Durability Of Acrylic Waterproofing Membranes For Wet Areas

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Summary: In recent years, environmental pressures have resulted in increasing use of acrylics as waterproofing membranes. A major barrier to the use of these materials has been concerns about the service life that they will achieve. CSIRO Appraisals has developed a testing protocol for the evaluation of the long-term serviceability of these materials, and this paper discusses the testing protocol and the interpretation of the results, including how they can be used to determine the suitability of a membrane to protect different substrates. As acrylic waterproofing membranes have a wide variation in their water vapour transmission rate, the paper includes the additional testing required to determine the suitability for use over substrates according to the water vapour transmission rate.

Membrane systems have a large variation in their elongation at break, thus requiring different types of bond breakers to cater for these varying elastic properties and thereby protect the membrane from fracturing at substrate discontinuities. The different types of bond breakers are discussed, along with their compatibility to the different elastic properties of the membrane systems.

The effect of curing time on acrylics is vital to the performance of the system. The lack of a sufficient curing time is one of the problems that has been highlighted in field monitoring that CSIRO Appraisals undertakes on membrane systems. The results from laboratory testing and those found in the field monitoring are discussed.

The test method developed by CSIRO Appraisals is currently being adopted by Standards Australia for inclusion in the Building Code of Australia as a deemed-to-satisfy requirement for the physical properties of membranes used in wet areas of buildings.

Keywords: Waterproofing membranes, wet areas, Building Code of Australia, bond breakers.

1. INTRODUCTION

In recent years, environmental pressures have resulted in increasing use of acrylic-based materials for waterproofing membranes. A major barrier to the use of these membranes has been concerns about whether they will have an acceptable service life. CSIRO Appraisals has developed a testing protocol for the evaluation of the long-term serviceability of these materials when used for waterproofing wet areas. This paper disucsses the testing protocol and interpretation of the results, including how they can be used to determine the suitability of a membrane to protect different substrate materials.

The testing program has been developed as a result of CSIRO Appraisals needing to evaluate membranes for fitness for purpose, so the four membranes referenced throughout the paper are required to be kept confidential and will be referred to as A, B, C and D.

2. CHEMICAL RESISTANCE

The practice in Australia is to lay the waterproofing membrane under the tile bed. Thus, the membrane needs to function below a saturated tile bed. Solutions of chemicals used within the wet area can find their way to the surface of the membrane. A critical position where waterproofing membranes need to function is at the wall/floor junction, where the membranes need

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to cater for the movements that occur between the changes of substrates. Leakage at this location can result in water penetration into adjoining rooms, which means non-compliance with the Building Code of Australia. Even though the recommended tile-laying procedure is for the floor tiles to be laid under the wall tiles, in practice it is often the opposite, with the floor tiles abutting the wall tiles. While both methods will allow cleaning chemicals to track down to the membrane, this non-preferred tile-laying method makes the membrane more vulnerable to attack from cleaning chemicals. With the floor tiles abutting the wall tiles, cleaning chemicals that run down the wall tiles will enter the vertical crack that, with the passage of time, develops between the wall and floor tiles. Thus, it is imperative that the waterproofing membranes used in wet areas have resistance to the commonly used cleaning chemicals. The most commonly used mould growth chemical is sodium hypochlorite (bleach), while detergents are also used in the cleaning process and so resistance to detergent is also required. As the tile bed is fully saturated, long-term resistance to a head of water above the membrane is also critical.

The testing method developed uses deionised water for the water immersion testing. For all three testing exposures, 12 specimens are fully immersed in a sealed container with 600 ml of solution. Three specimens are tested at each of the periods of exposure, and there are three spare specimens in case of any breakages before testing. The specimens are tested in tension to the testing method given in Australian Standard AS 1145–2001 (Standards Australia 2001) using a type 5 specimen. The specimens need to include reinforcement where this is part of the membrane.

The testing method uses more concentrated solutions of the chemicals than would normally be applied when cleaning. For sodium hypochlorite a 2% solution is used – about three times more concentrated than is commonly used in mould-removal solutions. For the detergent, a 30% solution of an industrial-grade detergent is used. The use of more concentrated solutions is somewhat similar to the testing of materials used externally where, with accelerated weathering, they are exposed to high levels of UV in short-term testing to give long-term predictions of performance. However, for the chemical testing, it is expected that significant changes in properties will occur. What needs to be determined using this accelerated exposure is whether the membrane will lose its integrity to the point where it will fail to provide an acceptable service life.

What is an acceptable service life for these membranes? They are installed under an expensive tile or stone finish, and thus they need to have a service life equal to at least that of their expensive covering. No one really expects to replace the tiles or stone covering, that can cost more than 10 times that of the waterproofing, because of a membrane failure. While the tiles or stone covering could have a service life greater than 25 years, in reality by this time it is most likely that they would have been replaced to bring them into a more fashionable scheme. During a renovation when the covering is replaced, the membrane would be damaged, and would also need to be replaced. Bathrooms are one of the more personal areas of the dwelling and when there is a change of ownership, the bathroom is usually one of the first rooms to be renovated. Real estate figures give the average ownership of a dwelling in Australia's capital cities as less than 10 years. Thus, a 25-year service life for the membrane would easily meet a 95% confidence limit that it would be replaced within this time.

Initially, it was thought that testing at 7, 14 and 28 days would give all the data required. But as can be seen in Fig. 1, there is a reversal of the trend sometimes after 7 days and, to get a reliable result, the testing was extended to 56 days. In these tensile test figures, the ordinate is a comparison of the exposure result to that of the control for the sample under test. Using this ratio enables both elongation at break and tensile strength to be graphed on the one plot for comparison. In other figures, it enables direct comparisons of the relative performance of different membranes. In the initial development of the testing method, the 14-day testing increment was continued. However, as the method was to become a standard test, and costs needed to be contained, the test exposure times finally chosen were 7, 28 and 56 days. The 7-day exposure was used in preference to 14, as it will show early if a membrane has little chance of meeting the test requirements.

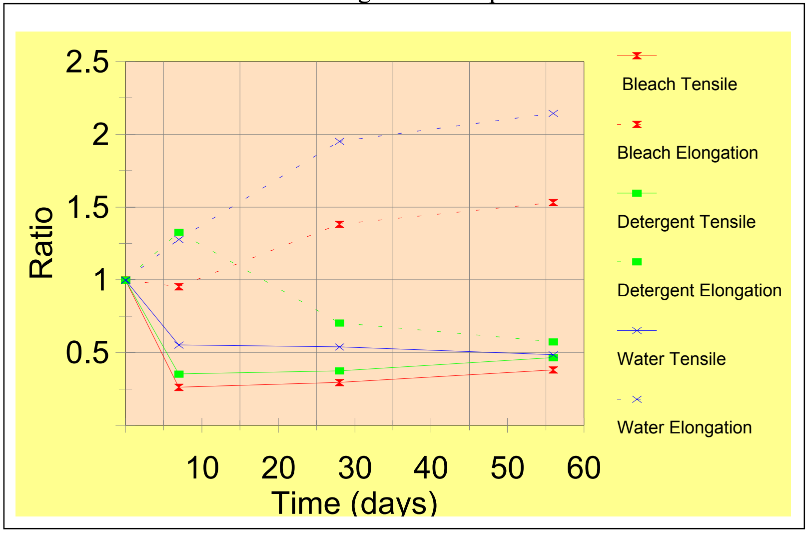

Figure 1. Tensile strength and elongation at break results for membrane C

For the membrane to remain serviceable, it is important that it maintains enough flexibility to enable it to accommodate any movements that occur over changes in substrates that it bridges. Thus, it is elongation at break that is the most important

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property to be maintained. Often, the membrane softens during exposure to both water and bleach, as happened with membrane C (Fig. 1). For both of these exposures, membrane C has had an increase in elongation at break with a corresponding reduction in the tensile strength. After the initial 7-day exposure to the detergent, this is not the case, with a loss of both elongation at break and tensile strength. A loss in both properties indicates that the membrane material is suffering some fundamental loss of its intrinsic property. In the case of membrane C, there is not sufficient loss under exposure to detergent to be of concern, with it keeping just over 50% of its initial elongation.

The results for membrane A are shown in Fig. 2. These are not nearly as convincing, with the continual loss of both properties on exposure to both bleach and detergent continuing significantly between the 28- and 56-day results.

The results for elongation at break for all four membranes exposed to detergent are given in Fig. 3. Membrane B shows a significant change in the results between 7 days and both 28 and 56 days. This reversal was observed for many of the membranes that we have tested and is an example of why extending the testing out to 56 days, rather than finishing at 28 days as originally proposed, is warranted. The results for tensile strength for all four membranes exposed to detergent are shown in Fig. 4. The rapid loss of both tensile strength and elongation at break for membrane B at 7 days, having lost over 50% of its elongation at break and about 50% of its tensile strength, would indicate that this membrane was unlikely to meet its long-term durability requirement. However, by 56 days it had virtually recovered all of it elongation at break while still retaining 25% of its tensile strength. Based on these longer exposure results, it was considered to be a satisfactory membrane for use in wet areas. The testing, as mentioned earlier, is using more concentrated solutions to show long-term effects to exposure to less concentrated solutions likely to be experienced in normal usage.

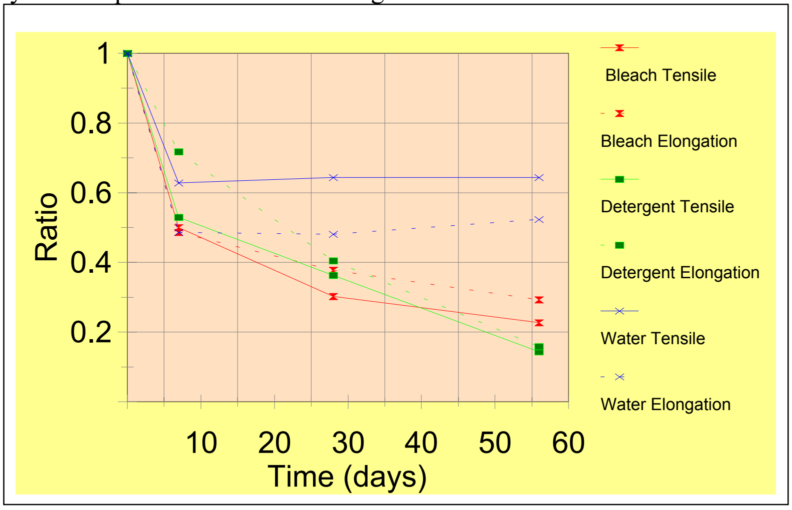

Figure 2. Tensile strength and elongation at break results for membrane A

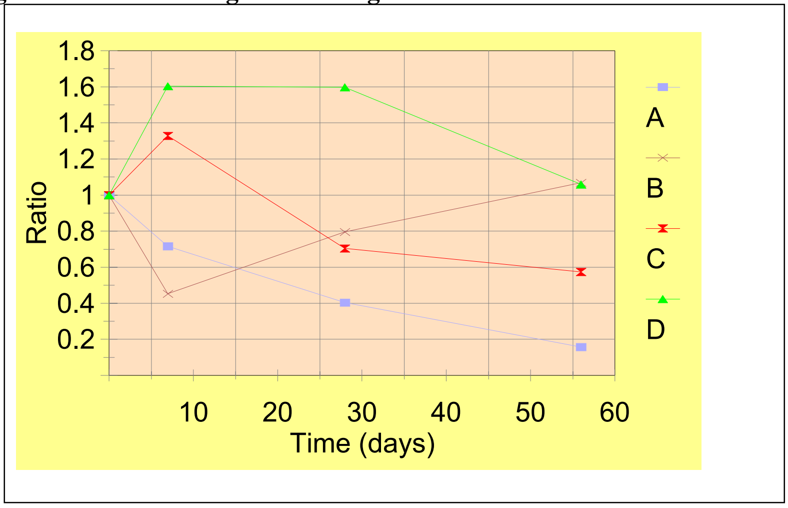

Figure 3. Elongation at break for all four membranes on exposure to detergent

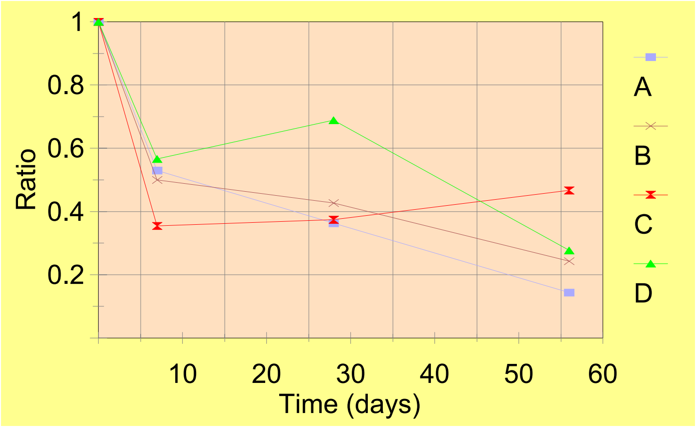

Figure 4. Tensile strength for all four membranes after exposure to detergent

The pass/fail criteria finally chosen was to require that at least 40% of the elongation at break needs to be retained after 56 days exposure. It was considered that if the specimen had retained sufficient strength to enable it to be tested, then it had retained sufficient tensile strength. In practice, with correct specification of bond relief over areas where the membrane is expected to be stretched, the membrane will only fail if it is stretched beyond its elastic limit, as given by its elongation at break property. The results for all four membranes for their elongation at break after exposure to bleach is given in Fig. 5, and after exposure to water in Fig. 6. Thus, membranes B and C passed the test criteria while A and D failed to do so.

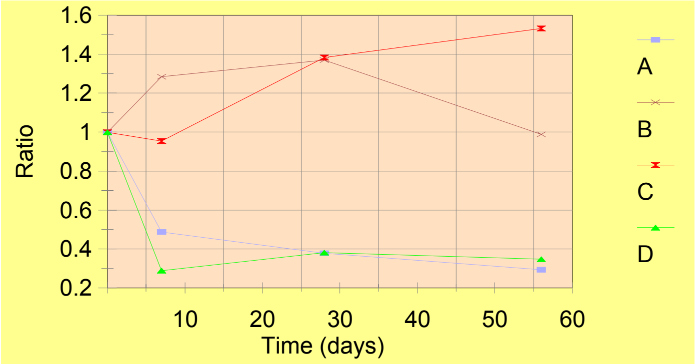

Figure 5. Elongation at break for all four membranes after exposure to bleach

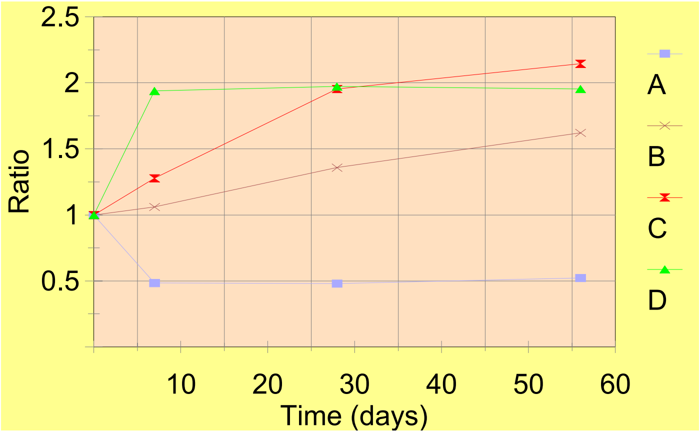

Figure 6. Elongation at break for all four membranes after water exposure

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Some membranes that we have received for testing reach a stage of collapse at 7 days exposure and are not even able to be tested as shown in Fig. 7. The three on the left were exposed to bleach, while the one on the right was exposed to detergent. The worrying fact is that these were membranes that had been marketed for some time before they were tested for durability.

Figure 7. Tensile test specimens that failed before they could be tested

3. FATIGUE FRACTURES

The membrane will have to continue to bridge over any cracks and gaps between changes in substrates, while these gaps have potential for ongoing movements with changes in temperature and/or moisture content. Martin (1977) described a test for membranes that have high elongation at break. This method can be used for unreinforced acrylic membranes that have elongations at break well over 300%. However, when they have some reinforcement, or are a combination of cement and acrylic resin, their elongation at break can be well below the elongation required by the test as described by Martin. What we have done is to modify the Martin method to cycle the membrane over 75% of its elongation at break rather than the 200% as given in Martin's method. The specimen includes any reinforcement that is used. This modification has developed a satisfactory method to check that the membranes do not fatigue fracture where they bridge over moving gaps.

To make sure that the membrane is kept within the movement it can accommodate, there is a need to give bond relief from the substrate at points of discontinuity subject to movement. Three classifications of membranes have been defined.

Class 1 membranes are those that have an elongation at break of less than 65%. Due to their low extension before they fracture, these need a bond breaker that takes up the movement by bending the membrane rather than stretching it. The bond breaker should be a backing rod utilised to place an initial curve in the membrane. The rod allows the membrane to straighten when a gap widens or become more curved to tolerate a shortening of the gap. Figure 8 shows this type of bond breaker.

Class 2 membranes are those that have an elongation at break between 65% and 200%. These need a bond breaker with a suitable unbonded length to allow the membrane to stretch to accommodate the movement. The width of the tape is determined so that the membrane will not go beyond 65% of its elongation at break to take up the movement. Figure 9 shows this type of bond breaker.

Class 3 membranes are those that have an elongation at break greater than 200%. These hardly need a bond breaker at all, but any bond relief will lower the risk of failure. A fillet of sealant will give all the bond relief that is required. Figure 10 shows this type of bond breaker.

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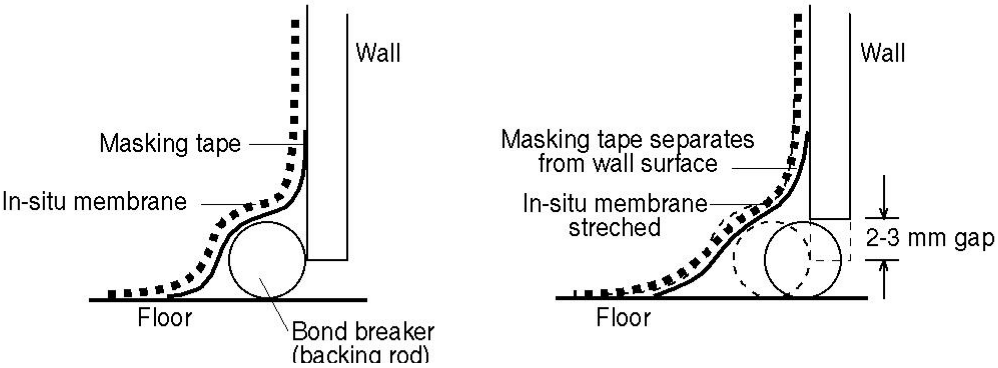

Figure 8. Bond breaker for a Class 1 membrane

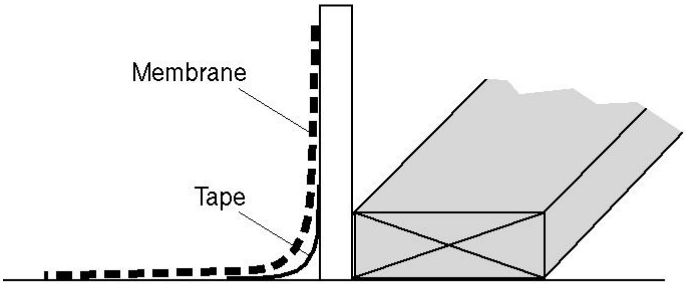

Figure 9. Tape bond breaker for a Class 2 membrane

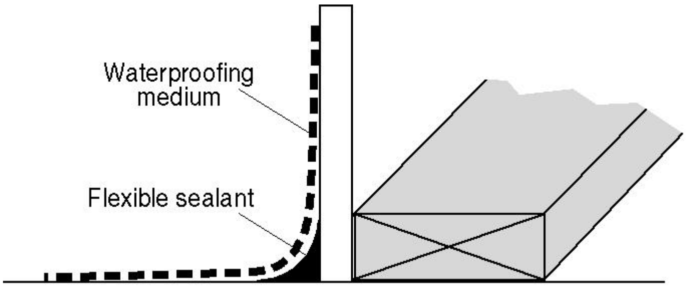

Figure 10. Flexible sealant bond breaker for use with a Class 3 membrane

4. SUBSTRATE PROTECTION

Acrylic membranes have high water vapour transmission rates. The actual rate for any membrane depends on its formulation and can be as low as 2 g/m²/24 hr to in excess of 60 g/m²/24 hr. For those at the upper end there is potential for moisture to build up in the substrate under the membrane by water vapour transmission through the membrane. To ensure that membranes do not cause this problem to the substrate, especially those subject to moisture damage, a ponding test was designed. In the test, a 600 mm square tray of the membrane is formed over a particleboard floor substrate which has a butt joint running across the middle of the tray. Insulated probes are installed from the underside of the particleboard to measure the moisture content 1 mm under the membrane by an electrical moisture meter. The probes are located at set distances each side of the butt joint in the particleboard. After the tray has fully cured, it is flooded with water to a depth of 25 mm and the moisture content recorded until it has stabilised. For the first five days, daily readings are taken, and thereafter twice a week (3 and 4 days between readings). Simultaneous readings are also taken for a control piece of particleboard, which is placed beside the test tray. Both the test tray and the control are located in standard laboratory conditions of 23°C and 50% RH. Figure 11 shows some of the results to date recorded from this test. Clearly the 66 g/m²/24 hr material was showing a real problem, with an increase in moisture content in the particleboard of nearly 30%, while the 2 g/m²/24 hr material had little increase and was of no concern.

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It is recommended that shower recess membranes not be used directly on top of particleboard where test results give a moisture content increase of 10% or greater than that of the control.

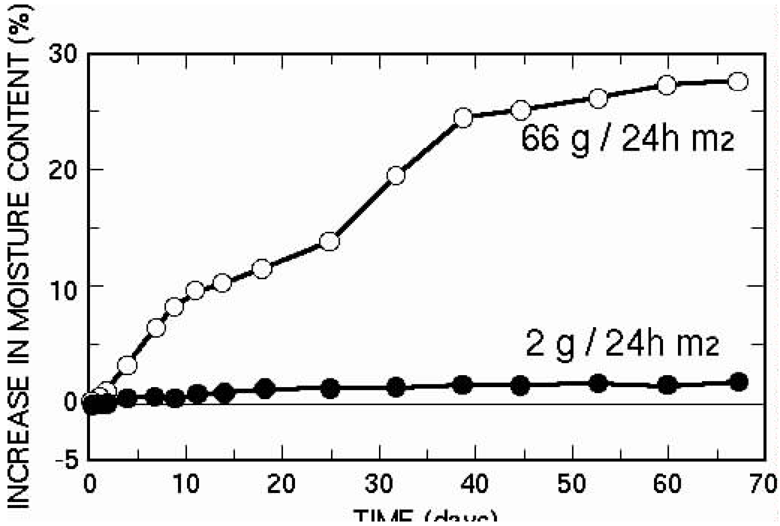

Figure 11. Moisture increase in particleboard flooring under different membranes

CSIRO Appraisals has collected enough data to know that if the water vapour transmission is 8 g/m²/24 hr or less, then the membrane can be used directly over particleboard under a shower. This limit may be raised in the future when more data is available for membranes above the current limit of 8 g/m²/24 hr.

5. CURE TIME

One of the main causes of failures of acrylic membranes that CSIRO Appraisals has found in field inspections is inadequate curing before the membranes are covered. Acrylics rely on water loss to cure, and when used in wet areas, such as small and poorly vented rooms (e.g. en suites), it can take over 7 days for a straight acrylic to cure in winter conditions. If covered before they are allowed to cure fully, they can re-emulsify where they are continually wet, as is the case when used in shower recesses. To retain the elastic properties, one either needs to wait for a full acrylic to cure or use heating and airflow to speed up curing. We stress in all our appraisal reports that slow curing has to be allowed for, but still we occasionally find installations where they have been covered without being cured.

To shorten the cure time, there are some two-part formulations consisting of a liquid acrylic mixed together with a cement-based powder. These will cure within 24 hours, but they loose the high elongation that is available with a full acrylic formulation.

One of the main problems with the cement–acrylic formulations is that, due to their thick creamy nature, they can be applied too thick, which results in drying crazing. This is caused by the skin curing before the body of the membrane cures.

Straight acrylics used without reinforcement can be applied too thinly. Some inspections have found a thickness of less than 0.1 mm where an unreinforced acrylic has been used. The usual specified thickness is about 1 mm.

6. CONCLUSION

CSIRO Appraisals has developed a testing program that has a proven record in being able to successfully evaluate the suitability of acrylic membranes for use in the waterproofing of wet areas within buildings. The testing program is currently being adopted into an Australian Standard. Several membranes have been found to be unsuitable for use in wet areas. We are now in a position to make sure any membrane that is proposed will give an acceptable service life.

7. References

1 Standards Australia 2001, AS 1145–2001 Determination of Tensile Properties of Plastics Materials, Standards Australia, Sydney.

2 Martin, K. G. 1977, ‘A note on roof membrane detail at movement joints’, RILEM 20 MIM Meeting, Paris, France, January 1977.

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