of fresh Pavix CCC100 was measured into a clean, empty 150mm square petri dish (E10) prior to

dipping. The face of the cube, supported on the 2mm plastic spacers, was dipped in Pavix CCC100 for 200 ± 5 secs. and removed. Excess liquid on the cube was allowed to drain back into the dish, and the cube immediately reweighed (giving W_t2). The contents of the dish were then discarded, and fresh Pavix CCC100 measured into a clean petri dish ready for the next cube face. This process was repeated successively for the other five faces of the cube, each treated face marked (small dot with fine marking pen), to avoid repeated treatment. The above procedure was repeated for the other two cubes.

The treated cubes were then stored in the fume cupboard, with the fan off for 48 hours after the start of the treatment. All cubes were supported to allow air was to freely circulate about all 6 faces.

Cube drying

The drying test was carried out on three treated and three untreated test cubes prepared as described above.

The rate of drying of three treated and three untreated test cubes was determined by measuring their weight loss in an environment cabinet. The treated and untreated cubes were tested at different times to avoid cross contamination of the specimens. Conditions inside the environment cabinet were monitored using a temperature and humidity-measuring device, which automatically took readings at 1 hour intervals.

Untreated cubes

The three untreated test cubes (No. 1 - 3) were weighed (d_0) and placed in a cabinet with a controlled environment of $30 \pm 2^\circ\text{C}$ and Relative Humidity of $40 \pm 5\%$ (E11) immediately after conditioning. They were reweighed (d_1) after 6 hours. The drying test was continued for a further 18 hours, after which time the cubes were again weighed (d_2).

Treated cubes

The three treated test cubes (No. 4-6) were weighed 48 hours after treatment (d_0) and then placed in a cabinet with a controlled environment of $30 \pm 2^\circ\text{C}$ and Relative Humidity ($40 \pm 5\%$). The cubes were then removed after 24 hours and weighed (d_1). At this stage it was confirmed that $d_1 < W_t$.

The drying test was then continued for a further 24 hours, after which the cubes were reweighed (d_2).

Storage for further testing

Following completion of the drying test, BD43/03 permits the use of the same test cubes for water absorption and alkali testing, but on the condition that the specimens are immediately placed in an airtight container over an aqueous solution of Potassium Sulphate (E12). This was done using separate airtight, sealed boxes for each cube.

Calculation of DRC

Notation used, is the same as that defined in BD43/03, is given in the Appendix of this report. The stages of determining the 'Drying rate coefficient, DRC' are as follows:

Conditioning stage

The *saturated surface dry moisture content* (M_{ssd}) of the 3 oven dried test cubes (No. 7-9) is calculated as:

$$M_{ssd} = [(W_{ssd} - W_{od}) / W_{od}] \times 100 \text{ in \% by weight}$$

The *estimated oven dry weight* (W'_{od}) of the remaining 6 test cubes (No. 1-6) is calculated as:

$W'_{od} = W_{ssd} / (1 + 0.01M_m)$ in grams, where M_m in % by weight is the mean saturated surface dry moisture content of three oven dry test cubes (No. 7-9)

The *estimated moisture content* of test cubes after conditioning (M'_t) is calculated as:

$$M'_t = [(W_t - W'_{od}) / W'_{od}] \times 100 \text{ in \% by weight}$$

Treatment stage

The *consumption of impregnant for each face* of a test cube (C_n) is calculated as:

$$C_n = (W_{t2} - W_{t1}) / 0.01 \text{ in g/m}^2$$

Drying stage

The *untreated test cube drying rate* (D_u) is calculated as:

$$D_u = (d_1 - d_2) / (18 \times 0.06) \text{ in g/m}^2\text{h}$$

The *treated test cube drying rate* (D_t) is calculated as:

$$D_t = (d_1 - d_2) / (24 \times 0.06) \text{ in g/m}^2\text{h}$$

The *drying rate coefficient* (DRC)

$DRC = (D_{tm} / D_{um}) \times 100$ in %, where D_{um} and D_{tm} are respectively the mean drying rates of the untreated and treated test cubes.

Dry rate test results

Mean saturated moisture content (Mssd)mean

Batch No.	Cube No.	Mssd%	(Mssd)mean%
B	13-PB7	6.14	
B	14-PB8	5.08	
B	15-PB9	5.24	5.489%
Batch No.	Cube No..	Mssd%	(Mssd)mean%
C	22-PC7	5.59	
C	23-PC8	5.20	
C	24-PC9	5.14	5.312%
Batch No.	Cube No..	Mssd%	(Mssd)mean%
D	31-PD7	5.70	
D	32-PD8	5.25	
D	33-PD9	5.45	5.467%

Mean moisture content of test cubes after conditioning (M't)_{mean}

Batch No.	Cube No.	M't %	(M't)mean %
B	7-PB1	4.57	
B	8-PB2	4.53	
B	9-PB3	4.53	
B	10-PB4	4.43	
B	11-PB5	4.57	
B	12-PB6	4.51	
B		Mean	4.523%
Batch No.	Cube No.	M't	(M't)mean
C	16-PC1	4.56	
C	17-PC2	4.54	
C	18-PC3	4.42	
C	19-PC4	4.55	
C	20-PC5	4.52	
C	21-PC6	4.54	
C		Mean	4.521%
Batch No.	Cube No.	M't	(M't)mean
D	25-PD1	4.56	
D	26-PD2	4.65	
D	27-PD3	4.59	
D	28-PD4	4.72	
D	29-PD5	4.61	
D	30-PD6	4.59	
D		Mean	4.618%

Mean Consumption of the impregnant $(C_m)_{mean}$

Batch No.	Cube No.	Cm	$(C_m)_{mean}$
B	10-PB4	246.37	
B	11-PB5	247.10	
B	12-PB6	227.37	
B		Mean	240.28 g/m ²
Batch No.	Cube No.	Cm	$(C_m)_{mean}$
C	19-PC4	193.69	
C	20-PC5	219.44	
C	21-PC6	207.70	
C		Mean	206.94 g/m ²
Batch No.	Cube No.	Cm	$(C_m)_{mean}$
D	28-PD4	216.39	
D	29-PD5	203.91	
D	30-PD6	237.21	
		Mean	219.17 g/m ²

The 'Drying Rate Coefficient' (DRC)

Batch B		DRC (%)
D_{tm}	0.564815	40.27%
D_{um}	1.123457	>30%
Batch C		DRC (%)
D_{tm}	1.416667	30.34%
D_{um}	4.669753	>30%
Batch D		DRC (%)
D_{tm}	1.388889	31.15%
D_{um}	4.765432	>30%

Where: D_{tm} is the mean drying rate of three treated test cubes (in g / m² x h) and D_{um} is the mean drying rate of three untreated test cubes (in g / m² x h).

It is noted that all three batches comply with the given criteria. The mean result of any combination of two results gives DRC > 30%.

Test dates and equipment

The dates of all activity are given in the Appendix of this report. A list of equipment used is also given in the Appendix.

Deviation from specified test method

There were no deviations from the specified testing procedure. As previously stated, the dipping time for each face of the test cubes was 200 ± 5 secs rather than 120 ± 5 secs. This increase is taken as permitted under the stated procedure as a necessary provision for achieving the manufacturer's specified minimum dosage of 200 g/m^2 . The necessary dipping time was determined prior to commencement of the tests here reported

Report authentication

All the data and information contained in this report is correct to the best knowledge of the investigator:

Signed:



Date: 31th October 2003

Laboratory Testing Part B

Tests for absorption & alkali resistance

Test Procedure

The test cubes (No. 1-6) were removed from storage (E9) 14 days after treatment of the treated cubes (No. 4-6). Both treated and untreated test cubes were placed into individual beakers (E14), supported on spacers which allowed coverage of 25mm when filled with demineralised water (E13).

Untreated Cubes

The three untreated test cubes (No. 1 - 3) were weighed (i_1) and immersed in demineralised water as described in 'test procedure', for 1 hour. After this time the three cubes were removed and surface dried using absorbent paper towel, and then reweighed (i_2)

Treated Cubes

The three untreated test cubes (No. 4 - 6) were weighed (i_1) and immersed in demineralised water as described in 'test procedure', for 24 hours. After this time the three cubes were removed and surface dried using absorbent paper towel, and then reweighed (i_2)

Alkali Exposure Procedure

Immediately following the absorption test, the three treated cubes (No. 4 - 6) were placed in individual beakers containing Potassium Hydroxide solution (E15), supported such that that the cubes were under a head of 25mm. The beakers were securely covered with cling film, and were left for 21 days.

After this time, the cubes were removed and allowed to dry on the laboratory bench, until their weight was found to be within $\pm 2g$ of the weight recorded prior to the absorption test (i_1). When this was satisfied, the three cubes were subjected to a second absorption test, using the same procedure outlined for treated cubes in 'test -procedure'.

Calculation of absorption rates

These calculations follow on from the calculation for DRC. The absorption test rate of increase in weight for a treated cube (l_t) is calculated as:

$$l_t = (i_2 - i_1) / (\sqrt{24} \times 0.06) \quad \text{in g/m}^2\text{h}^{0.5}$$

The absorption test rate of increase in weight for an untreated cube (l_u) is calculated as:

$$l_u = (i_2 - i_1) / (\sqrt{t} \times 0.06) \quad \text{in } \text{g/m}^2\text{h}^{0.5}$$

The *Absorption Ratio* (AR) is calculated as:

$$\text{AR} = (l_{tm} / l_{um}) \times 100 \quad \text{in } \%$$

where l_{tm} is the mean rate of weight gain of the three treated test cubes and l_{um} is the mean rate of weight gain of the three untreated test cubes

The *Absorption Ratio of cubes following the alkali treatment* (AR_{alk}) is calculated as:

$$\text{AR}_{alk} = (l_{tm(alk)} / l_{um}) \times 100 \quad \text{in } \%$$

where $l_{tm(alk)}$ is the mean rate of weight gain of the three test cubes after immersion in alkali, in grams.

Absorption rate test results before exposure to alkali (AR)

Batch B	$\text{g} / \text{m}^2 \times \text{h}^{0.5}$	AR (%)
l_{tm}	12.10	
l_{um}	228.78	5.3% < 7.5%

Batch C	$\text{g} / \text{m}^2 \times \text{h}^{0.5}$	AR (%)
l_{tm}	14.88	
l_{um}	248.65	5.9% < 7.5%

Batch D	$\text{g} / \text{m}^2 \times \text{h}^{0.5}$	AR (%)
l_{tm}	17.12	
l_{um}	278.52	6.1% < 7.5%

Where: l_{tm} is the mean drying rate of three treated test cubes (in $\text{g} / \text{m}^2 \times \text{h}^{0.5}$) and l_{um} is the mean drying rate of three untreated test cubes (in $\text{g} / \text{m}^2 \times \text{h}^{0.5}$)

As shown in the table above, the results for the '*Absorption Ratio*' meet the stated requirements.

Absorption rate test results after exposure to alkali (AR_{alk})

Batch B	$g / m^2 \times h^{0.5}$	AR (%)
I_{tm}	15.22	
I_{um}	252.13	6.0% < 10.0%

Batch C	$g / m^2 \times h^{0.5}$	AR (%)
I_{tm}	21.33	
I_{um}	243.32	8.8% < 10.0%

Batch D	$g / m^2 \times h^{0.5}$	AR (%)
I_{tm}	18.78	
I_{um}	263.21	7.1% < 10.0%

Where: I_{tm} is the mean drying rate of three treated test cubes (in $g / m^2 \times h^{0.5}$) and I_{um} is the mean drying rate of three untreated test cubes (in $g / m^2 \times h^{0.5}$)

As shown in the table above, the results for the 'Absorption Ratio' (following alkali treatment) meet the stated requirements.

Report authentication

All the data and information contained in this report is correct to the best knowledge of the investigator:

Signed:



Date: 31st October 2003

Conclusions

The impregnant material Pavix CCC 100 has been tested according to the testing methods set out in Appendix 2, Volume 2, Section 4, Part 2 of BD 43/02, Design Manual for Roads and Bridges.

Three, rather than two separate batches of Type C (0.45) concrete have been tested. And, according to the given acceptance criteria, Pavix CCC 100 is found to be a suitable material for protective impregnation of highway and marine structures.

The worst case result mean for any combination of two batches is given by batches C and D:

Factor	Criteria	Mean of two batches	Pass/Fail
Dry rate coefficient	>30%	30.74%	Pass
Absorption rate	<7.5%	6.0%	Pass
Absorption rate (after alkali)	<10.0%	7.8%	Pass

Appendix: Notation

Symbol	Explanation	Unit
AR	Absorption Ratio	%
AR(alk)	Absorption Ratio after exposure to Alkali	%
C _m	Mean consumption of impregnant during treatment	g/m ²
C _n	Consumption of impregnant for each face of test cube during treatment	g/m ²
d ₀	Weight of a test cube prior to placing in environmental cabinet	g
d ₁	Weight of a test cube after initial conditioning in environmental cabinet	g
d ₂	Weight of a test cube at end of drying test	g
DRC	Drying Rate Coefficient	%
D _t	Drying rate of a treated test cube	g/m ² × h
D _{tm}	Mean drying rate of three treated test cubes	g/m ² × h
D _u	Drying rate of an untreated test cube	g/m ² × h
D _{um}	Mean drying rate of three untreated test cubes	g/m ² × h
i ₁	Weight of a test cube at start of immersion test	g
i ₂	Weight of a test cube at end of immersion test	g
l _t	Rate of increase in weight of a treated test cube	g/m ² × h ^{0.5}
l _t (alk)	Rate of increase in weight of a treated test cube after exposure to alkali	g/m ² × h ^{0.5}
l _{tm}	Mean rate of increase in weight of three treated test cubes	g/m ² × h ^{0.5}
l _{tm} (alk)	Mean rate of increase in weight of three treated test cubes after alkali	g/m ² × h ^{0.5}
l _u	Rate of increase in weight of an untreated test cube	g/m ² × h ^{0.5}
l _{um}	Mean rate of increase in weight of three untreated test cubes	%
M _m	Mean saturated surface dry moisture content of 3 oven dry test cubes	%
M _{ssd}	Saturated, surface dry moisture content of a test cube, calculated	%
M' _t	Estimated moisture content of each test cube after conditioning	%
W _{od}	Weight of a test cube in oven dry condition	g
W' _{od}	Estimated weight of a test cube in oven dry condition	g
W _{ssd}	Weight of a test cube in saturated surface dry condition	g
W _t	Actual weight of test cube after conditioning	g
W _{t1}	Weight of test cube immediately prior to treatment	g
W _{t2}	Weight of test cube immediately after treatment	g

Appendix: Laboratory Log

BATCH B (Cube Marks 7-PB1 to 15-PB9)		
Activity	Start	Finish
PB1 - PB9 Casting / Curing	15/05/2003	12/06/2003
PB1 - PB6 Lab Conditioning	12/06/2003	19/06/2003
PB7 - PB9 Oven Drying	12/06/2003	19/06/2003
PB1 - PB3 Drying Test (untreated)	19/06/2003	20/06/2003
PB4 - PB6 Pavix Treatment	19/06/2003	19/06/2003
PB4 - PB6 Storage	19/06/2003	21/06/2003
PB4 - PB6 Drying Test (treated)	21/06/2003	25/06/2003
PB1 - PB3 Storage	20/06/2003	03/07/2003
PB4 - PB6 Storage	25/06/2003	03/07/2003
PB1 - PB6 Start Immersion Test	03/07/2003	
PB1 - PB6 Water emersion	03/07/2003	04/07/2003
PB4 - PB6 Alkali Immersion test	04/07/2003	28/07/2003
Repeat above Immersion Test	28/07/2003	23/08/2003

BATCH C (Cube Marks 16-PC1 to 24-PC9)		
Activity	Start	Finish
PC1 - PC9 Casting / Curing	09/06/2003	07/07/2003
PC1 - PC6 Lab Conditioning	07/07/2003	14/07/2003
PC7 - PC9 Oven Drying	07/07/2003	14/07/2003
PC1 - PC3 Drying Test (untreated)	14/07/2003	15/07/2003
PC4 - PC6 Pavix Treatment	14/07/2003	14/07/2003
PC4 - PC6 Storage	14/07/2003	16/07/2003
PC4 - PC6 Drying Test (treated)	16/07/2003	20/07/2003
PC1 - PC3 Storage	15/07/2003	28/07/2003
PC4 - PC6 Storage	20/07/2003	28/07/2003
PC4 - PC6 Start Immersion Test	28/07/2003	
PC4 - PC6 Water Immersion	28/07/2003	29/07/2003
PC4 - PC6 Alkali immersion test	29/07/2003	23/08/2003
Repeat above Immersion Test	23/08/2003	17/09/2003

BATCH D (Cube Marks 25-PD1 to to 33-PD9)		
Activity	Start	Finish
PC1 - PC9 Casting / Curing	21/07/2003	18/08/2003
PC1 - PC6 Lab Conditioning	18/08/2003	25/08/2003
PC7 - PC9 Oven Drying	18/08/2003	25/08/2003
PC1 - PC3 Drying Test (untreated)	25/08/2003	26/08/2003
PC4 - PC6 Pavix Treatment	25/08/2003	25/08/2003
PC4 - PC6 Storage	25/08/2003	27/08/2003
PC4 - PC6 Drying Test (treated)	27/08/2003	31/08/2003
PC1 - PC3 Storage	26/08/2003	08/09/2003
PC4 - PC6 Storage	31/08/2003	08/09/2003
PC4 - PC6 Start Immersion Test	08/09/2003	
PC4 - PC6 Water Immersion	08/09/2003	09/09/2003
PC4 - PC6 Alkali immersion test	09/09/2003	2/10/2003
Repeat above Immersion Test	02/10/2003	25/10/2003

Appendix: Apparatus and materials used in testing

Reference	Item
E1	Nine steel moulds for concrete cubes (100 mm x 100 mm x 100 mm).
E2	Soft wire brush.
E3	Absorbent paper towel
E4	Satorius "Excellence" Scales, Type: E5500 S. Fabrication No. 37010205. Accuracy of ± 0.01 g.
E5	Support for test cubes on bench in laboratory or in fume cupboard to allow air to circulate around all 6 faces.
E6	Chamber maintained at constant temperature (21 ± 2) °C and relative humidity of (60 ± 10) %. RH/TempLog (Temperature and Relative Humidity Data Logger) Product No: 35710-10. Supplied by Cole-Parmer Instrument Co., Ltd. Unit 3, River Brent Business Park, Trumpers Way, Hanwell, LONDON W7 2BR
E7	Forced air circulation oven to run at (105 ± 5) °C. Type E150/242S. Type E150/242S. Serial No. Y15178. Manufactured by Barlow & Whitney, Bletchley, London.
E8	Desiccator cabinet containing silica gel.
E9	Fume cupboard.
E10	150 mm diameter petri dishes with 2 spacers glued to bottom of dish to support the test cubes during treatment.
E11	Environmental cabinet which maintains temperature at (30 ± 2) °C and relative humidity of (40 ± 5) %. Type CT/DEG-1-R10-HED-100°C. Manufacture by Fission Scientific Ltd. Loughborough, Leicester.
E12	Air tight boxes containing saturated potassium sulphate solution for storing specimens. Note that treated and untreated test cubes are stored in separate boxes.
E13	Demineralized water (conductivity < 50 μ S)
E14	Six 5L beakers with suitable spacers to support test cubes
E15	Potassium-hydroxide solution (5.6g/L)
E16	Cling Film