Waterproofing Membranes, a history of problems, standards, and solutions.

This paper was prepared for the NZ Institute of Architects Technical Series, and presented in NZ’s main centers in June 2011 by Bill Grayson BSc, FNZIC. It remains the property of Grayson Wagner Co Ltd, but will be posted as a PDF at www.graysonwagner.co.nz. It must only be copied or reproduced in full.

This paper was written in frustration at the destructive power of an assumption, particularly when it is attached to a brand name. The assumption is that ‘waterproof’ means what it says. ASS/U/ME

The brands are many, and shall remain nameless for the present.

Early membrane Problems

Common themes

• By 2004 problems with membrane failure were surfacing in NZ. This later turned out to be a big issue in Canada, USA, and other areas of high rainfall/humidity

• Exterior membrane areas that were affected were flat roofs and exposed decks, particularly where tiles were in direct contact with membranes

• Structures with concrete, or timber/plywood substrates were both affected

• A common factor was a lack of falls on decks and roofs, ponding at drain heads, and in gutters

• A constant headache has also been leaks in showers and bathrooms, that are in daily use

Symptoms

• Leaks, rot, and smell
• Structural movement
• Wear surface lifting, movement, cracking of tiles and grout lines
• Membrane color changes, and stickiness or sliminess.
• We must dismantle the affected area, and photograph the membrane, particularly at movement joints, and changes of plane. We are looking for tearing due to structural movement, delamination along seams, and the membrane condition.

• We take samples of the membrane in waterproof containers, together with the surrounding water.

• An extremely common finding is surprisingly high levels of water absorbed into various membranes, often more than 50%

• The absorption of water by a membrane also causes it to swell, which may in turn cause loss of adhesion, delamination of tiles, fracturing of grout lines, etc.

• Immersion studies of lab prepared membrane samples at various water temperatures, show that onset of water absorption may take weeks or even months before becoming significant.

• Compatibility issues have also occasionally been found. These are usually obvious due to other components such as acoustic barriers being present, and the dramatic effects on the membrane.

• Our work on many different sites and membranes is usually initiated by litigation for water damage.

• Long experience has shown that the cause of a membrane absorbing excessive water is usually generic in character, and not caused by applicator problems.

• At one large Auckland site with multiple similar buildings of structural concrete, each building had numerous exterior terraces with direct stick tiles. All the buildings except one were waterproofed with a torch-on membrane. No water absorption problems were noted with that membrane, or with leaks in these buildings.

• However, the remaining single building on site was waterproofed with a bitumen modified liquid applied urethane, which failed badly by water absorption. In the following six years, this particular membrane has gone on to become a commercial hazard.

Overseas experience

• Hundreds of building failures have occurred due to water intrusion through membranes in wet areas of Canada and the USA.

• Recent work publish by ASHRAE suggests an osmotic effect through a semipermeable membrane as the cause.

• However, this raises the question of what is a semipermeable membrane? Somewhere between an impermeable and a permeable membrane!

• In other words a waterproofing membrane that absorbs water.
• The real question has now become:

**How much water absorption is too much, and how to best determine that??**
Applicable NZ regulations and standards for damp-proof membranes

**NZ Building Code** -note the wording change from waterproof membranes in this code!

- The applicable section of the NZBC is Durability B2 Acceptable solution AS1
- This sets out a Durability requirement of 50 years for tanking, and 15 years for membranes on top of concrete slabs, behind tiles, and for roofing membranes.
- Verification Method B2/VM1 1.1 requires consideration of the in-service exposure of a building element for:
  a) Length of service-- *15 or 50 years*
  b) Environment of use-- *exterior or interior*
  c) Intensity of use-- *think about this!*
  d) Reaction with adjacent material-- *compatibility?*
  e) Limitations of performance-- *do people read labels/ data sheets etc*
  f) Degree of degradation-- *UV exposure*
Verification Method B2/VM1

1.0 Durability Evaluation

1.0.1 Verification that the durability of a building element complies with the NZBC B2.3.1 and B2.3.2 will be by proof of performance and shall take into account the expected in-service exposure conditions by one or more of the following:
   a) In-service history,
   b) Laboratory testing,
   c) Comparable performance of similar building elements.

1.1 In-service history

1.1.1 Verification of durability based on in-service history of a building element, including materials, components and systems shall take into account but not be limited to:
   a) Length of service,
   b) Environment of use,
   c) Intensity of use,
   d) Any reaction with adjacent materials,
   e) Limitations in performance,
   f) Degree of degradation, and
   g) Changes in formulation.

1.2 Laboratory testing

1.2.1 Verification of durability based on successful performance in a laboratory test shall be accompanied by an assessment of the tests performed, their relevance to field and service conditions, and in particular:
   a) Types of degradation mechanisms likely to be induced by testing,
   b) The degradation mechanisms likely in service,
   c) Details of methods of assessment,
   d) Variability of results, and
   e) The relevance of the test to the building element under study.

1.3 Similar materials

1.3.1 For the purposes of evaluation, a building element may be considered as similar to another building element with proven performance, if both are subject to the same controls for composition and overall performance. Examples of such controls are Approved Documents or Standards. Where such a direct comparison is not possible, the building element shall be independently assessed to determine the degree of similarity.

1.3.2 Assessment shall take into account but not be limited to:
   a) Product composition,
   b) Method and quality assurance of manufacture,
   c) Degradation mechanisms,
   d) Local environment,
   e) Conditions of use,
   f) Required maintenance, and
   g) Performance in use.

COMMENT:

Environment

1. To be acceptable, any opinion in support of the assessed durability for a building element shall clearly identify the conditions of use and the environment under which that durability will be achieved. If the building element can be reasonably expected to be used in circumstances which will reduce the durability, any limitations in use shall be clearly identified and evaluated.

2. Circumstances which need to be considered include, but are not limited to:
   a) Maintenance required to achieve the required durability (e.g. painting, cleaning, replacing high wear items such as washers),
   b) Installation details of the total system (e.g. fixings, flashings, jointing materials),
   c) Compatibility with other materials (e.g. galvanic corrosion, plastoblock migration),
   d) Compatibility with other materials (e.g. galvanic corrosion, plastoblock migration),

DEPARTMENT OF BUILDING AND HOUSING

28 February 1998
<table>
<thead>
<tr>
<th>Building Element</th>
<th>Component</th>
<th>Situation/Function</th>
<th>Not less than 50 years</th>
<th>Not less than 15 years</th>
<th>Not less than 5 years</th>
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<td>Damp-proof membranes</td>
<td>Damp-proofing generally</td>
<td>DPMs applied to the top of concrete slabs</td>
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<td>DPMs behind retaining walls used for landscaping</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DPMs designed for ready access and replacement</td>
<td></td>
<td>✓</td>
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<tr>
<td></td>
<td></td>
<td>DPM behind tiles</td>
<td>Same durability as the tile covering it</td>
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<td></td>
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<td>Water-proofing of</td>
<td>Tanking, except those designed for ready access</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>basements</td>
<td></td>
<td>Tanking designed for ready access</td>
<td>✓</td>
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<td></td>
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<td></td>
<td>Decking</td>
<td>Structural (e.g. bracing diaphragm)</td>
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<tr>
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<td>Sub-floor structure</td>
<td>Non-structural strip decking</td>
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<td>✓</td>
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<td>All</td>
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<td></td>
<td>Partition including frame</td>
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<tr>
<td></td>
<td>fixings, and linings</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Doors (including</td>
<td>Non fire rated doors</td>
<td>Internal</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>frame)</td>
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<td>External</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Fire rated doors</td>
<td>Furniture and hardware</td>
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<td>✓</td>
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<tr>
<td></td>
<td></td>
<td>Internal</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td></td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Furniture and hardware</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>Electrical work</td>
<td>Wiring</td>
<td>Buried in or under concrete slabs or behind structural linings without ducts</td>
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<td></td>
<td>Concealed behind linings or in complex ducts or conduit, or surface mounted in</td>
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<td>✓</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>conduit</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wires in easy to access ducts</td>
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<td></td>
<td></td>
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<td>Fittings</td>
<td>Concealed and moderately difficult to access or replace</td>
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<td>✓</td>
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<td></td>
<td></td>
<td>Surface mounted</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Ducting or conduit</td>
<td>Difficult to access or replace</td>
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<td>✓</td>
<td>✓</td>
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<td>Moderately difficult to access or replace</td>
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<td></td>
<td>All others</td>
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<td>✓</td>
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<td>Fixings</td>
<td>Used to fix structural or difficult to replace building elements</td>
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<td>✓</td>
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<td></td>
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<td>Under water-proof membranes</td>
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<td></td>
<td>Under roofing membranes</td>
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<td>Used to fix non-structural or moderately difficult to replace building elements</td>
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<tr>
<td></td>
<td></td>
<td>All others</td>
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<td>Bolts</td>
<td>Used to fix structural or difficult to access or replace building elements</td>
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<td>✓</td>
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<tr>
<td></td>
<td></td>
<td>Elements including structural elements of decks and barriers</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
AS/NZS 4858-2004 (follow method AS3558.1) for wet area membranes

• Test by AS 3558.1 for testing of plastics, composite materials, and sanitary plumbing fixtures- One sided exposure to water for 24hrs at room temp

• AS/NZS 4858-2004 Specification: Water absorption- record result, max figure to be supplied.

• Water vapor transmission rate (WVTR), test by ASTM E96/M. If >8g/sqm/day and if it is to be used on plywood the water absorption must be <10%

• Problem 1- Testing of a membrane which must withstand 15-50yrs in water, by one sided immersion for 24hrs? The AS/NZS standards have no correlation with the NZ building code durability requirements.

• Problem 2- The standard gives no water absorption performance specification, although for plywood it must be <10% water absorption in 24hours.

• Problem 3- WVTR can only be carried out on carefully prepared lab samples, and is useless for testing field samples for compliance.

• Problem 4- NZS and AS are not responsive to questions on this subject (4).

Bill Grayson

From: Bill Grayson <bgrayson@woosh.co.nz>
Sent: Thursday, 5 November 2009 5:54 p.m.
Subject: AS/NZ4858:2004 and AS 3558.1-1999

To: The Chief Executive Officers

Re: Wet area membrane failures in exterior NZ applications.

• As invited on page two of AS/NZS 4858:2004 I write to advise you of a problem that has arisen with these standards.
• It has come to our attention on two occasions, that a deficiency in these two standards may be contributing to extensive failures in the field by misleading membrane suppliers/customers into assuming wet area membranes which use these standards in performance data in their Technical Specifications are fit for purpose.
• As Consulting Chemists we are often called to examine sites which are exhibiting membrane failure under ceramic tiles.
• Two different polyurethane moisture cure membranes have used test method AS 3558.1 to determine moisture absorption in the cured film, and use AS/NZS4858:2004 Table 8.1as the source of the property specification for water absorption.
• The problem lies it the fact that AS3558.1 was not designed for testing membranes, but sanitary plumbing fixtures.
• It tests the sample on one side only for 24 hours with cold tap water.
• In NZ membranes under tiles are typically exposed to water at temperatures of up to 40C at pH’s of 11.0 and higher for months on end from both sides.
• Hence the test conditions are inadequate when compared with field conditions.
• We have found in both Lab prepared samples, and field samples, that products which absorb <1% w/w water when tested by AS3558.1, may absorb >50%w/w of water when tested at 50C for 30days in tap water, with swelling that destroys the structure into which they are incorporated.
• This of course is not the Standards problem, but caused by inadequately formulated product.
• However the test results are misleading, especialy when compared with the water absorption requirements in AS/NZS 4858 Table 8.1—record result—Max figure to be supplied!!!!!!!!

I would appreciate being advised of your actions to correct this matter.

Regards,
Bill Grayson BSc, FNZIC,
Consultant Chemist,
Grayson Wagner Co Ltd,
4 Cain Rd, Penrose,
P O Box 112-318,
Auckland, 1642, NZ
Mobile ph 0274322761
Lab ph/fax 00649 5712444
Default Standards for membranes

- We have carried out a complete review of applicable standards, and as you can see the most comprehensive are the ASTM standards.

- Disclosure—I sit on the ASTM technical committee D08 for roofing and membrane materials

- The ASTM standards test a variety of membrane types in different ways and with different specifications, however the common themes of the test methods are:

  a) Water immersion for 7 days at 23°C-------------------Specification <4% or <20% for acrylics?
  b) Water immersion for 4 days (~100 hrs) at 50°C-------Specification <3.2%
  c) Water immersion for 7 days at 50°C-------------------Specification < 10%
  d) WVTR at 32.2°C and 54% humidity-------------------Specification < 8.52g/sqm/day

- The good news about the three water immersion standards is that they readily allow testing of field samples of problem membranes

**Problem 5** - *Why is there such a wide range of test conditions for different membrane types; and of greater concern, different performance specifications.*

**Problem 6** - *Do you understand intuitively what is meant by a WVTR of < 8.52g/sqm/day?*
<table>
<thead>
<tr>
<th>Membrane Type</th>
<th>ASTM STANDARD SPECIFICATION NUMBER</th>
<th>ASTM STANDARD TEST NUMBER</th>
<th>Max Water Absorption</th>
<th>Test Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Applied Neoprene and Chlorosulfonated Polyethylene used in Waterproofing and Roofing</td>
<td>D3468-99 (2006)</td>
<td>D471</td>
<td>4%</td>
<td>7 days @ 23°C</td>
</tr>
<tr>
<td>EPDM Sheet used in Single Ply Roof Membrane</td>
<td>D4637-08</td>
<td>D471</td>
<td>Range (+8 - -2)%</td>
<td>166hrs @ 70°C</td>
</tr>
<tr>
<td>Nonvulcanised (Uncured) Rubber Sheet used as Roof Flashing</td>
<td>D4811-06</td>
<td>D471</td>
<td>Range (+8 - -2)%</td>
<td>Type 1 166hrs @ 70°C, Type 2 46hrs @ 70°C</td>
</tr>
<tr>
<td>Reinforced Chlorosulfonated Polyethylene sheet used in Single Ply Roof Membrane</td>
<td>D5019-07a</td>
<td>D471 sections 8,9</td>
<td>10%</td>
<td>166hrs @ 50°C</td>
</tr>
<tr>
<td>Liquid Applied Acrylic Coating used in Roofing</td>
<td>D6083-05</td>
<td>D471</td>
<td>20%</td>
<td>7 days @ 23°C</td>
</tr>
<tr>
<td>Atactic Polypropylene Modified Bituminous Sheet Materials using Polyester Reinforcing</td>
<td>D6222-08</td>
<td>D5147</td>
<td>3.20%</td>
<td>100hrs @ 50°C</td>
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<tr>
<td>Atactic Polypropylene Modified Bituminous Sheet Materials using a Combination of Polyester and Glass Fibre Reinforcing</td>
<td>D6223-02</td>
<td>D5147</td>
<td>3.20%</td>
<td>100hrs @ 50°C</td>
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<tr>
<td>Atactic Polypropylene Modified Bituminous Sheet Materials using Glass Fibre Reinforcing</td>
<td>D6509 / D6509M-09</td>
<td>D5147</td>
<td>3.20%</td>
<td>100hrs @ 50°C</td>
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<tr>
<td>Thermoplastic Polyolefin based Sheet Roofing</td>
<td>D6876-08</td>
<td>D471</td>
<td>3%</td>
<td>166hrs @ 70°C</td>
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<td>Liquid Applied, Single Pack, Moisture Triggered, Aliphatic Polyurethane Roofing Membrane</td>
<td>D7311-07</td>
<td>E96/E96M</td>
<td>Water Vapour Transmission permeability Max = 8.52 g/m²/day</td>
<td>32.7°C @ 54% humidity Procedure C</td>
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<tr>
<td>Spray Polyurethane Foam used for Roofing Applications</td>
<td>D7425-08</td>
<td>D2842</td>
<td>5%</td>
<td>See standard Method D</td>
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<td>Standard guide for High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane with an Integral Wearing Surface</td>
<td>C1127 – 01 (Reapproved 2009)</td>
<td>Check Standards</td>
<td>Check Standards</td>
<td>Check Standards</td>
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<tr>
<td>Standard Specification for High-Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane With Integral Wearing Surface</td>
<td>C957</td>
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<table>
<thead>
<tr>
<th>Membrane Type</th>
<th>Australian/New Zealand Standard Numbers</th>
<th>Standard Test Method</th>
<th>Max Water Absorption</th>
<th>Test Parameters</th>
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<tbody>
<tr>
<td>Australian/New Zealand Standards Wet area Membranes</td>
<td>AS/NZ 4858 - 2004 (Follow Method AS 3558.1)</td>
<td>AS 3558.1 - 1999 (Australian Standard Method for testing plastics and composite materials, sanitary plumbing fixtures. Method 1 (Determination of water absorption) characteristics</td>
<td>Suitability for use over Plywood = 10%</td>
<td>24hrs @ Room Temperature</td>
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<td>Australian/New Zealand Standards Wet area Membranes</td>
<td>AS/NZ 4858 - 2004 (Follow Method AS 3558.1)</td>
<td>ASTM E96 / M for water vapour transmission rate</td>
<td>if &gt;8g / m² / day, must be &lt;10% water absorption for plywood</td>
<td>32.3°C @ 54% humidity Procedure C</td>
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<tr>
<td>European/British Standards for coatings for exterior masonry and concrete</td>
<td>EN1062 - 1 Classification by liquid-water transmission rate, Class III low.</td>
<td>EN1062 - 1 Test Method</td>
<td>Class III low &lt;0.1 kg / m² / 0.5 Hour</td>
<td>24hrs @ Room Temperature in Tap Water</td>
</tr>
</tbody>
</table>
Will a particular membrane waterproof a structure?

- To clarify this question, we decided to test a number of membrane samples by ASTM methods, using water immersion at 23°C and 50°C, until they reached equilibrium, and stopped absorbing water.

- This data is presented for eleven unnamed membranes, all available in the NZ market, and all tested for 30 days as follows:
  a) 23°C water immersion results
  b) 50°C water immersion results

- To help our understanding of this data, we have also included two Standard specifications for each test temperature, labeled S.

- We have also included two particular membrane samples which are useful as benchmarks, and were referred to earlier in the multiple Auckland buildings:
  a) A torch-on APP modified bitumen sheeting membrane, which we have never seen implicated in a generic water absorption membrane failure, labeled 10.
  b) A liquid applied bitumen modified urethane membrane, which is a known commercial hazard, labeled 9.

The membrane families are color coded for ease of understanding into:

a) Red for acrylics (1-6)
   b) Blue for urethanes (7-8)
   c) Black for modified bitumen (9-11)
Percentage water absorption of various membranes immersed in tap water at 23°C over 30 Days
Percentage water absorption of various membranes immersed in tap water at 50°C over 30 Days

- 1 Liquid Applied Acrylics
  - Camellia with Non Reinforcing
- 2 Liquid Applied Acrylics
  - Camellia with Short Strand Synthetic fibre Reinforcing
- 3 Liquid Applied Acrylics
  - Camellia with Short Strand Synthetic fibre Reinforcing
- 4 Liquid Applied Acrylics
  - Camellia with Short Strand Synthetic fibre Reinforcing
- 5 Liquid Applied Acrylics
  - Camellia with Short Strand Synthetic fibre Reinforcing
- 6 Liquid Applied Acrylics
  - Camellia with Non Woven Glass fibre Reinforced
- 7 Liquid Applied Urethane with No Reinforcing
- 8 Liquid Applied Urethane with No Reinforcing
- 9 Liquid Applied Urethane modified Bitumen with No Reinforcing
- 10 Torch on coating of SFP modified Bitumen with non woven Polyester Reinforcing
- 11 Self Adhesive Sheet of Rubberised Bitumen with Synthetic Fabric Reinforcing

Maximum water absorption accepted by standard ASTM D522-08
Polypropylene Modified Bituminous (Sheet Water-proof)

Maximum water absorption accepted by standard ASTM D5035-97a
Chlorinated Natural Polyethylene
Conclusions from test data

• We are firmly of the view that the NZ Building Code for Durability B2 approach is correct, and that waterproofness of an occupied building is a non-negotiable requirement that must be achieved.

• Consequently any membrane that serves a waterproofing function should not absorb more than 10% water at equilibrium. From the data presented, this equilibrium will be effectively established after 7 days immersion in water at 50°C, if less than 10% water is absorbed.

Other significant influences on waterproofing membrane success or failure

• From this data, it is clear that higher water immersion temperatures increase a membrane’s water absorption.

• Water absorption is established as a reversible process, so periods of drying will reduce water absorption, if only temporarily. Hence design improvements by:

  a) Provide an air gap above the membrane, as capillary action will keep a membrane constantly wet when in contact with a wear surface. This effectively outlaws the long standing method of direct sticking tiles to waterproofing membranes.

  b) Note ACC requirements for deck membrane access, a good call for a different reason.

  c) Ensuring no ponding.

  d) Maximizing falls, although Canada reports some failures on vertical surfaces?

  e) Choose a membrane with the lowest possible water absorption- ask to see water absorption data for that membrane!!!

• This strikes directly at the use of Bentonite membranes for tanking purposes, as they are highly water absorbent/desorbent. Drying conditions cause shrinkage, and failure by cracking, which does not heal reliably on rewetting.

• Protect membranes from UV light, which generally causes membrane surface breakdown.

• Check compatibility of the membrane with all the components that it will be exposed to. Example: Peel and stick membranes on LOSP treated framing timber?
And finally a thoughtful quote from the developer of modern quality systems, Dr Edwards Deming:

Don’t test the product- control the process