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INT.CHEM-CRETE PAVIX CCC100 (PAVIX): FREEZE-THAW TESTING OF CONCRETE POSTS IN ACCORDANCE WITH ASTM C 1262-98

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INTRODUCTION

This report covers an investigation into the effectiveness of impregnating reinforced concrete components with Pavix, as a means of protecting them against the damaging effects of freeze-thaw loading. Factory made reinforced concrete posts were used for the investigation. Both treated and untreated post samples were subjected to 100 freeze-thaw loading cycles during the period mid December 2004 to late June 2005. The degree of damage was assessed by the accumulative weight loss in each sample. All aspects of testing were carried out in strict accordance with ASTM C 1262-98 [1], the most appropriate and internationally recognised standard for evaluating the freeze-thaw durability of manufactured concrete units. In all cases, untreated samples showed significantly greater weight loss than their treated counterparts. The main conclusion is that Pavix impregnation delivers a high level of resistance to frost damage.

STUDY OBJECTIVE & METHODOLOGY

The objective of the investigation is to quantify the benefits of protecting reinforced concrete with PAVIX concrete impregnate.

To determine the benefit, both treated and untreated samples have been tested in the study, these extracted as pairs from reinforced concrete posts. Both old and new post samples have been tested on this comparative basis.

Two testing methods have been used in the investigation (i) cyclic freezing and thawing and (ii) water absorption by florescent dye penetration in cut sections. Freeze-thaw testing was undertaken in accordance with ASTM C 1262-98 [1], the most relevant testing standard. A detailed explanation of the testing regime practised under ASTM C 1262-98 is given in this report. This provides an extreme testing environment that serves as an accelerator of deterioration. In all, 100 complete freeze-thaw cycles have been applied in the tests. Based on previous testing experience, this is sufficient to produce detectable weight loss, the direct measure of freeze-thaw damage.

The water absorption investigation carried out at the end of freeze-thaw testing, follows commonly adopted procedures. These tests combine to give a view on durability derived from the impregnation process.

PAVIX CCC100

PAVIX is a concrete impregnate formulated to protect new and old reinforced concrete from such highly destructive effects as water penetration, cyclic freeze-thaw and surface contamination. This water based, non-toxic product is rapidly gaining acceptability in several application areas, including statutory measures for highway bridge protection under UK Highway Authority Regulations [2].

PAVIX is a crystallising hydrophobic material that responds defensibly to the prevailing moisture environment. Under wet conditions, tests prove that a high level of water proofing is delivered. Conversely, under drying conditions, the concrete is rendered vapour permeable i.e. it is able to breathe.

A range of product application methods are allowed, including brush and roller, back-pack spray and automated spray for large area projects. Application rates vary, depending on the condition of the concrete. For new concrete, a single coat application at $200ml/m^2$ is appropriate. In the case of weathered or porous concrete, it is sometimes appropriate to increase this dosage. In the reported test programme, a dosage rate of $200ml/m^2$ was used in all cases.

CONCRETE SAMPLES

Description of samples

Figure 1 shows part of a post specimen. The cross-section design of these is illustrated in figure 2, with the cut sample denoted by the dotted red line. Table 1 gives the designation of samples, their weights and reinforcement cover statistics.
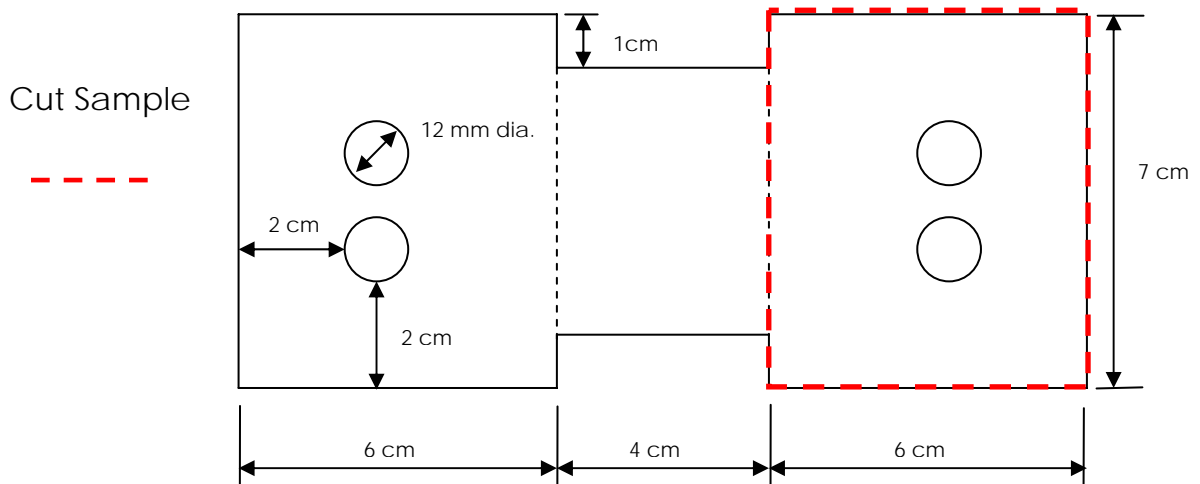

Figure 1: End of typical specimen

Cut Sample

- - - -

1cm

12 mm dia.

2 cm

2 cm

7 cm

6 cm   4 cm   6 cm

Figure 2: Post cross-section (Nominal Dimensions)

Sample Mark	Dry Weight (kg)	Impregnated (Y/N)	Soaking Face (Cast/Towelled)	Rebar Cover (mm)
P1-S1-T (old post)	3.59	Y	Towelled	14-17
P1-S2-T (old post)	3.31	Y	Cast	10-12
P1-S3-U (old post)	3.62	N	Towelled	8-10
P1-S4-U (old post)	3.45	N	Cast	10-12
P2-S1-T (new post)	3.51	Y	Towelled	14-15
P2-S2-T (new post)	3.52	Y	Cast	11-11
P2-S3-U (new post)	3.40	N	Towelled	14-16
P2-S4-U (new post)	3.55	N	Cast	7-9
P3-S1-T (new post)	3.38	Y	Cast	11-15
P3-S2-T (new post)	3.60	Y	Towelled	11-15
P3-S3-U (new post)	3.45	N	Cast	13-15
P3-S4-U (new post)	3.53	N	Towelled	12-12
P4-S1-U (old post)	3.50	N	Cast	4-4
Table 1: Post Sample Designations				

Thirteen post samples, in the form of solid coupons, were saw-cut from 4 full sized concrete posts, using a water-cooled saw. The sample dimensions are 35 cm length, 7.3 cm (nominal 7 cm) height and 6.4 cm (6 cm nominal) width. Figure 2 delineates in red the portion of the post section sampled. Using the adopted dimensions, the surface area exposed to water is 225 cm^2, the maximum permissible area according to ASTM C 1262-98. Samples taken from the old post have designations P1-S1to P1-S4, and samples taken from the two new posts, P2-S1 to P2-S4 and P3-S1 to P3-S4, respectively. An additional sample P4-S1, stamped with the manufacturer's name, was cut from a further old post. This particular sample is of interest because of its low cover value (about 4 mm). Treated samples have the postscript T and untreated U.

Reinforcement cover

Whilst the designed cover to the reinforcing steel is shown as 2 cm in figure 2, inspection revealed that it varies considerably. The actual cover values are given in table 1. Knowledge of the range of cover is important because this has a direct bearing on durability and the need for protection. To quantify this, eight (two for each reinforcing bar) cover measurements for each of the 13 post samples are combined in the frequency diagram given below (figure

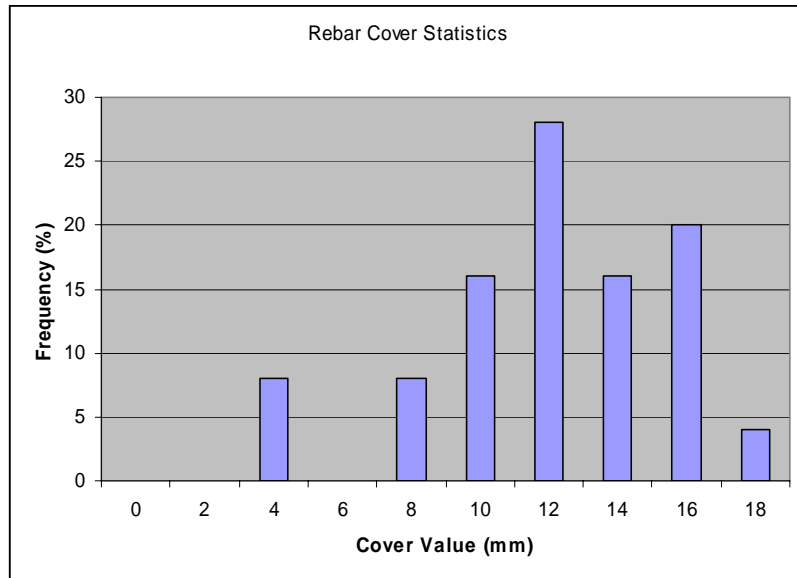3). From this it is apparent that 30% of the reinforcing bar cover is 10 mm or less.

Figure 3: Reinforcing bar cover statistics

FREEZE THAW TESTING

Impregnating samples

For each post, two treated and two untreated samples were prepared, with the addition of a special untreated sample. Of the sample pairs, one was assigned for 'rough towelled face' soaking and the other for 'smooth cast face' soaking.

Prior to Pavix impregnation, samples were dried for 24 hours in free circulating air. The appropriate volume (equivalent to 200ml/mm2) of Pavix CCC100 was measured into a beaker and this applied uniformly by brush to all faces. Weighing between changing face was done to ensure uniformity of application. A clean beaker and brush were used on each new sample treated. Following this impregnation process, all samples were air dried at a temperature of 24 ± 8 ^{0}C for a period of 48 hours. During this air drying period, the samples were arranged with 25 mm minimum free air space around them.

Sample Conditioning

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 giving the surrounding clearances specified in ASTM C 1262-98. Within this container, the sample was supported at each end by 3mm diameter brass rods. Figure 4 shows a typical sample in its individual Perspex box.

Figure 4: Sample in specially fabricated Perspex box

The procedure started by adding water at a temperature of 16-27 ^{0}C to the container in order to achieve a water depth of 13 ± 2 mm, taking care not to pour water directly onto the sample. After 1 hour, the containers were

opened and water added as necessary to maintain the water level at the stated value. Using water-proofing tape, the containers were then closed and resealed. After a further 23 hours, the samples were removed from the water and allowed to drain for 1 minute by placing them on 10 mm coarse sieves, removing visible surface water with a damp cloth. Immediately after, the samples were weighted to the nearest gm and their weight recorded as Wp. Finally, samples were placed back inside their containers and the water level adjusted. The freeze-thaw cyclic testing commenced from this point.

Freezing cycle

The test began with a freezing cycle. For this, the sample containers were placed inside the ASLAND 470 L chest freezer in such a way that each container was surrounded by a minimum air space of 13 mm on all sides (in accordance to ASTM C 1262-98).

During the freezing cycle, the air temperature inside the chest freezer was maintained at $-18 \pm 5\ ^0C$ for 4.5 hours. The cycle time did not include the time required for the air temperature in the freezer to reach the above temperature, which is typically 3.0 to 3.5 hours. This delay was due to the temperature rise caused by placing the air warm sample containers in the freezer. The start of the freezing cycle time period began only after the air temperature within the freezer reached -13^0C. During freezing, the air temperature was monitored every 10 minutes using a thermocouple.

Thawing cycle

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 $24 \pm 5\ ^0C$ in accordance with ASTM C 1262-98. Using this facility, the duration of the thawing cycle proved to be about 16 hours, which is within the limits set by ASTM C 1262-98.

The thawing cycle time did not include the time required for the air temperature around the containers to reach the previously specified temperature. During thawing, the air temperature was monitored every 10 minutes using an OAKTON digital thermometer.

According to convenience of timing, the next freezing cycle was applied, as previously described. The number of freeze-thaw cycles necessary for durability assessment depends on the degree and pattern of the working application exposure environment. In some circumstances, many cycles can occur in the first few months of service life. Based on the progress of material loss, it was decided that 100 freeze-thaw cycles would be appropriate.

Weight loss measurement

At the completion of each 10th complete freeze-thaw cycle, the weight loss of each sample was determined using digital scales of accuracy +/- 0.1 gram. For this purpose, the sample container water was filtered through high wet strength filter paper in equilibrium with the laboratory temperature. Material loss was measured to the nearest 0.1 gram and recorded as Wf for each sample.

Each sample was then removed, held above its container and rinsed with pure water using a squeeze bottle, taking care to collect rinse water and all loose particles from the sample. Particles separated from the sample were taken to be part of the total residue. The water from the sample container was poured through the filter paper to collect the residue for weighing.

The sample was then placed back in its container. Using fingertips and a squeeze bottle, all loose particles were removed from the sample again, being careful to collect all rinse water and loose particles in the sample container. At no time was the top surface of the sample immersed in water and the collected rinse water allowed to exceed 13 mm depth in the container. Samples were again removed from the container and the rinse water poured through the filter paper. The container was rinsed with water until all residues were collected on the filter paper. Finally, the sample was placed back in its container.

The filter paper and residue collected from each sample were dried at 100-115 ^{0}C for at least 4 hours and until 2 successive weightings at intervals of 2 hours show an increment of loss not greater than 0.2% of the last previously determined weight. The filter paper and residue were then placed in a draft-free location within the laboratory for a period of 2 hours to allow the filter paper and residue to come to equilibrium temperature with the laboratory environment. The filter paper and residue were then weighted to the nearest 0.1 gram and recorded as W_{f+r}. The residue weight W_r was calculated using the following expression:

$$W_r = W_{f+r} - W_f$$

Where:

W_r is the weight of residue in grams

W_{f+r} is the weight of the dried residue and filter paper in grams

W_f is the weight of the filter paper in grams

At the completion of freeze-thaw testing, each sample was dried at 100-115 ^{0}C for 24 ± 1 hours. Each oven-dried sample was then weighted to the nearest

0.1 gm and its weight recorder as W_{final}. The initial weight of the sample was calculated by the following expression:

$$W_{initial} = W_{final} - W_{residue}$$

Where:

$W_{initial}$ is the calculated initial weight of the sample in grams

W_{final} is the final weight of the sample in grams

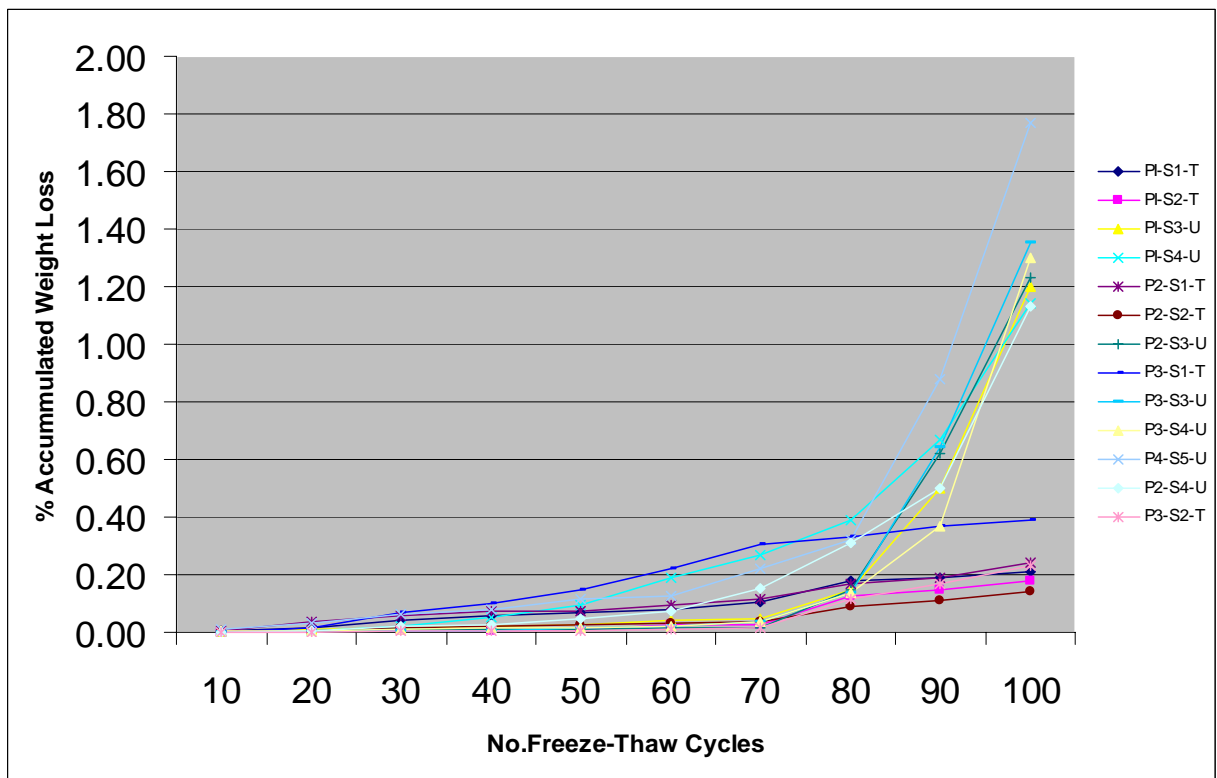$W_{residue}$ is the total accumulated residue weight in grams
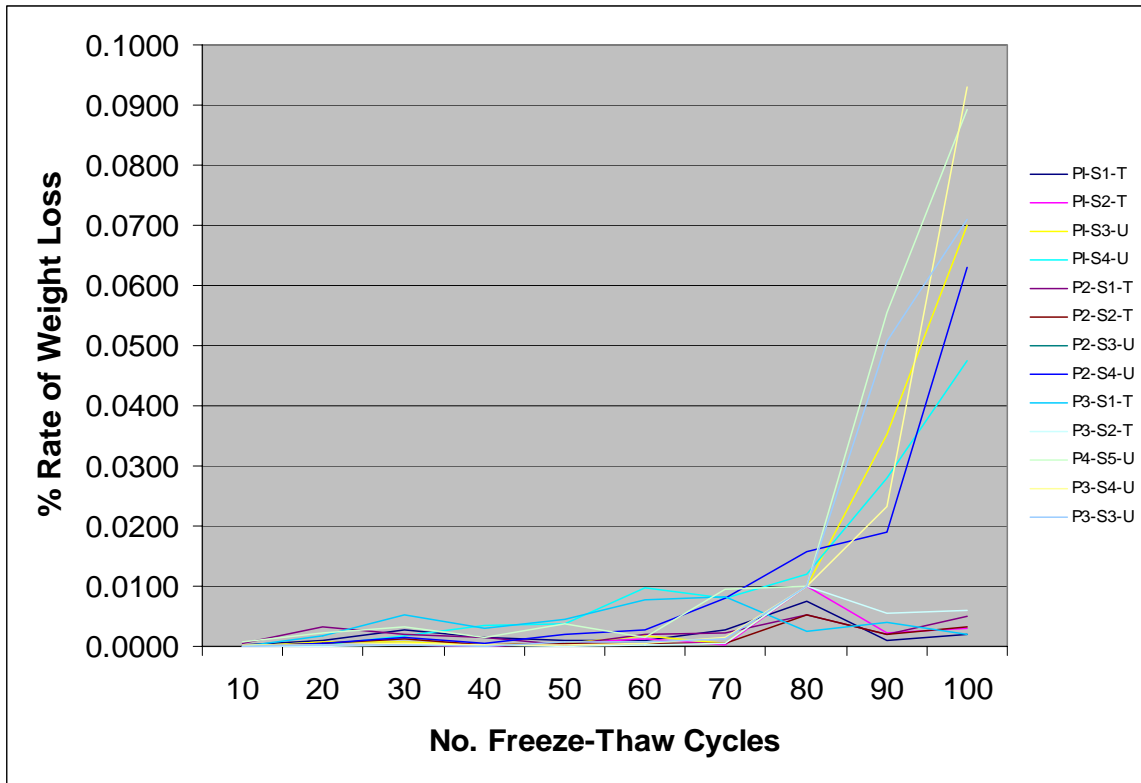

Figure 5: Percentage Accumulative Weight Loss

Figure 6: Rate of % Weight Loss
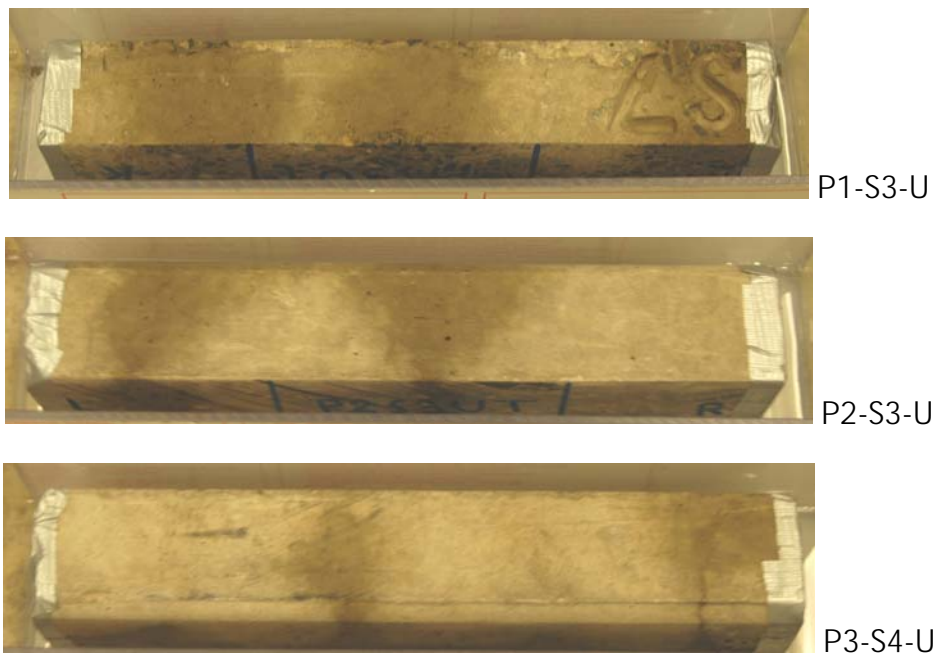

P1-S3-U

P2-S3-U

P3-S4-U

Figure 7: Moisture transmitted up through cracks to the top face of untreated samples

Figure 5 shows the accumulative percentage weight loss for all samples. From this, it is apparent that the treated samples experience significantly less weight loss than their untreated counterparts, the 'old post' samples producing the greatest losses. The results shown in figure 5 are reworked as first order loss rates in figure 6. Without exception, the untreated samples have developed significantly higher rates of weight loss than their treated counterparts. All the treated samples experience a similar low rate for weight loss without the notable increases experienced with the untreated samples.

WATER ABSORPTION TESTING

To assess the continuing effectiveness of Pavix impregnation, following the freeze-thaw loading programme, an investigation into surface absorption was carried out. Two 60mm diameter 20mm thick button cores were cut from the soaking faces of the posts, P1-S1-T and P1-S3-U. The cut cylinder faces of both cores were then water-proofed using silicone. This was done to confine dye absorption to the post's external face.

The core buttons were placed 'soaking face' downwards in a florescent sodium dye solution for a period of 4 days. This was arranged by standing them on 2mm edge spacers in Petri dishes maintained with 10mm depth of dye solution. The buttons were then removed and air dried for 48 hrs before sectioning with a diamond saw, and polishing lightly.

The cut sections shown in figure 8 were photographed under ultra-violet light. To amplify the presence of the water based dye, which appears purple in the photographs, the photographic negatives have been used.

Section from treated sample P1-S1-T   Section from untreated sample P1-S3-U
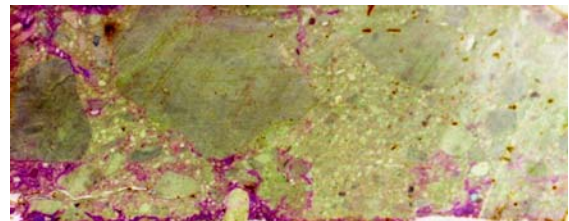
Figure 8: Absorption test for treated and untreated post samples

Comparing dye penetration in the two specimens, it is apparent that significantly more penetration has occurred in the untreated specimen (right in figure 8) than in the treated specimen (left in figure 8). The moisture blocking mechanism, claimed with Pavix impregnation, appears to be still active after subjecting the post samples to 100 freeze-thaw loading cycles.

RESULTS

The principal results are summarised as follows:

- The testing programme, which delivered 100 freeze thaw cycles, resulted in sufficient weight losses to justify testing and analysis.

- Water proofing the cut end of specimens provided effective protection against ingress through the ends of both *treated* and *untreated* samples.

- In all cases, samples *treated* with Pavix experienced significantly less weight loss than their *untreated* counterparts.

- *Untreated* samples develop a significantly faster rate of weight loss than *treated* samples.

- To the extent of the test programme, the depth of reinforcement has no detectable influence over weight loss in both *treated* and *untreated* samples.

- Unlike *treated* samples, the upper faces of *untreated* samples show moisture rise in through-depth cracks (figure 7).

- *Treated* samples indicate significantly greater resistance to surface water absorption after 100 cycles of freeze-thaw loading than *untreated* samples

- The highest weight losses occurred in 'old post' samples (PS1 & PS4).

- *Treated* samples have similar patterns of small weight loss for both 'smooth cast face' and 'rough towelled face' soaking.

- The moisture blocking mechanism claimed with Pavix impregnation appears to be still effective after 100 freeze-thaw loading cycles.

CONCLUSIONS

For the freeze-thaw testing programme undertaken in accordance with ASTM C 1262-98, impregnation of old and new post samples with Chem-Cete Pavix CCC100 at a dosage of 200ml/m² (i) significantly reduces the rate of weight loss, (ii) opposes moisture transmission through cracks and (iii) resists water absorption on water soaked surfaces.

Regarding the first consideration, it is reasonable to expect significantly extended, maintenance free life from both 'old' and 'new' treated concrete compare with untreated concrete. This is apparent in both the accumulative weight lass and the rate of weight loss. Taking cracks as a separate issue, the main defence provided by the Pavix impregnation is limiting the scope for expansive freezing in the near surface region. In treated samples, the surface profile was observed to be less deteriorated than with untreated samples. This is taken as being due to the pore blocking action of the treatment which limits the availability of internal moisture and water.

The second part of the conclusion supports the manufacturer's claim that Pavix has crack filling properties (<1.4mm width). This is an important consideration in view of the variable cover to the reinforcing steel, which is generally much less than the design value of 20mm. If the freeze-thaw cycles were allowed to continue, expansive corrosion of the reinforcing bars would rapidly lead to concrete spalling and ultimately the break-up of the post. This would be assisted by the expansive action of water freezing in cracks. The evidence gathered through the tests clearly indicates that impregnation with Pavix opposes these deteriorating actions.

The water absorption test conducted following the completion of 100 freeze-thaw loading cycles indicates that Pavix's moisture blocking mechanism is not detectably degraded. It would be reasonable to expect the impregnated Pavix to penetrate to a depth of 6mm-8mm in treated posts. On this basis, considerable weight loss would have to occur before the impregnation was no longer effective.

REFERENCES

1. ASTM C 1262-98 Standard Test Method for Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units, American Society for Testing and Materials, 1998

2. Design Manual for Roads and Bridges, Appendix 2, Volume 2, Section 4, Part 4, BD43/02.

3. Interim report prepared for SSL Alliance (Metronet), Chemcrete Pavix CCC100 (Pavix): Freeze-Thaw Testing of Concrete Posts in Accordance with ASTM C 1262-98, City University, February 2005.

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RERORT AUTHENTICATION

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

Project Leader

Name: Professor D.A.Chamberlain

Signed:

Research Fellow

Name: Dr Vejen Hlebarov

Signed:

Date: 26th June 2005

APPENDIX

Equipment Used

Equipment Item	Use in Testing	Specification
ASLAND 470L Freezer	Performing freezing cycles	Max volume capacity: 470 Litres Max freezing capacity: 24 kg/24 h Lowest temperature achieved: -24 ^{0}C
ADAM ADG 6000L Scale	Weighting collected residue	Max weight capacity: 6000 gr Accuracy: ± 0.1 gr
ThermoCouple	Recording temperature during freezing cycles	Accuracy: ± 0.1 ^{0}C Temperature range: -30 to 50 ^{0}C
OAKTON Thermometer	Recording temperature during thawing cycles (digital)	Max number of stored readings: 1000 Accuracy: ± 0.33 ^{0}C Temperature Range: -30 to 50 ^{0}C
WHATMAN Filter Papers	Collecting residue	125 mm Diameter ashless filter papers

Pavix

Pavix CCC100 is manufactured by:

> International Chem-Crete Corporation
> 800 Security Row
> Richardson, TX 75081 USA