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## INVESTIGATION REPORT

### EARLY SILANE TREATMENT OF CONCRETE

#### GLEBE ISLAND BRIDGE

**CLIENT:** DRYTREAT (AUSTRALIA) PTY LTD

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**PROJECT:** GLEBE ISLAND BRIDGE  
EFFECT OF AGE OF CONCRETE ON SILANE TREATMENT

**PREPARED BY:** FRED SALOME

**DATE:** 09/11/92 **JOB No.** 291

**REPORT No:** C9120 **REF:** DRYTREAT\291R9120

## SUMMARY

The tests carried out showed that applying silane to the concrete used on this project immediately after removal of the forms gave equal efficiency to application after a longer curing period. The reductions in both water uptake and chloride ion ingress were comparable to results obtained when applying silane to well-cured concrete.

The silane was found to be compatible with the Concure and Ashford curing membranes; and could be applied before or after the membrane with no direct effect on the silane efficiency.

Application of the silane prior to the curing membrane was shown to have no detrimental effect on the ability of the membrane to retain moisture in the concrete, and gave a slight improvement in efficiency.

The silane acted as an ion filter allowing some water uptake while excluding dissolved chloride ions.

## INTRODUCTION

The new Glebe Island Bridge is being built by Baulderstone Hornibrook Pty Ltd for the Roads and Traffic Authority of NSW. Silane impregnation is desired by the RTA to ensure the long-term durability of the concrete.

The concrete towers are being constructed using slip-forming techniques. As the structure grows, concrete surfaces are only accessible for a short period after they are cast. Consequently it is not practicable to wait the usual 28 days before applying the silane to the concrete surfaces.

The concrete mix design for the towers is a 50 MPa mix containing 440 Kg GP cement per tonne, and having a water/cement ratio of 0.4. Under the site conditions, the forms remain in place for approximately 48 hours after the pour. Current practice is to apply a wax-based curing membrane as soon as possible, after any necessary patching has been carried out.

A number of alternative application procedures were suggested to overcome the limited period during which access was available. These variations included

- 1) applying the silane as soon as the surface is exposed, prior to the application of the curing membrane.
- 2) applying a silane compatible curing membrane, followed by application of the silane after a number of days.

C.T.I. Consultants Pty Ltd was asked to investigate the effect on silane efficiency of these variations, and to determine if there would be any deleterious effect on the performance of the curing membrane.

## EXPERIMENT 1 - EFFECT OF APPLICATION SCHEDULES ON SILANE EFFICIENCY

### TEST DETAILS

The tests were carried out on cylinders produced from typical concrete delivered to the Glebe Island Bridge site. The test samples were cast in 100 mm diameter cylinders on 26/09/92. They were placed in plastic bags for transport to CTI. On arrival the cylinders in their moulds were removed from the bags and transferred to a fog room.

The cylinders were stripped at an age of 48 hours, on 28/09/92, and were then left exposed to full sunlight and wind for 2 hours before being treated as below. All treatments applied in full sunlight, commencing at 12.00 noon.

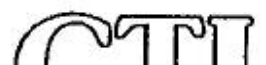
Treatment with DryTreat 100N involved immersing the sample in the silane for 10 seconds. The immersion was repeated after a 6 hour period.

The curing membranes used were "Ashford 3799" (a silane compatible water-borne curing membrane supplied by Remedial Building Systems Pty Ltd) and "Concure" (a wax based product currently used on site). Each of these membranes was applied at the recommended rate by brush, two hours after stripping the moulds. Where the curing agent was applied after the silane treatment (ie. samples 1 & 2) a thirty minute interval was allowed between the second silane treatment and the application of the membrane.

After treatment the cylinders were left outside for 4 days, then cut into three sections by taking a 25 mm slice out of the middle leaving test samples of approximately 160 mm length.

After two more days the cut face of each top and bottom portion was sealed with epoxy, and the samples were left outside for a further 17 days to ensure adequate curing and a practical reduction in the free moisture content. The samples were then placed in an 80°C oven for 24 hours, then removed and allowed to cool for 24 hours before testing as described below.

The slices taken from the middle of each core were not treated any further, and were retained to check the depth of penetration of the silane.

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## IMMERSION IN 15% SALT WATER SOLUTION

One half of each cylinder (the lower half) was tested for water and chloride ion uptake on salt-water immersion. The samples were immersed for the periods below in a 15% solution of salt (NaCl) in water, at room temperature.

Water uptake was determined as the weight gain after each immersion. Two immersion cycles were performed, separated by a 4 day drying period at 80°C. The first immersion period was of 48 hours duration, the second of 24 hours.

The figures presented in Table 1 are the cumulative weight gains for each specimen over the two cycles, and the percentage by which this is less than total weight gain for the untreated specimen (%-reduction in weight gain).

The unconfined compressive strengths and the chloride ion contents of the samples were determined by analysis on completion of the test program, and are presented in Table 3.

Sample No.	Treatment	Total Weight Gain (g)	%-Reduction in Weight Gain
3	No Treatment	79.5	0% (= STD.)
4	Ashford Only	82	N/A *
5	Concure Only	76.9	N/A *
6	DryTreat 100N	7.2	90.9 %
1	DT 100N/Ashford	5.4	93.2 %
2	DT 100N/Concure	5.5	93.1 %
7	Ashford/DT100N @ 3 days	7.9	90.1 %
8	Ashford/DT100N @ 5 days	6.8	91.4 %
9	Ashford/DT100N @ 7 days	6.4	91.9 %
11	Concure/DT100N @ 3 days	8.2	89.7 %
12	Concure/DT100N @ 7 days	5.3	93.3 %

\* On the second immersion, the untreated sample absorbed less water than the samples treated with curing membrane alone.

Table 1; Weight gain on immersion in salt water

## EXPOSURE TO SALT FOG CONDITIONS

The top half of each cylinder was placed for a period of 10 days in a salt fog machine running at a temperature of 50°C and generating the fog from a 5% NaCl solution.

The weight gain over the ten day period was recorded, and compared to the weight gain for the untreated specimen (sample 3). These are presented in Table 2.

The unconfined compressive strengths (UCS) and the chloride ion contents of the samples were determined by analysis on completion of the test program, and are presented in Table 3.

Sample No.	Treatment	Total Weight Gain (g)	%-Reduction in Weight Gain
3	No Treatment	23.7	0% (= STD.)
4	Ashford Only	32.4	N/A *
5	Concure Only	26.7	N/A *
5			
6	DryTreat 100N	5.9	75.1 %
1	DT 100N/Ashford	4.2	82.3 %
2	DT 100N/Concure	3.8	84.0 %
7	Ashford/DT100N @ 3 days	4.5	81.0 %
8	Ashford/DT100N @ 5 days	3.7	84.4 %
9	Ashford/DT100N @ 7 days	2.8	88.2 %
11	Concure/DT100N @ 3 days	4.0	83.1 %
12	Concure/DT100N @ 7 days	5.1	78.5 %

\*Both samples treated with curing membrane alone showed a greater weight gain than the untreated sample.

Table 2; Weight gain in salt fog machine

EFFECT OF TREATMENT ON STRENGTH AND CHLORIDE ION UPTAKE.

Table 3 shows the compressive strength (UCS) and the total chloride ion concentration (Cl, in ppm) for the samples after the test program.

Sample No.	Treatment	After Immersion UCS*	Cl	After Salt Fog UCS*	Cl
3	No Treatment	59.5	2900	41.0	1500
4	Ashford Only	61.0	3700	46.5	870
5	Concure Only	58.5	2600	39.5	1100
6	DryTreat 100N	56.5	15	45.0	79
1	DT 100N/Ashford	59.0	23	49.5	140
2	DT 100N/Concure	54.5	28	45.5	74
7	Ashford/DT100N @ 3 days	60.5	40	44.0	> 5
8	Ashford/DT100N @ 5 days	59.5	> 5	42.5	> 5
9	Ashford/DT100N @ 7 days	57.5	8	42.0	> 5
11	Concure/DT100N @ 3 days	54.5	32	44.5	> 5
12	Concure/DT100N @ 7 days	62.0	> 5	49.0	47

\* UCS test cylinders were 80 mm in height and 100 mm diameter with a height/diameter ratio of 0.8, and therefore showed a higher strength characteristic than standard cylinders with a height/diameter ratio of 2.0.

Table 3: Compressive Strength and Salt Content after Testing



## EXPERIMENT 2 - EFFECT OF SILANE ON EFFICIENCY OF CURING MEMBRANES

This test was intended to parallel the standard procedure for evaluating curing membranes, as outlined in ASTM-C-156 and also in Australian Standard AS 3799-90.

However no direct comparison can be made to the water-retention rates in these methods, since the concrete samples tested here was already about 43 hours old at the commencement of exposure, the samples are much larger and bulkier, and the mix used differs markedly from that used in the standards. However the results can be used to determine the effect of the silane treatment on curing membrane efficiency by direct comparison within the series of samples tested.

### TEST DETAILS

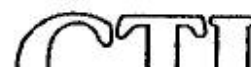
These tests were carried out on concrete cylinders produced from concrete delivered to the Glebe site. Six 150 mm diameter cylinders were cast on 28/10/92. They were placed in plastic bags for transport to CTI, removed from the bags and transferred to a fog room in their moulds.

The cylinders were stripped at approximately 40 hours, on 30/10/92, weighed, and placed inside polythene bags to minimise evaporative losses. Sample 1 and 2 were immediately treated with silane, and returned to the bags. The second silane treatment was carried out on samples 1 and 2 after a 3 hour period, and then the curing membranes were applied by brush as follows.

Samples 1 and 3 had Ashford 3799 applied to them, while samples 2, 4 & 5 had Concure applied. Sample 6 was left untreated as a control.

The cylinders were then immediately placed in a controlled environment chamber maintained at 36°C and 32% RH, for a three day period.

The solids contents of the two membranes were determined separately and found to be 32.5% for the Ashford 3799 and 37.8 % for the Concure.

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## RESULTS OF EXPERIMENT 2

The cylinders were weighed at the completion of the three day period, and weight loss was determined after correction for the effect of coating with silane and membrane.

The cylinders were returned to the fog room to cure and tested for compressive strength at 7 days age. The results are given in Table 4.

The effect of the curing membranes were not as great as that achieved when they were applied to concrete immediately after it sets, as in ASTM-C-156. However even for 40 hours old concrete there was a significant reduction in evaporation of water.

Sample No.	Description	Weight loss (grams)	Compressive Strength (MPa)
1	Silane/Ashford	73.4	42.5
2	Silane/Concure	71.4	42.0
3	Ashford Only	82.5	42.0
4	Concure Only	81.8	41.0
5	Concure Only (Duplicate)	75.5	43.0
6	Untreated (Control Sample)	104.8	43.0

Table 4 Water Loss after Membrane Application

## RESULTS AND DISCUSSION

### Experiment 1 - Silane Efficiency

The Chloride ion levels in untreated samples 3,4 & 5 after immersion were approximately as expected from the total weight gains.

The results of the immersion tests (see Table 1) show that overall the best performance was obtained by applying the silane immediately after the forms were removed, followed by application of the curing membrane.

Both samples 1 & 2 (silane followed by curing membrane) performed better than sample 6 (silane alone) which probably results from the extra water in the curing membrane being available for reaction with the silane.

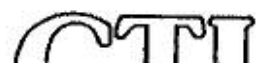
All of the silane treated samples demonstrated a reduction in water uptake of more than 90%, and in the chloride ion uptake of more than 98%. This is regarded as an excellent result even for 28 day or older concrete

Exceptional results were also obtained by applying the membrane first, and then applying the silane after a number of days. This result was confirmed by observing the depth of penetration of the silane on the 25 mm slices taken from the test cylinders.

However silane application before the membrane is preferred for site use. Possible over-application of the membrane under site conditions could lead to reduced penetration of the silane. However this application sequence could be altered if there is an inadvertent delay in applying the silane, providing strict control on the membrane spreading rate is implemented.

Both the Concure and Ashford membranes were found to be compatible with subsequent silane application, when applied in strict accordance with the instructions. This suggests that silane application can be carried out successfully to the surfaces already treated with these curing membrane.

The untreated samples (No. 3) absorbed an average of 48.6 grams of water in the first 48 hour immersion. This corresponds to a weight gain of 2.9 %. This figure is quite high for a 28 day sample of a 50 MPa design concrete that had been protected from excessive moisture loss.



The Salt-Fog results (Table 2) show the same trend as the immersion results. The absolute weight gains are predictably lower than for the immersed samples, whilst the chloride ion contents for the untreated samples were higher than expected simply from the weight gain.

#### Experiment 1 - Chloride Ion Content

Salt fog exposure is known to be a more severe test condition than full immersion for chloride ion ingress.

The Chloride ion levels in untreated samples 3,4 & 5 after exposure to salt fog were approximately twice that calculated from the total weight gains. This suggests that chlorides are carried into the samples by liquid water and then concentrated as the water evaporates.

The silane treated samples all show vastly reduced chloride ion uptakes, of a greater magnitude than expected from the reduced weight gains.

After immersion all silane treated samples show a reduction in chloride ion uptake between 98.6 % and 99.8% of the untreated sample, compared to water uptake reductions ranging from 89.7 to 93.3%.

For the silane treated samples under salt fog exposure the reductions in water uptake ranged from 78.5% to 88.2% of value for the untreated sample, while the chloride ion uptakes were reduced by between 90.6% and 99.6%.

This demonstrated that silane treatment (with and without the curing membranes) acted as an ion filter, allowing in some water but selectively excluding dissolved species (chlorides).

Table 3 suggests that some of the samples which had the curing membrane applied before the silane (samples 7 to 12) had lower salt contents than when the curing membrane was applied after silane treatment (samples 1 & 2). This trend is not thought to be significant as all the figures are within the statistical variation expected from the small number of samples tested.

However this might be the result of the membranes themselves (in the samples where they were applied last) absorbing some chloride ions, thereby retaining them on the surface. It is thought that subsequent treatment with silane may have disrupted the membrane film and therefore minimised its ability to absorb chlorides. If so, the degradation of the membranes with time would also results in a lessening of this effect.

### Compressive Strength

The samples used in Experiment 1 for immersion testing were the lower half of the cylinders, while the upper half was used in Experiment 2 for exposure to salt fog. The cut faces of the samples were sealed with a thin layer of epoxy to prevent moisture ingress on this face.

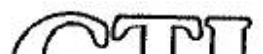
The difference in strength of the two series of samples is attributed to the well known phenomenon of lower strength in the upper section of a concrete cylinder (caused by the lesser amount of compaction applied to this section on casting).

No conclusion should be drawn from the differences between the immersion and salt fog samples. Only comparisons within one set of samples can be made. Also the absolute figures presented are for half cylinders, with a non-standard aspect ratio and cannot be compared to design strengths or comparable results obtained for full cylinders.

### Experiment 2 - Curing Membrane Efficiency

Experiment 2 has shown that the application of the silane prior to application of the curing membrane has no deleterious effect on the efficiency of either curing membrane, and in fact appears to be of some benefit. The water loss from the samples treated with curing membrane was marginally greater than for the samples that had both silane and curing membrane on them. The 7 day strength are all regarded as being identical and revealed no variations.

No significant difference was noted in the results between the two curing membranes tested, however it was noticed that the Ashford 3799 was easier to apply over silane treated surfaces than the Concure. Since application was by brush, it is thought that an even greater difference will exist between the two when applying by spray over silane treated surfaces.



## CONCLUSIONS

- 1 Isobutyltriethoxysilane may be applied to green concrete of this type of mix without detriment to its efficiency.
- 2 Application of silane results in the water uptake on immersion being reduced by more than 90% and chloride ion uptake being reduced by more than 98%.
- 3 Application of silane results in the water uptake on exposure to salt fog being reduced by approximately 80% and chloride ion uptake being reduced by more than 90%.
- 4 Curing membranes may be applied over concrete surfaces immediately after treatment with silane without detrimental effect on either the silane or the curing membrane.
- 5 Silane may be applied to surfaces to which either of the two curing membranes tested has been applied (at the recommended spreading rate) without significant loss in performance of the silane.
- 6 The silane preferentially excludes dissolved chlorides from absorbed aqueous systems, acting as an ion filter.



9/11/92