PRE-SEALING CONCRETE BLOCKS & PAVERS USING SILICONE NANOTECHNOLOGY

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Abstract

The permeability and hydrophilic nature of pressed concrete products leads to easy water penetration. Water penetration is a well-known factor affecting the performance and the durability of pressed concrete masonry.

Efflorescence of concrete blocks is one of the problems associated with water penetration which is particularly important for decorative concrete. Efflorescence is caused by moisture moving through the capillaries and carrying the calcium hydroxide produced from cement hydration to the surface. The carbonation of the calcium hydroxide on the surface results in efflorescence of an insoluble white calcium salt.

Water repellent admixtures can minimise water movement within the concrete and hence reduce water absorption and efflorescence of the concrete.

The performance of conventional admixtures such as stearates and oleates is not completely satisfactory due to the fact that they are not permanently bonded to the substrate. The water repellency is due to hydrophobic deposits of calcium stearate or oleate within the concrete. These admixtures are subject to breakdown due to weathering and biological deterioration.

The current research exhibits an admixture involving silicone nanotechnology using a silicone water repellent admixture. The nano-molecular polysiloxane lines the capillary walls of the concrete via strong siloxane linkages which overcomes the limitations inherent in traditional non-reactive admixtures resulting in long term durability of the hydrophobic treatment. The treated concrete achieves low water permeation and high efflorescence resistance. This innovative technology has achieved market success in creating pre-sealed decorative concrete blocks and pavers in Australia during the past 10 years.

\textbf{Keywords:} Silicone, nanotechnology, pressed concrete, admixture, pre-sealing concrete

1. INTRODUCTION

Pressed concrete masonry such as concrete blocks, pavers and roof tiles have been used in the building industry for many years. Due to high energy consumption in manufacture, the traditional fired clay products will be gradually replaced in the future by more energy efficient
building materials such as concrete blocks and pavers. In Australia, coloured concrete blocks and pavers have made pressed concrete masonry more attractive to modern building and landscaping design and the products have been widely accepted by the local building industry.

However, the permeability and hydrophilic nature of pressed concrete products leads to easy water penetration. According to Browne (1986), Egan (1991) and Shaw (1993), water penetration is a well-known factor affecting the performance and the durability of pressed concrete masonry. Damp walls due to water penetration often lead to surface staining such as surface soiling or deposits of other staining materials. Water penetration damages the thermal insulation properties of concrete block buildings. Cold concrete block walls due to high moisture content within the wall require additional heating in winter. Cold walls due to water penetration also cause internal surface condensation resulting in problems such as mould growth and efflorescence on the internal wall surface.

Efflorescence of concrete masonry is another problem associated with water penetration which is particularly important for decorative concrete masonry. Efflorescence is caused by moisture moving through the capillaries and carrying the calcium hydroxide produced from cement hydration to the surface. The carbonation of the calcium hydroxide on the surface results in insoluble white calcium salt efflorescence according to Dreyer (1995). Efflorescence may also be caused by the transport of soluble salts, due to the permeability of concrete masonry, either from the sub-soil or from ground water and re-crystallisation at the surface after water evaporation.

Water repellent admixtures can minimise water movement within the concrete and hence reduce problems associated with water absorption and efflorescence of the concrete.

Conventional oil-based water repellent admixtures such as stearates or oleates have been used in pressed concrete for many years according to Russell (1983). The performance of these admixtures is not satisfactory due to the fact that they are not permanently bonded to the substrates. The water repellency is due to the hydrophobic deposit of calcium stearate or oleate within the concrete. These admixtures are subject to breakdown due to weathering and biological deterioration over a period of time.

The current research reveals an admixture involving the application of silicone nanotechnology using a silicone water repellent admixture. According to Kaesler (2003), Ohama et al. (1992), Ren (1995), and Silfwerbrand (1005), the nanomolecular polysiloxane lines the capillary walls of the concrete via strong siloxane linkages converting the hydrophilic nature of concrete into a hydrophobic matrix. The silicone admixture overcomes the limitations inherent in traditional non-reactive admixtures. The treated concrete achieves low water permeation and high efflorescence resistance. This innovative technology was initially developed at Victoria University in Australia in 1996. The technology was then successfully commercialised by an Australian company, Tech-Dry for the pressed concrete industry. This innovative technology has achieved market success in creating pre-sealed decorative concrete blocks and pavers during the past 15 years both in Australia and overseas.

Figure 1 shows the molecular structures of both conventional oil-based admixture and the admixture using modern silicone nanotechnology.
2. MATERIALS AND SUBSTRATES

Pressed Concrete Substrates

Unless otherwise stated, the test concrete used in this research was prepared using cement and sand at a ratio of 1:4. The water addition rate was controlled to obtain a consistent semi-dry concrete mix (not wet slurry). The admixture was first dispersed into the water and then mixed into the dry concrete mix. The semi-dry concrete mixture was then pressed into a plastic mould and removed immediately to obtain the test disk of size 30mm high x 70mm diameter as shown in Figure 2. The curing conditions involved 24 hours covered in a plastic container and a further 7 days curing to an approximate constant weight at ambient conditions.

Silicone Water Repellent Admixture

The admixture used in this research is a silicone water repellent admixture containing reactive silane/siloxane. The advantage of this admixture is that the silane and siloxane reacts with pressed concrete ingredients via a strong siloxane bond and it also crosslinks to form polysiloxane which lines the capillary wall of the concrete matrix. Due to the chemical bonding, the polysiloxane lining becomes part of the concrete substrate resulting in long term durability compared to that of a traditional oil-based admixture which relies on an hydrophobic calcium stearate or oleate salt deposited within the capillaries (see Figure 1). Figure 3 shows the silane reaction forming polysiloxane within a masonry capillary wall. The alkylalkoxysilane or siloxane first hydrolyses in the presence of water to form a silanol which then reacts with the masonry substrate forming crosslinking nano-polysiloxane structures via siloxane linkages within the concrete matrix resulting in a permanent hydrophobic attachment to the treated concrete substrate.
Figure 3: Molecular structures of polysiloxane in concrete masonry

Because the silicone water repellent admixture effectively forms a nanomolecular polysiloxane lining within the capillaries rather than blocking the capillaries, small amounts of silicone are required to achieve molecular lining compared to that of capillary blocking. However, such molecular lining by small amounts of silicone can effectively reduce the surface tension of the substrate and therefore convert the hydrophilic nature of masonry capillaries to an hydrophobic state. Figure 4 represents the capillary rise due to a hydrophilic masonry capillary versus capillary depression due to an hydrophobic capillary treated with silicone water repellent. Figure 5 shows the practical water repellent (hydrophobic) effect in a commercial pressed concrete block containing 0.05% silicone water repellent admixture-Emulsion KR2.

3. RESULTS AND DISCUSSIONS

Resistance To Water Penetration

Resistance to water penetration of pressed concrete was investigated via the following tests:
Capillary water absorption was conducted in the laboratory using the test disk according to DIN 52617 as shown in Figure 2. The water absorption after 24 hours is presented in Figure 6. A 24 hour water absorption result clearly indicates that the capillary water absorption of test substrates containing the silicone admixture is significantly reduced. The results also indicate that at an addition of 0.05% of Emulsion KR2, the admixture achieves approximately over 80% reduction in water absorption which was sufficient to make water resistant concrete substrates. Feedback from the pressed concrete industry also confirmed that addition at a rate of 0.05% silicone admixture is sufficient in practice for pressed concrete products. Some of the concrete manufacturers lower the addition rate to 0.025% and still achieve satisfactory water repellent performance from this admixture.

![Graph showing water absorption of concrete with different admixture levels.](image)

**Figure 6: Capillary water absorption of the concrete containing Emulsion KR2**

A resistance to rising damp test was conducted by placing a commercial concrete block in a water bath. The treated block and the control were placed in water for 24 hours, removed and broken in half as shown in Figure 7. Results showed that a block containing 0.05% Emulsion KR2 was dry inside while the control was fully saturated with water. The results indicated that the treated block containing the silicone water repellent admixture shows a good resistance to rising damp. Rising damp in a masonry building is generally caused by moisture rising through the building footings and is a difficult problem for remedial treatment in buildings. This test result clearly indicates that the silicone admixture in the treated substrate provides a good resistance to rising damp.

![Image of a concrete block before and after rising damp test.](image)

**Figure 7: The resistance to rising damp of concrete blocks**

The efficacy of the silicone admixture is further confirmed by a test carried out to model the resistance to wind-driven rain (water penetration under pressure) for pressed concrete block walls conducted by the Commonwealth Scientific and Industrial Research Organisation.
(CSIRO) according to ASTM E514-90. This test is equivalent to wind-driven rain at a wind speed of 120km/h (or 500pa) against a single skin pressed concrete block wall containing 0.05% silicone admixture. The test device is shown in Figure 8. The result shows that the test wall successfully passed the 4 day test period which was far superior to the industrial standard (ASTM standard) of 4 hours. In comparison, a standard pressed concrete block wall without silicone admixture generally resisted water penetration for only 20 minutes under the same test conditions.

![Figure 8: Resistance to water penetration under pressure of 500pa](image)

**Efflorescence Resistance**

The resistance to efflorescence endowed to pressed concrete substrates by the silicone water repellent admixture is significant. Table 1 shows the results of an accelerated efflorescence test for a pressed concrete substrate. The test was conducted by laying the test substrate into a tray containing 10% sodium sulphate solution at a depth of 10 mm (less than 30% of the substrate total height) for 7 days. The top surface of the substrate above the solution was visually examined for evidence of efflorescence. The test results in Table 1 indicate that the substrate containing 0.05% silicone water repellent admixture showed no evidence of efflorescence after 7 days of the test period whereas the control was fully covered with efflorescence within 1 day. The efflorescence of the sample containing 0.025% of the silicone admixture was also significantly reduced compared to that of the control substrate.

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<th>After 1 day</th>
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<tr>
<td>0.025% Emulsion KR2</td>
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<td>20% covered</td>
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<td>0.10% Emulsion KR2</td>
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An efflorescence test in outdoor conditions was conducted by using commercial pressed concrete blocks under natural weathering conditions in Tasmania, Australia for 7 years (as shown in Figure 9). The result indicates that the block containing 0.05% silicone admixture
showed remarkable resistance to efflorescence against natural weathering. The treated samples remained in almost as original condition after 7 years whilst the control blocks showed a poor surface appearance mainly due to efflorescence (white salts) and other water-based staining problems associated with water penetration.

![Image](image1.png)

**Figure 9: Resistance to efflorescence under natural weathering conditions**

**Durability of Concrete**

The durability of concrete by incorporating silicone water repellent admixture is also significantly improved. A durability test was conducted by an accelerated salt erosion test. A pressed concrete substrate was dipped into a 10% sodium sulphate solution for 12 hours and subsequently dried at 80°C in an oven for 12 hours. This was repeated over many cycles. The ingress of salty water into the substrate and drying can result in serious damage to substrates due to repeated salt crystallisation which expands in the capillaries of the substrate. In this test, treated samples containing 0.05% silicone admixture and standard pressed concrete substrate as the control were used. A substrate containing conventional stearate water repellent admixture was also used as a comparison sample.

The salt erosion test demonstrated that after 15 cycles of dipping and drying, the disk with silicone admixture remained almost unchanged whilst the control commenced to erode after 5 cycles. The sample with silicone admixture still showed a good water repellent effect at the end of the erosion tests. The test also indicated that the sample with the stearate admixture showed some resistance to erosion during the early cycles but the erosion accelerated after 10 cycles. Figure 10 shows the pressed concrete substrates before and after 15 cycles of the salt erosion test. This test confirms that the durability of the concrete with silicone admixture is significantly improved compared to that of the control and the test also indicates that the result with silicone admixture is superior to that of a traditional oil-based admixture.

![Image](image2.png)

Figure 11 shows the weight losses of the test substrates after 15 cycles. The substrate containing silicone admixture almost retained its original mass whereas the control lost 12% and the sample with stearate lost 9% of its total weight. This result again confirmed that the durability of the substrate containing silicone admixture was superior to that of the sample without admixture. The traditional stearate admixture was not sufficiently resistant for long
term protection against erosion from natural weathering.

Control  |  Silicone Stearate

**Before salt crystallisation test**  |  **After salt crystallisation (15 cycles)**

![Concrete disks before and after salt crystallisation test](image)

**Figure 10:** Appearance of the concrete disks before & after the salt crystallisation test

![Weight loss graph](image)

**Figure 11:** Weight loss of the concrete disks after salt crystallisation test

4. APPLICATIONS

The application of silicone water repellent admixture is simple and cost effective. The admixture is simply mixed into the pressed concrete pre-mix at the final stage of mixing before being pressed into the mould. The water repellent concrete substrate is immediately formed after the substrate is removed from the mould. No further procedure or extra post-treatment is required for the substrate. However, it is worthwhile to mention that, due to the immediate surface water repellency, further spaying of water onto the ready-formed substrate in order to help cement curing becomes difficult. Therefore, it is important to retain the moisture level within the pressed concrete substrate during the curing period in order for the concrete to cure completely. This may be done by extending the curing time in a curing room or by covering the freshly made substrate if there is no curing room facility.

This silicone water repellent admixture has been widely used by Australian block and paver manufacturers including the two major concrete masonry producers: Boral and Adbri for the past 15 years. The concrete blocks and pavers containing this admixture are highly recommended by architects in Australia. The product is also used in many other parts of the world including South Africa, Europe, Asia and America. This admixture is particularly useful for coloured or decorative pressed concrete products and for applications where water resistant construction is required.

A residential house built with concrete blocks manufactured with the silicone admixture has retained its original condition after many years (Figure 12). Retaining walls built with split face concrete blocks containing the new admixture showed a clean finish for years (Figure 13).
Pavers containing the silicone admixture around salt water swimming pools retained their original appearance in a salty water environment for many years (Figure 14).

Figure 12: A house built with concrete blocks containing the silicone admixture.

Figure 13: A retaining wall built with concrete blocks containing the silicone admixture.

Figure 14: Concrete paving with the silicone admixture around salt water pool.
5. CONCLUSION
Addition of the silicone water repellent admixture into pressed concrete imparts significant water repellency. Efflorescence of the concrete was effectively controlled. Due to a permanent siloxane linkage and polysiloxane nanomolecular lining within the concrete, the addition of the silicone admixture significantly improves the durability of the pressed concrete. The successful application of the silicone admixture in Australia for the past 15 years has proved the remarkable value of this new technology to the concrete block and paver industries.

REFERENCES


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