# WATERPROOF CONCRETE: AUSTRALIAN STATE GOVERNMENT RESEARCH

## NSW Roads & Traffic Authority (RTA) & VicRoads (Victoria)

## COMPARATIVE PERFORMANCE:

## Hydrophobic Pore-blocking Ingredients (HPI's) -"Caltite" & "3CC" vs. Silica fume, GGBF Slag, Fly Ash & "Crystal-growth" additive

Cementaid's "Caltite" and "3CC" Hydrophobic Pore-blocking Ingredients (HPI) for membrane-free waterproof concrete construction provide many practical and performance advantages over alternative waterproofing methods. Over more than 40 years continuous use, they have gained wide acceptance throughout Australia, South East Asia, Britain, the Middle East and the USA. In addition to traditional densifying additives for concrete, new silicate-based products have recently entered the market and there has been some ambiguity as to modes of action and comparative performance.

Water & contained salts or acids are unable to penetrate Non-Absorptive "Caltite" or "3CC" System concrete.

- Effective integral **Hydrophobic Pore-blocking Ingredients ("HPI")** were successfully researched & developed over a ten year period by the Australian owned Cementaid International Group.
- Known as "Everdure Caltite" and "3CC", they were released for use in the Australasian construction markets in 1960.
- Both ingredients profoundly modify the **surface tension** properties of the cement hydrates which form the capillary walls and other hydrate surfaces, producing a non-absorptive, Hydrophobic Matrix.
- Capillaries and voids are internally sealed by ***reversing*** the normal "wicking" or absorptive action of concrete.
- "Caltite" additionally incorporates discreet polymer components and is dosed at twice the rate of 3CC, to provide the most powerful pore-blocking performance.
- Absorption reduction; ~92%: Permeability reduction; ~ x 10 ("Caltite")
- HPI's produce structural concrete that is intrinsically **non-absorptive** & inherently dry throughout it's mass**.** These effects are permanent.
- HPI's prevent capillary absorption of moisture and contained salts or acids etc., and transmission of dampness, including under pressure.

- HPI concretes have now been in place in structures in Australia and internationally since 1960 (44+ years).
- These continue to demonstrate effectively permanent waterproof and corrosion-proof performance.
- Applications include sub-sea basements, underground rail stations / pedestrian tunnels, landscaped roof and podium decks, pools, jetties, marine structures, chemical / industrial & food processing floors, foundations in acid / sulphate soils, as well as many others.

Some years ago, the NSW Roads & Traffic Authority (RTA), and separately "VicRoads" in Victoria, conducted research into extending durability of bridge structures through "waterproofing" of concrete.

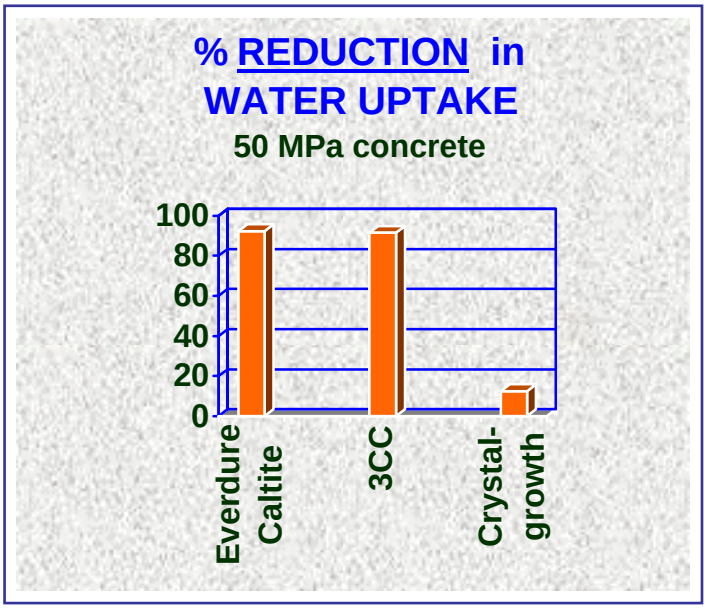
This allowed a direct comparison of the performance of "Caltite" and "3CC" Hydrophobic Pore-blocking Ingredients against densifiers such as pozzolans (silica fume, slag, PFA, etc.) and the recent "crystal-growth" (silicate) additives.

*Darling Park, Sydney*
Membrane-Free "Caltite" concrete basements, up to 19m deep

## NSW Roads & Traffic Authority (RTA) Results

The NSW RTA undertook a long-term testing & research program to compare the performance of a number of waterproofing materials in high quality 50 MPa concrete. These were subjected to immersion & drying cycles in salt water (CTI Consultants P/L, NSW) The **water up-take** and **chloride penetration** data for the additives tested -"Caltite", "3CC" and "crystal-growth" - are summarised here (Appendix 1).

### WATER UPTAKE DATA:




**Reduction in Water Uptake**

Relative to "Control" (- See Table 3 & Fig. 1)

| | |
|---|---|
| **Everdure Caltite** | **92.4%** |
| **3CC** | **91.5%** |
| **"crystal-growth"** | **12.5%** |

The report notes from the weight change data that the HPI's ("Caltite" and "3CC") ***"..exhibit a characteristic pattern similar to silanes, with the concrete losing more weight during each drying stage than was absorbed in the previous immersion phase, and with a continual overall weight reduction leading to drier concrete."*** This effect is clearly observed in the Product Performance Graphs in the test report (Figs. B12 and B13), and reproduced below;

**Weight Change Data; Control vs. "CALTITE" :**

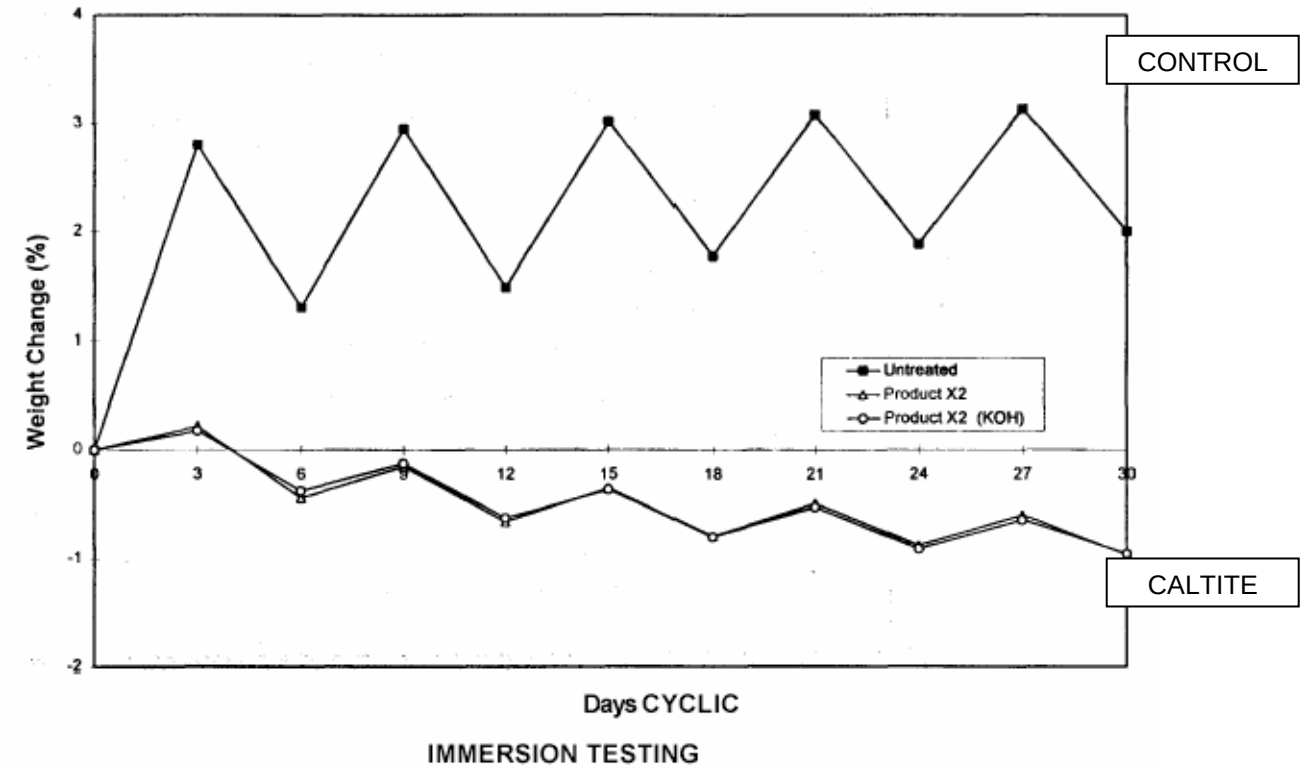



Figure B12. Performance Data for Product X2: 50MPa Concrete

**Weight Change Data; Control vs. "3CC" :**

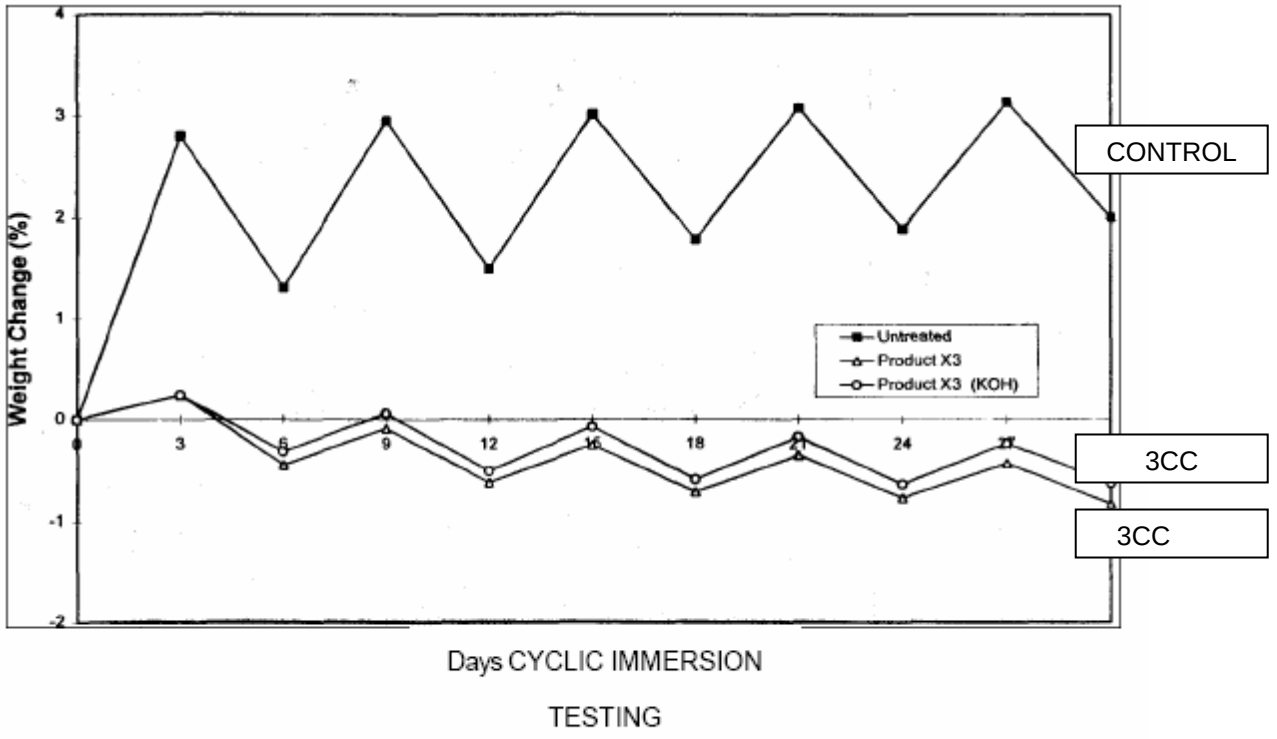



Figure B13. Performance Data for Product X3: 5OMPa Concrete

The report further notes from the weight change data that the ""crystal-growth" concrete shows ***"..little difference to untreated concrete, absorbing and losing water freely during each stage of the test".*** This effect is observed in the Product Performance Graph in the report (Fig. B11).

**Weight change Data; Control vs. "crystal-growth" :**

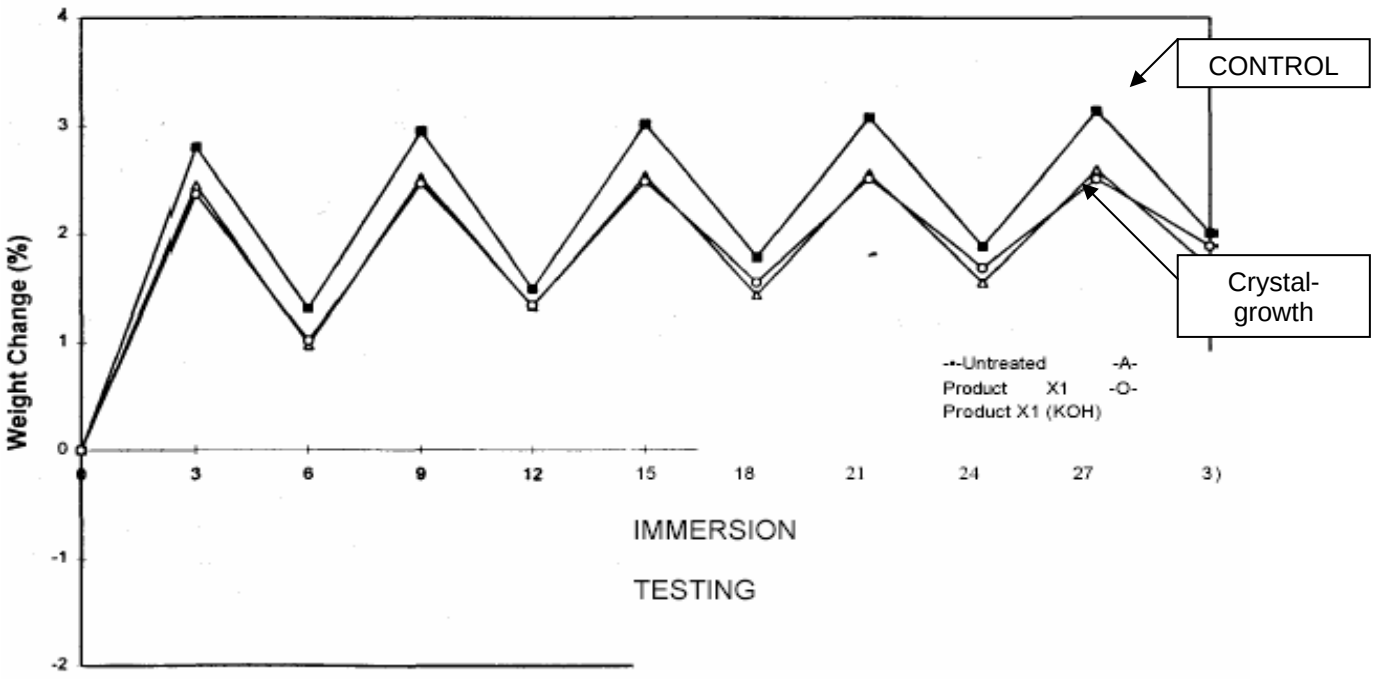
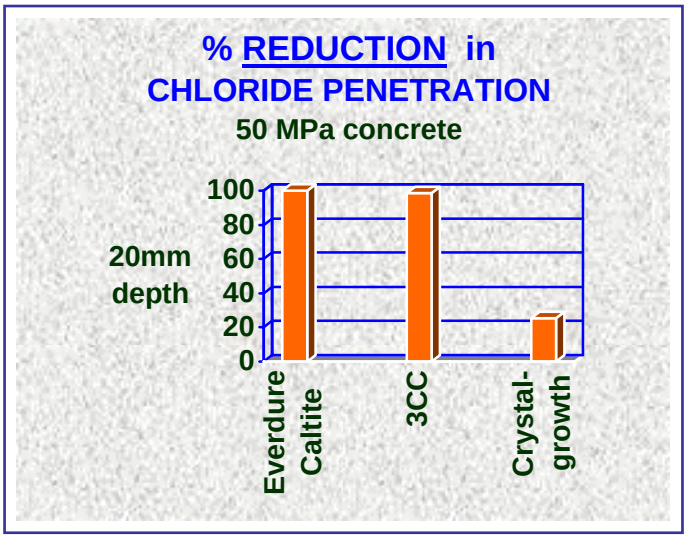



Figure B 11. Performance Data for Product XI: 5OMPa Concrete

**CHLORIDE REDUCTION DATA:**




**Reduction in Chloride Penetration (20 mm depth)**
Salt Water Immersion & Drying Cycles

| | |
|---|---|
| **Everdure Caltite** | **100%** |
| **3CC** | **98.4%** |
| **"crystal-growth"** | **25.3%** |

Regarding performance of the three additive materials tested in the research, the report concludes;

***"The pore-blocking hydrophobic additives (Caltite and 3CC) performed very well, especially at the deeper intervals where chloride reductions in excess of 97% were recorded."***

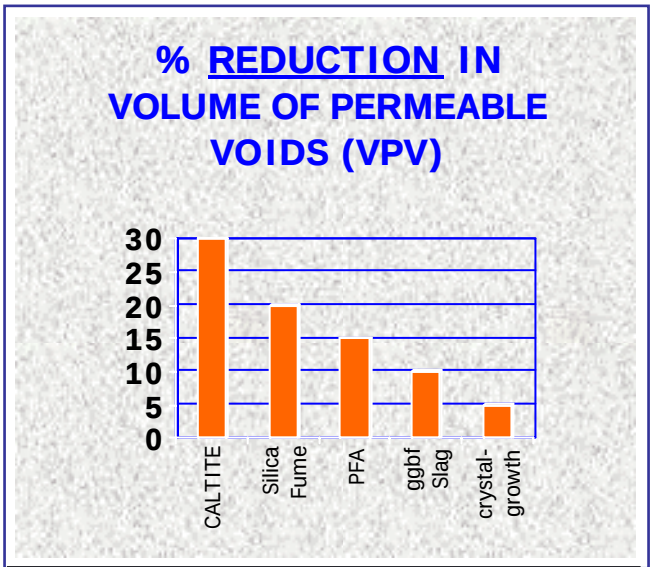
***"These results are better than those for the organo-silanes sealers, and are probably due to the presence of the hydrophobic additive throughout the concrete rather than only in the outer layer, as is the case for the post-applied sealers."***

***"The inorganic hydrophobic additive ("crystal growth") performed very poorly"***

## VicRoads Results

For waterproofing & durability of their structures, VicRoads measured and compared the reduction in the **Volume of Permeable Voids (VPV)** provided by "Caltite" against densifying additives, including a "crystal-growth" additive as used in the RTA tests. The VicRoads research report concludes:

(Appendix 2)




| | |
|---|---|
| **Everdure Caltite** | **30%** |
| Silica Fume | 20% |
| Fly Ash | 15% |
| ggbf Slag | 10% |
| "crystal-growth" | 5% |

***Recommendations ("Caltite"):***
***"The Hydrophobic Pore-blocking admixture (Everdure Caltite) has been found to outperform both conventional and SCMs concrete (fly ash, slag, silica fume) with far greater reductions in VPV. This is a very efficient material in terms of reductions to VPV and consideration can be given to its use where it is cost-effective or where it is proposed by a Contractor".***

***Recommendations ("crystal-growth"):***
***"The waterproofing admixture (WPA / "crystal-growth") has the least effect on reducing VPV compared to either SCMs (pozzolans) or the hydrophobic pore-blocking admixture. WPA (crystal-growth additive) should not be used for the sole purpose of reducing permeability (VPV) of conventional concrete, unless a more detailed investigation work proves otherwise. ..WPA should not be used in combination with SCMs (pozzolans) concrete. Under no circumstances should be WPA be used in conjunction with high replacement SCMs".***

## MEMBRANE-FREE WATERPROOF CONCRETE

1.0 Even the best quality concretes contain a network of interconnected capillary and void spaces, and so are porous to a greater or lesser extent. Typical capillary volume ranges between 8 – 14%, absorbing around 3 to 5% water by weight (BS 1881: Part 122: 1983).

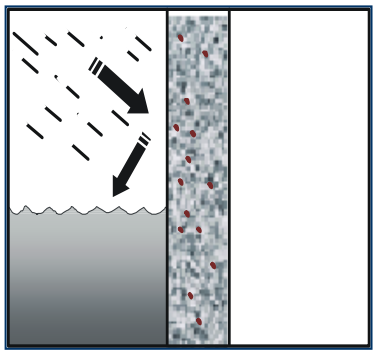
1.1 This capillary network actively promotes the ingress and transmission of moisture and dampness throughout the cement matrix, drawn by powerful surface tension forces within the capillaries ("capillarity"). This property is measured by testing the concrete's **sorptivity** or **absorption**. Absorption is a property of dry concrete, or of wet concrete with an air-exposed drying surface.

1.2 When concrete is submerged, water ingress can also be assisted by an external head of water pressure. The *rate* of this pressure-ingress, is *resisted* by the density of the concrete. This property is measured by testing the concrete's **permeability.** Permeability is a property of saturated concrete.

1.3 In 1997, the UK Transport Research Laboratories (TRL) confirmed that **capillary absorption** is ***" the primary transport mechanism by which water and chlorides infiltrate concrete"*** [1]

1.4 Capillary absorption is the mechanism for wick action, which is defined as "the transport of water (and any species it may contain) through a concrete element from a face in contact with water to a drying face" [2]. Buenfeld *et al* state that; "wick action is a combination of capillary absorption and water vapour diffusion, with evaporation being the linking process".

1.5 Such transport will occur in all concrete in contact with water regardless of the hydrostatic pressure, and will operate in addition to transport due to permeability [3]



1.6 In a (hollow, submerged) structure below water table for instance (basement or tunnel), "permeability" is involved initially, as the extreme outer surface of the concrete is penetrated. However, the pressure gradient is rapidly diminished by the resistance / density of the matrix itself. The vapour pressure differential at the air-ventilated interior face then draws the moisture through the section by capillary action, which is evaporated at or near the surface. In this way capillary absorption takes over and dominates as the main water transport mechanism, and is responsible for the progressive transmission of dampness, moisture and any contained salts into the interior of the structure. The greater the humidity differential across the section, the faster the transmission rate.

2.0 This means that while "low permeability" is a desirable basic requirement, prevention of water movement by **capillary action / absorption**, is the essential property for achieving truly waterproof and durable concrete, which will not absorb water or transmit dampness. This after all, is the purpose of applied membranes and tanking.

2.1 The RTA and VicRoads research above, confirms that both Caltite & 3CC significantly reduce concrete absorption to negligible levels (<1% and <1.5% w.w. respectively). Because of this, Caltite & 3CC concretes do not absorb water or transmit dampness and contained salts. These effects are also independently verified to have persisted undiminished over more than 40 years[4]

2.3 By permanently preventing moisture & chloride transmission by capillary action, "Caltite" and "3CC" concretes are proven suitable for membrane-free waterproof construction, as well as enhanced durability and long term corrosion protection.

4.0 "Crystal-growth" products have been available in Australia in *additive* form since approximately 1994. Prior to this, they were marketed as a surface-applied, post-construction coating. These are claimed to react with hydration by-products to form a crystal-gel within capillary and void spaces, increasing density to resist water penetration.

4.1 However like other *densifiers* (e.g. PFA, silica fume), crystal-growth products do not provide any significant change or reduction in the *absorption* of concrete in which they are used. This means that these concretes can absorb water and transmit dampness freely by capillary absorption, in much the same way as plain concrete, despite any permeability reduction (*densification)* achieved.

4.2 The RTA and VicRoads research both clearly confirm this.

4.3 The VicRoads research report notes that the addition of "crystal-growth" additive to concrete containing PFA, silica fume or slag was observed to be counter-effective (i.e. *increases* VPV), and recommends strictly against its use with blended cements in any State-owned structures. Almost all pre-mixed concrete in Australia includes some PFA.

4.4 The VicRoads research indicates that ordinary PFA is approximately 3 times (300%) more effective in reducing the Volume of Permeable Voids (VPV) in concrete than "crystal-growth" additive. The "Caltite" HPI is shown to be approximately 6 times more effective.

5.0 The ranking of all the waterproofing / permeability reducing additives tested across both State Govt. research programs (RTA & VicRoads) is as follows;

**Performance Ranking of Materials:**

| **NSW RTA (CTI Consultants)** | **Benefit Confirmed** | **VicRoads*** | **Benefit Confirmed** |
|---|---|---|---|
| 1st CALTITE (HPI) | YES | 1st CALTITE (HPI) | YES |
| 2nd 3CC (HPI) | YES | 2nd Silica fume (pozzolan) | YES |
| 3rd "crystal-growth" (silicate) | NO | 3rd PFA (pozzolan) | YES |
| | | 4th Blast furnace slag (pozzolan) | YES |
| | | 5th "crystal-growth" (silicate) | NO |

(*Note: Cementaid "3CC" was not included in VicRoads research program)

6.0 The RTA and VicRoads research results confirm that the Hydrophobic Pore-blocking Ingredients CALTITE & 3CC provide significant performance advantages over all other additives tested, including pozzolans and "crystal-growth" additive, and are suitable for corrosion protection and membrane-free waterproof concrete construction.

7.0 The HPI's CALTITE & 3CC have an ongoing, time-proven history of safe, successful and corrosion-free use in these applications for over 44 years and in 23 countries.

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Appendices;

1 CTI Consultants P/L; Investigation Report (For RTA, NSW);
"Further Investigation of Waterproofing Measures for the Long Term Durability of Concrete".

2 Govt. Of Victoria; VicRoads Materials Technology;
"Establishing The Durability Performance of Structural Concrete" ( – Relevant sections)

References;

1 Butler, A. "Capillary Absorption by Concrete" – Transport Research Laboratory (UK)

2 Buenfeld, N.R., Shurafa-Daoudi M.T. and McLoughlin, I.M. (1997) "Chloride Transport due to Wick Action in Concrete." in "Chloride penetration into concrete" Nilsson, L.O. and Ollivier, J.P. eds.(RILEM, Paris) 1997, pp. 315-324

3 McLoughlin, I.M. "Modelling of chloride and moisture transport in concrete." PhD. Thesis, Imperial College, London 1997

4 British Board of Agrément (BBA) Certificate N$^{o.}$ 93/2888 - "Everdure Caltite System"