# LIFETIME CONCRETE WATERPROOFING AND PROTECTION

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## ABSTRACT

*Waterproofing concrete for life including the cracks.*

*This paper describes a continuous, sub-surface amorphic membrane waterproofing system by means of a clear, biochemically modified silicate solution that penetrates and integrates with trafficable and vertical concrete surfaces.*

*It is suitable for use on new structures – as well as repair, rehabilitation and/or replacement applications. More so, it is ideal for above-grade concrete structures undergoing high thermal stresses.*

*The system remains reactive inside cracks and matrix of concrete for the life of the structure where, in the presence of water, it reacts with available free calcium to recommence its process – described as the "Virtuous Cycle".*

*The result; Lifetime concrete waterproofing biochemically.*

**Keywords:** Amorphic, Biochemical, Calcium, Cracking, Silicate, Virtuous Cycle, Waterproofing

## INTRODUCTION

When concrete deteriorates, it is frequently due to cracking.

Six effects of drying concrete are: plastic shrinkage cracking, bulk shrinkage, microcracking and increased permeability, weakening of the cement-aggregate bond, a decrease in tensile strength and, if re-wetted, a tendency to expand due to disjoining forces[1].

The technology described herein is a biochemically modified silicate waterproofing technology as found in the proprietary product, RADCON Formula #7. There is no other known product of its type – or performance capability – in the world.

RADCON Formula #7 is the name given to the biochemically modified silicate waterproofing technology by its inventor, the late Dr. A.W. (Bill) Smith, in 1975. A self-educated American biochemist, Dr. Smith realized a number of achievements in his life including invention of certain blood analysis diagnostic equipment - a breakthrough that led to his nomination for a Nobel Prize in Chemistry.

This waterproofing technology's performance can be likened to that of the skin of the human body – and its ability to self-heal cuts (cracks). However, it uses water and free calcium available in the substrate to create waterproofing and, in effect, the more water there is the harder it works.

Treatment is a one-time application – and is effective for the design life of the structure.

The biochemically modified sodium silicate solution is spray applied to cured concrete however it is <u>not</u> a surface coating (membrane), admixture, crystal growth, or water repellent (sealer). It is, in essence, an invisible sub surface membrane.

Through a 3-day watering process, the solution penetrates concrete reacting with water and free calcium to create a non-water soluble CSH (calcium silicate hydrate) gel complex in matrix and cracks, a *continuous sub-surface amorphic membrane*, that;

- bridges and seals existing cracks (<u>and</u> future stress cracks as occur), and,
- waterproofs pores/capillaries against ingress of water and contaminants.

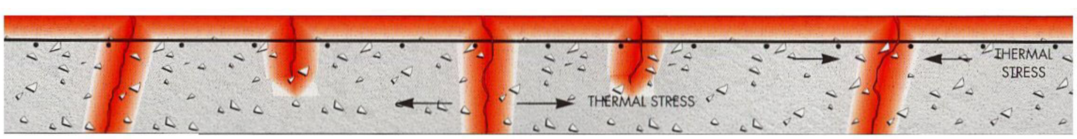


Fig. 1 Suspended Slab Cross Section

For above-grade concrete structures undergoing high thermal stresses (and with leaking cracks present) – including bridge decks, flyovers, car park decks, podiums and balconies – it is a pivotal alternative to traditional waterproofing approaches. Being fully trafficable and ideal in freeze/thaw conditions the technology lends itself to multifarious applications.

And, being non-toxic, non-flammable and totally environment friendly, this biochemically modified silicate waterproofing technology can be safely used even on potable water sites.

## PERFORMANCE DYNAMICS

The Product is a non-toxic, clear, odorless silicate based material with proprietary biochemical modification. This solution penetrates into the general matrix and cracks of the concrete to react with calcium hydroxide, alkalis and water at ambient temperatures to form a continuous, sub surface, non water-soluble complex calcium silicate hydrate amorphic gel in the cracks, pores and capillaries. This CSH gel complex prevents the ingress of water, salts and other dissolved contaminants into cracks and concrete matrix from reaching embedded steel reinforcement – even under high thermal and trafficable stresses.

Existing cracks the product will be able to seal existing leaking cracks up to 2.0mm (0.08”). Future cracking within the concrete matrix, the product shall remain reactive with water to provide autogenous healing properties to seal hairline cracks as occur up to 0.3mm (0.012”).

Fig. 2 Underside Parking Deck – Precast Tees

In order for the technology to work and achieve lifetime waterproofing the concrete mix design must be cementitious and not pozzolanic in nature. Therefore suitable concrete is high calcium content concrete design mixes such as Ordinary Portland Cement concrete with no supplementary ash additives. Suitable blended concretes include concrete with Type C fly ash or slag replacement.

In simple language, the cracks must leach calcium.

As untreated concrete cracks and leaks, ‘free calcium’ is leached from the matrix of the concrete and forms efflorescence (calcium carbonate) on the soffit of the concrete. If the leak is not repaired a significant proportion of the ‘free calcium’ will be leached from the concrete in that area. Old or carbonated concrete usually requires a pre/post-treatment with a calcium acetate solution in order to activate the biochemically modified silicate waterproofing material.

SCOPE OF TESTING

A global portfolio of Testing and Evaluation reference from 1979 has been conduct on the biochemically modified silicate waterproofing known as RADCON Formula #7.

Here in the *United States* the material is supported by specific test reference to;

- AASHTO - T259 and T260,
- ASTM C-192, C-672-76, C-876-91, C-952, D-1644 and E-514.
- It was also subject of FHWA Study "Low Cost Bridge Deck Treatment" (1981-84)[2].

In addition, numerous tests supporting the performance and capability of the technology have been conducted by recognized institutions in *Australia*, *Canada*, *Israel*, *Italy*, *Japan*, *Norway*, *Portugal*, *Singapore* and *Spain*.

Amongst the international test portfolio available there is some notable studies:

1) Sydney, Australia (1995)
   *Capability to Maintain Waterproofing of Cracks during a Full Thermal Cycle*
   a) Structure treated in July 1988
   b) 7-years after treatment 48-hour pond tests over treated and non-treated cracks were conducted March 1995
   c) No leakage noted on the treated cracks

2) Oslo, Norway (1995)
   *Water Permeability Test*
   400-meter (1,312') pressure head of 40kg/cm$^2$ (577lb/in$^2$)
   a) The untreated reference concrete actually cracked under pressure

3) Bologna, Italy (1995)
   *Crack Sealing and Resealing Performance*
   a) Treated samples sealed new cracks to 0.3mm (0.012").
   b) Treated samples with calcium acetate addition sealed new cracks to 1.3mm (0.051").

Fig. 3 Test Rig to Simulate Cracking (University of Bologna)

## SCOPE OF USE

### Road Bridge Decks

Fig. 4 Suspension Bridge Deck, Can Ctio Town, Vietnam, 2001

### Raised Freeways <> Elevated Ramps

Fig. 5 K11A Prince Edward Road West, Kowloon, Hong Kong, 1997

### Railway Bridges

Fig. 6 Tuc-Rail Bridge, Brussels, Belgium, 2001

Cut & Cover Tunnels

Fig. 7 NASCAR Race Track Service Tunnel, Bristol, Tennessee 2001

Balconies

Fig. 8 Apartments, Wollongong, Australia, 2001

Parking Decks

Fig. 9 Northside Hospital, Atlanta, Georgia, 1999

Rooftops

Fig. 10 BMW Dealership, Atlanta, Georgia 2000

Stadiums


Fig. 11 Sports Complex, Gosford, Australia 2000

Monuments

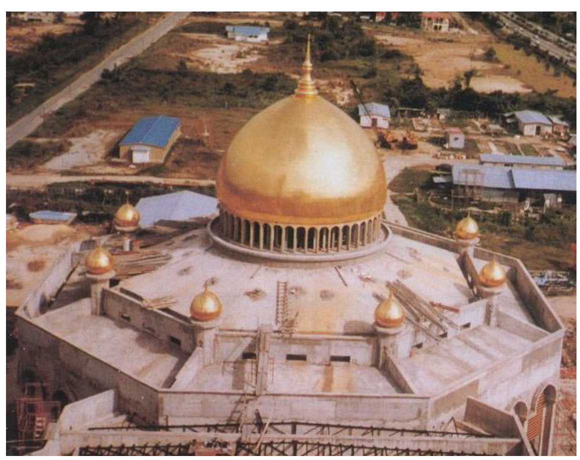
Fig. 12 Mosque Dome Roof, Sultan of Brunei, Brunei, 1991

Industrial

Fig. 13 Recycling Center, Yokosuka City, Japan, 2002

Dams

Fig. 14 Olio Dam, Sardinia, Italy, 2000

Swimming Pools

Fig. 15 Aston Mansion, Singapore, 1998

Tilt Up Panels

Fig. 16 Removal Storage Complex, Lane Cove, Australia, 1993

Wharves

Fig. 17 Australian Navy Facilities, Sydney, Australia, 2001

Aquariums

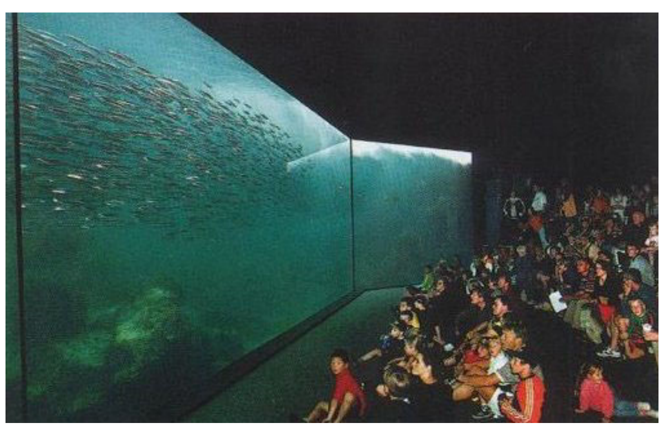

Fig. 18 Atlantic Park, Alesund, Norway, 1998

Holding Tanks

Fig. 19 Electricity Power Plant, Vietnam, 2001

Potable Water Tanks

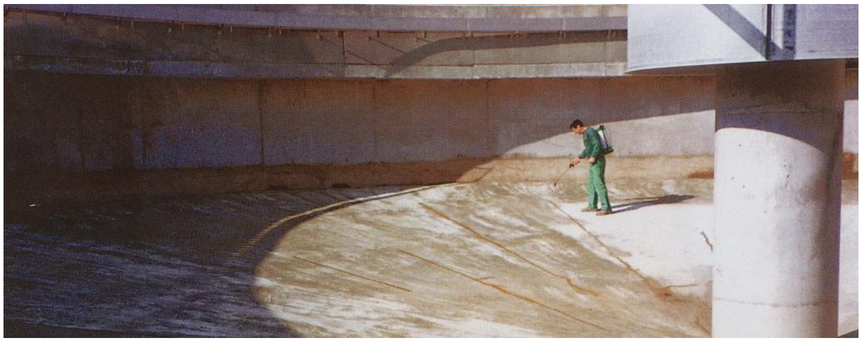

Fig. 20 Water Tank, Cadiz, Spain, 1999

Artificial Lakes

Fig. 21 Darling Walk, Sydney, Australia, 1997

Aviation

Fig. 22 Helipad, Manila, Philippines, 2001

Towers

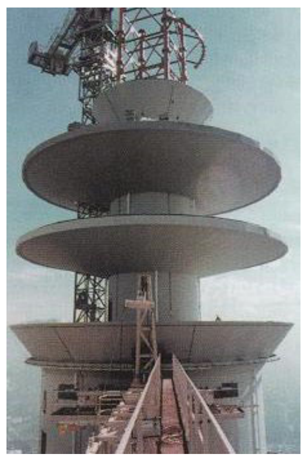

Fig. 23 Telecommunications Tower, Kuala Lumpur, Malaysia, 1994

Silos

Fig. 24 Wheat Silos, Enfield, Australia, 1991

Nuclear Storage

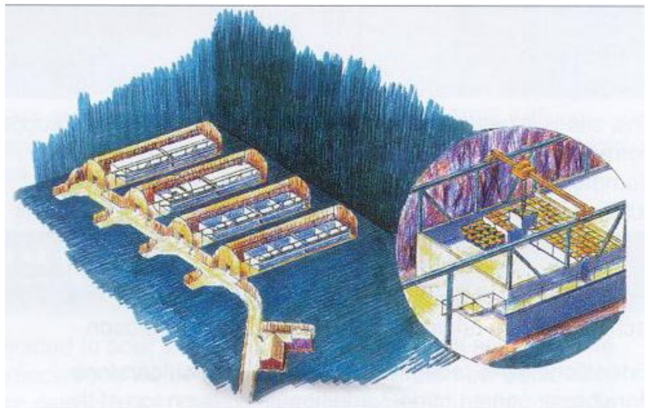

Fig. 25 Himdalen Atomic Storage Deposit, Norway, 1998

Canals

Fig. 26 400-year-old Structure Restoration, Venice, Italy 2002

SCOPE OF COST

The biochemically modified silicate liquid material covers on average 200 square feet per US gallon.

The material itself costs approximately $0.60 per square feet.

Cost of installation, including material and labor, is approximately $1.40 per square feet. This is one time installation that will last for the life of the structure.

Real cost considerations take into that alternative traditional methods such as sheet membranes can cost up to $10.00 per square feet (installed) – and will fail at some point. Remedial costs will then far exceed original installation cost. Similarly, liquid membranes, sealers and repellents have limited service life.

**THE VIRTUOUS CYCLE**

An appreciation of a lifetime waterproofing solution for structural above-grade concrete with biochemically modified silicate waterproofing requires, chemically, an explanation.

Biochemically modified silicate waterproofing remains re-reactive inside the cracks and matrix of the concrete for the life of the structure.

The following chemical explanation is adapted from the "Virtuous Cycle testing" activity undertaken by the Australian Federal Government's own testing authority – the CSIRO (Commonwealth Scientific and Industrial Research Organisation) – on RADCON Formula #7.

Some very interesting principles are described. The foundation is catalytic reactions of which there are two. A catalyst is a material that enables, speeds up or slows down a chemical reaction without its changing itself.

For a product to seal new cracks that develop after application it must produce more mass than originally applied - i.e. it must "grow".

When biochemically modified silicate waterproofing is applied and watered in, it penetrates into the concrete and the silicates react with the available metallic ions – primarily calcium in hydroxide form (calcium hydroxide is a by-product of cement hydration). At this stage the biochemically modified silicate waterproofing is highly reactive and creates a complex Calcium Silicate Hydrate (CSH) gel.

Cement hydration itself forms CSH gel and there are many different permutations of this. This gel swells when in contact with water that stops the passage of water deeper into the concrete and is one of the important "waterproofing" functions of biochemically modified silicate waterproofing.

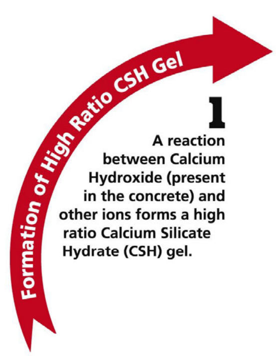


Fig. 27 The "Virtuous Cycle" – Stage 1

Over time $CO_2$ from the atmosphere extracts some of the calcium from this gel to form Calcium Carbonates. This is an inert mass that fills pores, capillaries and cracks and this reduces permeability in itself. However, the problem normally associated with $CO_2$ is "carbonation" of concrete. Why it is not a problem in the biochemically modified silicate waterproofing reaction is explained further on.

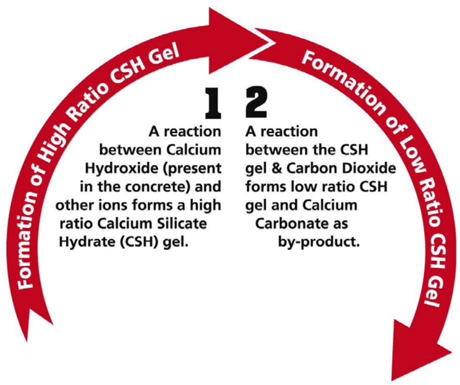


Fig. 28 The "Virtuous Cycle" – Stage 2

With atmospheric $CO_2$ extracting some of the calcium out of the gel this results in a low ratio CSH gel. This means it is "reactive ready" again and wants to grab some more calcium ions to put it back in "equilibrium".

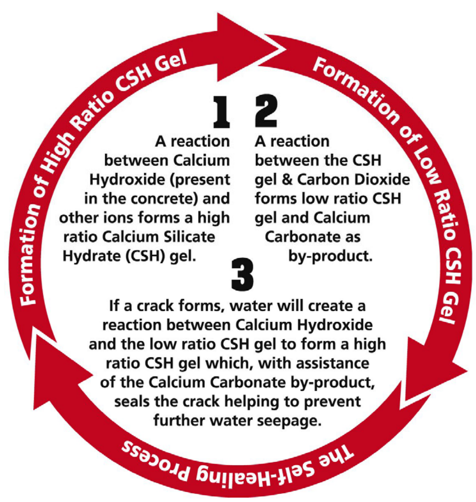


Fig. 29 The "Virtuous Cycle" – Stage 3

When water enters the concrete the cement continues to hydrate and, through diffusion within the concrete, calcium moves from areas of high concentration to low concentration. The low ratio CSH gel reacts with this newly available calcium and forms a high ratio CSH gel. This is reactive with $CO_2$ and so some calcium carbonate forms and it returns to low ratio CSH gel. And so the cycle continues.

This process should be seen as a much more dynamic and reliable version of concrete "autogenous", or self-healing process, although the $CO_2$ normally reacts directly with the $Ca(OH)_2$ calcium hydroxide.

Carbonation is normally considered dangerous to concrete because it drops the pH of the concrete. It is the high pH of concrete that creates the "passive" layer on the steel reinforcement that protects it from corrosion – hence a reduction in pH will have deleterious effect. What is overlooked is that the calcium carbonate produced also reduces porosity and permeability as well, which is good for durability. Biochemically modified silicate waterproofing creates a "virtuous" carbonation cycle in that the alkalinity of concrete is not reduced through this part of the reaction – in fact, it increases the alkalinity and affords even greater protection to the reinforcement.

The difference between biochemically modified silicate waterproofing and normal silicates is that the biochemical materials allow this reaction to cycle indefinitely. Plain silicates get "stuck" when they carbonate and do not become available again to react. This means plain silicates cannot maintain a seal on cracks nor have a capability to seal new cracks.

There are two (2) important reaction components. The calcium carbonate acts as a consolidating "glue" and "space filler" in cracks, pores and capillaries. The gel also plays a vital role - not only is it the "calcium carbonate factory" but the colloidal gel is not rigid and so allows for small dynamic movement such as shrinkage and thermal movement. When in contact with water it swells filling the remaining spaces that have allowed the water to enter and blocks them off. Then the "factory" gets to work depositing calcium carbonate to permanently seal it. The gel will return to equilibrium and remain "dormant" until water comes in contact again.

Primary Steps in the Process

1. Biochemically modified silicate waterproofing applied to the concrete and watered in.
2. The biochemically modified silicate waterproofing reacts with Calcium Hydroxide and other ions to form a high ratio complex Calcium Silicate Hydrate (CSH) gel.
3. The high ratio CSH gel reacts with Carbon Dioxide to form Calcium Carbonate and low ratio CSH gel
4. The low ratio CSH gel reacts with Calcium Hydroxide to form high ratio CSH gel. The cycle continues ad infinitum so long as there is water, calcium or other ions and carbon dioxide available.

The CSIRO study on the "Virtuous Cycle" is critical from two perspectives: -

- Firstly, it scientifically supports the lifetime waterproofing claims for biochemically modified silicate waterproofing.

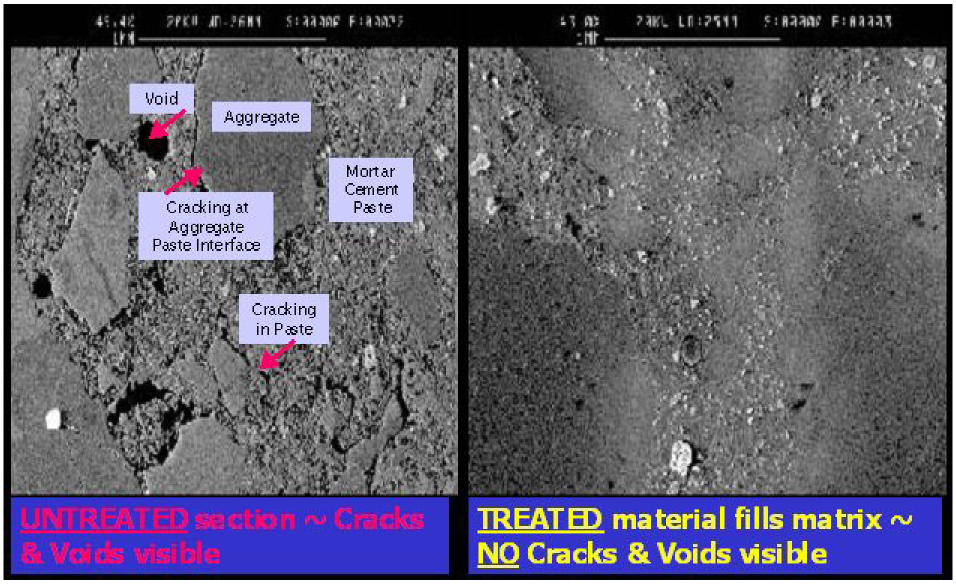


Fig. 30 SEM Images – Non-Treated and Treated Sections

- Secondly, through SEM (Scanning Electron Microscopy and X-ray microanalysis) photography of this cyclical process, one can confirm that genuine biochemically modified silicate waterproofing was applied to site as per specifications. If the product has been substituted, diluted or applied without the critical watering procedures, then the SEM images will reveal all.

## CONCLUSION

Structural preservation and low maintenance are primary considerations in the concrete construction industry. A dynamic yet cost effective solution is available to provide waterproofing and protection for the life of a structure through a single application.

A 29-year proven track record, and use in over 50 countries around the world, are legacies to the effectiveness and ability of biochemically modified silicate waterproofing to bridge and seal existing cracks and stress cracking as occur post application plus waterproof/protect the concrete matrix including pores and capillaries.

## REFERENCES

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U.S. Dept. of Transportation, Federal Highway Administration, *Low Cost Bridge Deck Surface Treatment*, PB84-238740, Report FHWA/RD-84/001 Final Report April 1984