



Tiling at the Deep End...Revisited

by Peter Hartog

In August 2000 *Tile Today* published an article by Peter Hartog titled *Tiling at the Deep End*. The author cautioned that some mesh-backed glass mosaic tiles then being marketed in Australia were unsuitable for use in swimming pools, spa pools, fountains and similar conditions of immersion. From several well-documented investigations of tiling failures in pools in the suburbs of Sydney and in Southeast Asia, he concluded that mosaic tile producers in some developing countries were reducing manufacturing costs by haphazardly using inappropriate glues, such as dilute polyvinyl acetate (PVA), to mount tiles on backing mesh. These glues interfere with contact and bonding between mosaic tiles and tiling adhesives. When immersed in water, the glues soften and may swell as they absorb moisture. Tiles eventually fall from the walls. This may occur two or three years after tiling, but in one of the pools discussed in *Tiling at The Deep End*, hundreds of tiles detached during construction, before joints could be grouted.

Tiling at the Deep End was immediately controversial. No-one offered to refute the author's opinions, but a few tile merchants privately criticized publication of the article in a magazine that usually extols the industry's successes. In a later issue of *Tile Today*, Mr Hartog responded that while it may be wise to learn from one's mistakes, it is much wiser – and usually less expensive – to learn from someone else's mistakes.

Tiling at the Deep End soon became the most frequently requested back issue of *Tile Today*. A protracted and recently concluded claim before the District Court in Sydney has again focused attention on the potential shortcomings of backing-mesh glues applied to mosaic tiles destined for use in swimming pools. Peter Hartog served as an expert witness for the buyer of thousands of sheets of defective glass mosaic tiles. In revisiting *Tiling at the Deep End*, he recounts the exchange of successively more lengthy expert reports over a period of 20 months, the five-day hearing in which the tiles were finally judged to be unfit for use in conditions of immersion, and some of the lessons that may yet be learned.

The Whole Sorry Saga

In 2001 a long-established tile wholesaler based in Sydney received samples of mesh-mounted glass mosaic tiles and a brochure illustrating their use in swimming pools. For commercial reasons, the importer of the tiles did not want to disclose their ultimate source but it was generally understood that they were manufactured in southern China. Cardboard packaging identified the contents simply as glass tiles. The wholesaler ordered several thousand square metres. He anticipated the market for the tiles would be retailers supplying builders and owners of residential swimming pools.

Soon after taking delivery of the consignment, the wholesaler noticed that translucent bubble-filled glue, attaching tiles to sheets of nylon backing mesh, appeared to have been applied haphazardly and in excess. He immediately sought from the importer (1) written confirmation that the tiles were suitable for use in conditions of immersion, and (2) the importer's or the manufacturer's written instructions for fixing the tiles in swimming pools. In correspondence to the importer, he explained his misgivings:

There is one area of concern, and that is the adhesive on the back of the glass tiles that adheres the mesh to the tile. In our opinion they [the manufacturer] have used too much glue. The proper method of adhesion is to apply the glue to the mesh and not to the back of the tile. The largest potential problem is that if there is too much glue on the back of the tile, it is very hard to get adhesive to then stick to the glass part of the tile, and if it does not the tiles will fall off the swimming pool wall.

As you have had some experience in swimming pool glass mosaic tiles, I naturally take it that the tiles you are selling to us will be trouble-free to the tilers and the owners. Please confirm this.

...Please confirm to me in writing that the glass mosaics we have purchased are suitable for swimming pools and wet areas installation.

Despite renewed requests, no written response was received from the importer. The wholesaler declined to pay for the tiles without written assurance that they were fit for the purpose anticipated and discussed when he placed his order. He asked that the tiles be removed from his company's warehouse and offered to compensate the importer for the cancelled transaction. That offer, which in retrospect appears to have been extraordinarily generous, was curtly refused. A dispute developed, with the importer demanding full payment and the wholesaler responding that he would not complete the transaction without the supplier's confirmation or reliable evidence that the tiles were fit for the purpose for which they had been marketed and purchased. The matter was eventually set down for hearing before the NSW District Court in Sydney.

In February 2004 the wholesaler requested that Davco Technical Services and Building Diagnostics Asia Pacific (BDAP) separately examine samples of the contentious glass mosaic tiles and comment on whether they were suitable for use in swimming pools. Both Davco and BDAP immersed samples of tiles and attached nylon backing mesh, cut from 300 x 300 mm sheets, in cold water. Both observed that the brittle coating of clear glue soon absorbed water and changed to a soft weak

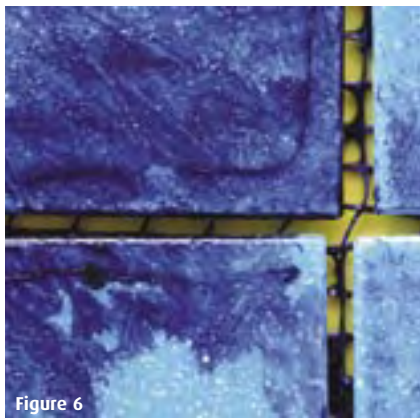
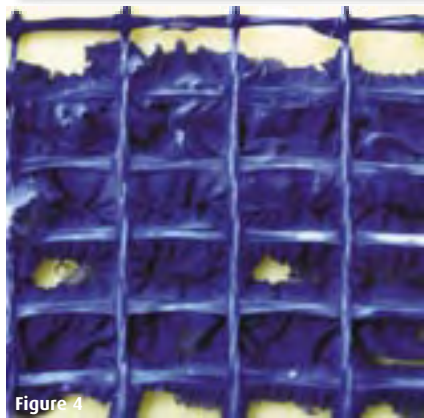
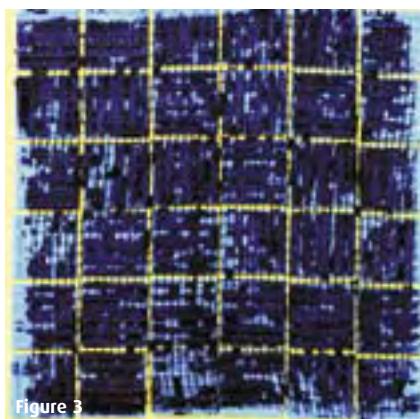
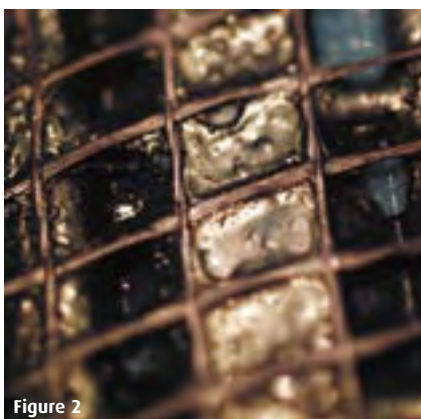
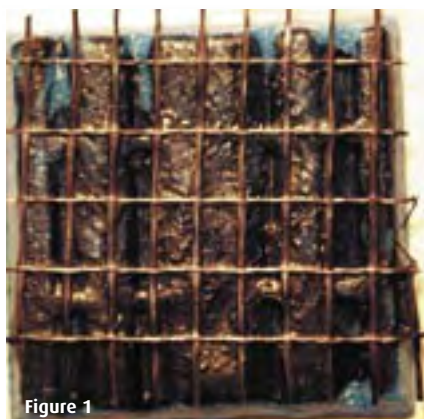


Figure 1. A 46 x 46 mm glass mosaic tile prepared for submission in evidence. The glycol-based black dye shows the spread of water-absorbing backing-mesh glue. Computer-assisted image analysis calculated that the mesh and its weak water-softening glue covers 96.83% of the rear surface of this tile. **Figure 2** A macrophotograph of the film black-dyed backing-mesh glue suspended over shallow grooves in the rear face of a tile. Craters, from burst bubbles of air entrained in the fluid glue, are clearly visible. **Figure 3** A sheet of 36 back-mounted glass mosaic tiles with backing mesh glue stained black. According to the first report of the tile importer's expert witnesses, the maximum coverage of glue and mesh on the rear surfaces of tiles in their "random" sample was 34.9%. **Figure 4** A macrophotograph of a stained and largely intact film of water-absorbing backing-mesh glue suspended between mesh fibres. With care, the glue and mesh can be peeled from the rear face of glass tiles after 24 hours soaking in cold water. These films are often so thin that they cannot reliably be detected without dye-staining. **Figure 5** Tile adhesive revealed by removal of a loose mosaic tile. Flakey white residues of the backing-mesh glue remain on the flattened surface of the adhesive layer. The glue has prevented contact and bonding between the missing tile and adhesive paste. **Figure 6** Residues of dye-stained backing-mesh glue smeared across the front faces of tiles. The clear fluid glue was sometimes applied in such excess that it flowed between joints, across front faces of tiles and onto cardboard packaging.

whitish translucent gel. When samples were suspended vertically in still tapwater, tiles fell away from the mesh under their own weight in less than 24 hours. Davco and BDAP recorded that the glue was spread haphazardly and coated in excess of 50% of the rear faces of some tiles, thereby preventing direct contact between glass and separately applied tiling adhesives. BDAP also immersed samples of tiles and mesh in a solution of sodium fluorescein, a strong yellow water-soluble dye, to accentuate the irregular spread of glue on the rear surfaces and mesh. In a two-page fax to the tile wholesaler, I estimated that the combination of glue and mesh averaged between 30% and 40% and exceeded 70% on isolated tiles. The reports of Davco and BDAP were forwarded to the tile importer. Given that the tiles were conspicuously defective, in that the glue was both unsuitable and excessive, I assumed that the dispute would be quickly resolved. I doubt that any party then expected the matter would eventually occupy more than a week of the District Court's time, involve questionable expert evidence from professorial and post-doctoral researchers in materials science and incur legal costs far greater than the value of the tiles.

In mid-2004, in response to the brief reports of Davco and BDAP, the tile importer submitted a report prepared by two members of the staff of an academic institution in New South Wales long known for preparation of expert evidence in litigation, arbitration, mediation and so on. The report tabled the academics' marvelously precise measurements of the combined coverage of mesh and glue on 55 tiles taken from a purportedly random sample of five sheets supplied by their client, the tile importer. Average coverage was claimed to be 26% with a standard deviation of +/- 5%. The maximum coverage was reported to be 34.9%. The report argued that Australian Standard AS3958.1, specifically Clause 5.6.4, requires a minimum of 65% contact between tiles and tiling adhesive. Its authors therefore concluded that any tiles with backing-mesh glue coverage of less than 35% are

acceptable to *manufacturer's generally*. These manufacturers were not identified. The report concluded that the importer's glass mosaic tiles complied with the requirements of the Australian Standard and that there was *no barrier* to their satisfactory use in swimming pools. Its authors noted, in passing, that tiles in their sample had not been *observed* to fall away from the backing mesh when suspended vertically in water.

This first exchange set off a series of successively more elaborate and discursive reports and responses that stretched over 20 months and ultimately ran to hundreds of pages. Indeed, in delivering his findings in October 2005, the District Court judge noted that the importer's expert witness reports had needlessly *consumed a forest of paper*.^{NOTE 1}

BDAP's first response in August 2004 emphasized that even in the limited context of the cited sentence in Clause 5.6.4 of AS 3958.1:1991, namely internal wall tiling in dry conditions, backing-mesh glue contamination of 35% of the rear surface area would be regarded as excessive. To achieve adhesive contact coverage across all the 65% of the tile surface not contaminated by backing-mesh glue, installation would need to be close to perfect. More importantly, BDAP drew the importer's experts' attention to the simple and seemingly conspicuous reality that AS 3958.1:1991 does not apply to tiling in swimming pools and similar conditions of immersion. The *Preface* on Page 2 of the standard notes that:

Specialized applications such as swimming pools...are not considered.

On Page 4 Section 1 – *Scope and general* – advises that:

Recommendations for tiling in situations where there are specific functional or environmental requirements are provided in BS 5385 Part 4.

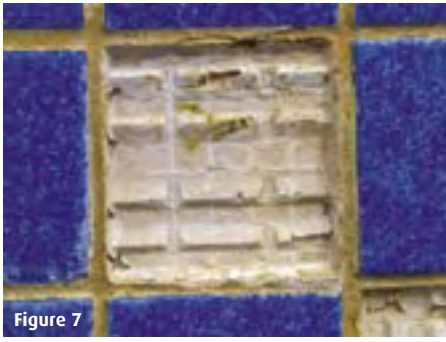


Figure 7



Figure 8

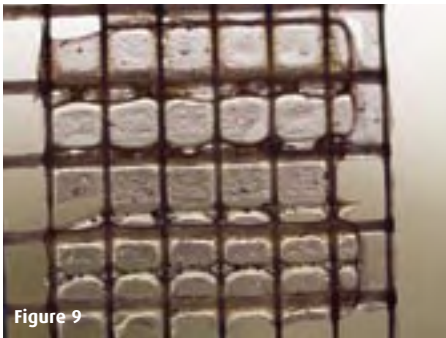


Figure 9

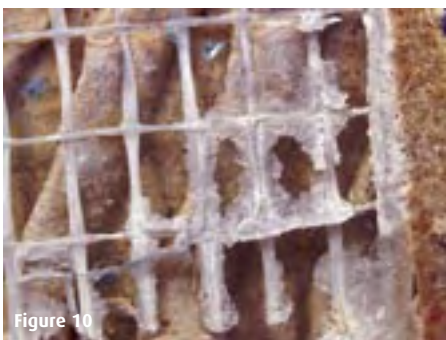


Figure 10

Figure 7 The missing mosaic tile has left a neat impression confirming that it was pressed firmly against the adhesive layer but did not achieve a bond. Parts of the dried film of backing-mesh glue remain on the surface where they prevented contact between the tile and adhesive.

Figure 8 The rear surface of the corresponding glass mosaic tile. Most of the grey and white encrustations on the surface of the tile consist of backing-mesh glue and cement salts absorbed when the glue was a gel.

Figure 9 An example of a translucent backing-mesh glue that stays firm and does not change colour when immersed in water. The film prevents initial contact between the mosaic tiles and adhesive. As water penetrates to the glue-line, the bond between glue and tile quickly decays.

Figure 10 Nylon backing mesh, flakes of dried glue and underlying tile adhesive revealed by removal of a loose tile from the top of the overflow wall in the pool at Daleys Point. There is no sign of a layer of irresistibly expanding sea salt crystals that supposedly forced tiles from the wall.

The 1991 Australian Standard thus refers - in the peculiar language of the Standards Association, it *references* - the corresponding British Standard, particularly Part 4, *Code of practice for ceramic tiling and mosaics in specific conditions*. These specific conditions include swimming pools and similar situations in which tiles are immersed in fresh and salt water. Part 1 (1995), Part 2 (1991) and Part 3 (1989) of the same British Standard observe that:

To facilitate ease of handling, mosaics are assembled in sheets, the individual tessera being glued face down to paper (paper-faced mosaics) or bed side down to synthetic mesh or small tabs.

It should be noted that paper-faced mosaics are preferable since they allow full contact to be achieved with the mortar or adhesive bed. When sheets are assembled by means of a backing mesh, it should be made of water-resistant synthetic fabric such as nylon, not cotton or paper.

For a mosaic which has been assembled with a backing fabric or tabs it is essential that:

- a) The fabric or tabs and their adhesive should not occupy more than 25% of the area of each tessera; the critical factor is the contact of the adhesive with the backs of the tesserae;
- b) The fabric or tabs and their adhesives should be water-resistant, should not weaken when exposed to moisture and should be compatible with the mortar or adhesive bed.

These parts of BS 5385 have been widely appreciated - and sometimes expediently overlooked - by many involved in the Australian tile, tiling and

offices of Standards Australia. Nevertheless, the British standard and its recommendations were neither acknowledged nor cited by the tile importer's expert witnesses until late in 2004 when an extract belatedly appeared as the seventh appendix to their penultimate evidentiary report. The authors explained that their copy of the relevant parts of BS 5385 had arrived at their workplace too late to be cited or even referred to within the main text of that report. They also declared that they were unsure whether the seemingly relevant paragraphs are intended to apply to mosaic tiles in swimming pools and conditions of immersion generally. I consider it is common sense that if a 25% limit on the area covered by *the fabric and [its] adhesive*, i.e. the mesh and its glue, applies to mosaic tiling on walls and floors generally, no less stringent limits should apply to the same tiling on walls and floors immersed in water - hot and cold, salt or fresh, chlorinated or unchlorinated, turbulent or still - in swimming pools.

By this stage of the dispute, the importer's experts were at least prepared to acknowledge that AS 3958.1:1991 does not apply to swimming pool tiling. Having measured, calculated, statistically analysed and tabulated the areas of glue and mesh, on 55 sample tiles, as percentages to two decimal places, they now argued that limits based on the proportion of the rear surface area contaminated by glue and mesh were both irrelevant and ill-conceived. Such limits were, in their opinion, *arbitrary, unsound and unscientific*: only case-by-case laboratory measurement of direct adhesive tensile strength of the backing-mesh glue, for instance after the 21 days of immersion required by AS 4992.2 (Int.)-2003, could demonstrate whether its softening eventually interfered with the long-term performance of mesh-mounted mosaic tiles.^{NOTE 2}

The importer's expert witnesses insisted that their own laboratory tests demonstrated that the glue on their client's glass mosaic tiles does not reduce adhesion, between the tiles and separately applied tiling adhesive, enough to be of concern. In direct evidence before the District Court in Sydney in October 2004, the chief author of the evidentiary reports prepared for the tile importer declared the unlabelled tiles to be *...the best I had ever seen*. He acknowledged that he had little experience investigating adhesion failures of glass mosaic tiles in swimming pools in Australia but recalled that four or five years earlier he had twice been called to Jakarta, by a loss assessor based in Kuala Lumpur, to investigate mosaic tiling failures in hotel swimming pools:

Each job required a trip there actually in Indonesia. I had to go there and I would spend one day on site and then I'd come back and do the testing that was involved, and that might have been one or two days, and then a couple of days to write the report.

Immediately after this impromptu evidence in late October 2004, the hearing was adjourned. By the time it resumed a year later, enquiries in Indonesia and Malaysia had cast doubt on the expert's recollection of his travels and work in Indonesia. This information was conveyed to the wholesaler's solicitor and barrister who decided to keep it in reserve. Meanwhile, the tile wholesaler learned of recurring adhesion failures of the importer's glass mosaic tiles on an overflow wall of a residential pool at Daleys Point on the NSW Central Coast. In July 2005 the Court granted a further adjournment to allow the experts to investigate this and other mosaic tiling defects on pools in suburban Sydney. Representatives of Davco and BDAP separately visited the Central Coast pool. They concluded that the water-sensitive backing-mesh glue hinders direct contact and bonding between tiles and tiling adhesive., as predicted when pristine samples were first tested early in 2004. Yet another report was produced and submitted to the Court. Most of the photographs illustrating this article were taken during BDAP's work on site at Daleys Point and in the laboratory between August and October 2005.

BDAP's final report provoked a three-volume response of more than 100

swimming pool industries. For more than a decade, copies of the document have been readily available for viewing and purchase at the

pages from the importer's experts. They attributed the Daleys Point pool's problems exclusively to expansive forces generated by salt sub-florescence and crystallization within the adhesive layer, between the backing-mesh glue and tiles and between the backing-mesh glue and trowelled tile adhesive. Their report contained the results of computer image analyses and measurements of backing-mesh glue coverage on 28 fluorescein-dyed tiles taken from five sheets. The data revealed that the maximum backing-mesh glue coverage measured on the importer's tiles has risen from 34.9% reported in mid-2004 to 62.8%. The average area of glue contamination in their sample had meanwhile increased from 26.1% (with a standard deviation of plus and minus 5%) to 39.4%. The most senior of the importer's experts offered a series of seemingly concluded opinions on geology, foundation and structural engineering, concrete construction, salt diffusion through concrete and much more. In cross-examination, most were shown to be expedient assumptions unsupported by observation or other enquiry.

More alarmingly, he wrote that adhesion failure of tiles does not constitute a defect until the number of distressed tiles exceeds 10% of the whole installation. Since fewer than 10% of the tiles in the Daleys Point and other affected pool had detached or become drummy, the tiling as a whole could not properly be regarded as faulty. This part of the experts' evidence relied on the hearsay opinion of the construction manager of a widely advertised east coast pool contractor. The contractor reportedly advises dissatisfied pool owners that consumer protection legislation in NSW does not recognize tiling as defective unless 10% or more of the tiles in an installation come loose or crack. The judge in the District Court vehemently rejected this imaginative interpretation of a single clause in the NSW State Government's consumer handbook *Guide to Standards and Tolerances for Home Builders and Renovators*. In due course, officers of the NSW Department of Fair Trading were alerted to the possibility that the pool contractor's warranty relies of the same 10% threshold to deflect complaints and to limit its liability under warranty.

The hearing resumed in the second week of October 2005. By that time, BDAP had dye-tested more than 1000 tiles from scores of sheets taken from separate cartons quarantined in the wholesaler's warehouse. We had also performed our own more accurate computer image analyses and measurements on 56 tiles from this sample. The maximum backing-mesh and glue coverage was found to be 96.83%; in other words, only 3.17% of the rear surface of the tile was available for direct contact and bonding between glass and tiling adhesive (see Fig. 1). The combination of glue and mesh covered more than 90% of the rear surfaces of 8 of the 56 tiles. The importer's experts had previously claimed that laboratory measurement of a small sample of tiles from five sheets is sufficient to identify the probable maximum glue-and-mesh coverage on all tiles in a consignment of thousands of sheets or in a larger production batch. By contrast, more than half of the sheets examined by BDAP included one or more tiles displaying combined glue-and-mesh coverages in excess of the 62.8% maximum inconspicuously tabled in the opposing experts' final report. More than half of the tiles on some sheets in BDAP's sample displayed glue-and-mesh coverages greater than the 34.9% initially claimed, by the importer's experts, to be the maximum likely to occur in the whole consignment of many pallets.

More than 450 of BDAP's dyed tiles and the corresponding computer-assisted measurements and images were mounted for presentation as evidence and brought to the Court in sealed boxes. As the hearing progressed, however, the tile wholesaler's legal team recognized that it would not be necessary to submit further physical evidence to refute the opposing expert's direct testimony and 197 pages of reports. The importer's senior expert stated confidently that he could see crystals of sea salt – sodium chloride – in BDAP's enlarged photographs of glue residues under loose mosaic tiles in the Daleys Point pool. The judge

preferred BDAP's evidence that these distinctively shaped crystals could not be detected on site using a 60 magnification field microscope, nor in the laboratory using a 400 magnification stereo microscope.

On the fourth day of the hearing, the judge remarked that the evidence of the tile importer's professorial expert witnesses demonstrated the adage that *Those who can, do. Those who can't, teach*. In a judgment read to the Court one day later, the judge dismissed that expert's evidence in its entirety as unsound, unscientific, tendentious and lacking in objectivity. In finding for the tile wholesaler, the judge accepted that the mesh-backed glass mosaic tiles at the core of this unnecessarily prolonged and extraordinarily expensive dispute are unsuitable for use in swimming pools, spa pools and similar conditions of immersion. He noted that in seeking to refute the same opinion, offered separately by Davco Technical Services and BDAP in March 2004, the tile importer's expert witnesses had, in the long run, effectively verified it. Their final measurement of a maximum glue-and-mesh coverage of 62.8% was close to BDAP's initial estimate of 70% but still fell far short of the maximum of 96.83% measured by our own computer image analyses of tiles from a sample of more than 1000.

In the course of the dispute, the importer's principal expert witness seems to have become convinced that some sort of conspiracy is afoot, among the members of Standards Australia's Committee BD44 and perhaps further afield, to drive mesh-mounted mosaic tiles, including the unlabelled glass mosaic tiles imported from China by his client, from the Australian market. Such speculation is febrile nonsense. The witness is not a member of the BD44 committee, has made no submissions to the committee (at least prior to the resolution of the dispute) and seems to have been previously unknown to all but one member of that committee. In the impressive CV appended to his evidentiary reports, he lists no relevant publications on ceramic tiling in swimming pools or elsewhere. In testimony before the Court in October 2004, he volunteered that his local experience investigating pool tiling failures was negligible and irrelevant. During the course of the dispute, however, he bought a subscription to *Tile Today* and back issues with articles on swimming pool tiling, notably *Tiling at the Deep End*. He also wrote to Richard Bowman, the chairman of Committee BD44, seeking information to assist in preparation of his own expert evidence. By citing Mr Bowman's responses in his evidentiary reports, the scientist inadvertently opened the way for his e-mail correspondence to the CSIRO be obtained under subpoena.

There is no conspiracy to disparage or proscribe mesh-mounted mosaic tiles generally, glass mosaic tiles specifically, mosaic tiles from a particular company, country or region, tiles of undisclosed origin, those within a particular price range and so on. There is, however, genuine concern that consumers at all levels may have limited recourse in the event of failures of unlabelled or "generic" tiles sold, without reliable assurances of fitness for specific purposes, by parties two, three or more times removed from distant and anonymous manufacturers.

Committee BD44 brings together representatives of tile and adhesive producers and importers, wholesalers, the tile-fixing industry, vocational training colleges, research institutes and the building design professions. The regular members of the committee, without exception, have reliable knowledge of instances of poor performance of mosaic tiles in swimming pools. They are aware that reported adhesion failures of mosaic tiles in pools, ponds, spas and fountains disproportionately involve back-mounted tiles with weak, unstable, incompatible and excessive backing-mesh glues.

Recognition of the link between weak backing-mesh glues and tiles failing in service is not new; some tile-fixers in Australia can still recall incidents in the 1960s when glass mosaic tiles were exported by low-cost manufacturers in Japan. The members of BD44 have merely expressed a sound preference supported by decades of feedback from

tiling industries in Australia, Britain, Europe and North America. The informative Appendix E of the revision of AS 3958.1 now explains that:

For swimming pools and other installations where frequent or constant immersion is expected, front-mounted mosaics are preferred. This is because the adhesive holding back-mounted mosaics can sometimes seriously interfere with the ability of the tile adhesive to bond to the back of the tile. It is strongly advised that the suitability of mesh-backed tiles for constantly wet applications be established prior to the commencement of tile application.

As I noted in *Tile Today* in 2000, the American Materials & Methods Standards Association alerted its members to the same problem in a bulletin on *Back-Mounted Ceramic Tiles* published in 1984:

In many cases, thin-bed adhesive bonded either to paper or a thin layer of water-soluble glue on the back of the tiles, with no contact made with the tiles themselves. Water eventually soaked through the Portland Cement grout joints and rewet the mounting glue sufficiently to break the bond and cause a failure.

...We strongly urge all ceramic mosaic tile manufacturers to clearly indicate on their cartons, in the cartons, or on each sheet of tile, whether or not their mounted tiles are suitable for use in swimming pools, exteriors, or other wet areas.

Michael Byrne is the author of *Setting Tile*, a popular handbook first published in the USA in 1995, and of a series of training videos. In *How to Install Mosaic Tiles*, an article in a recent issue of the *US Tile Magazine*, he writes:

Mounting is an important aspect of mosaic installation because the mounting may sometimes interfere with – and reduce – the adhesive bond between the mosaic bits and the setting bed. Because individual tiles on mosaic sheets are so small, practically any interference is disruptive.

Some tile adhesive manufacturers have lately set their own limits to surface contamination by mesh and mounting glue on mosaic tiles destined for use in conditions of immersion. Davco, for example, recommends a limit of 10%. Other manufacturers request samples of back-mounted mosaic tiles for project-by-project appraisal. Writers of standards and codes of practice have also addressed the issue, in part by urging manufacturers to be candid and explicit about the performance characteristics of their products. Under the heading *Mounted Tile*, the Tile Council of America's *Handbook for Ceramic Tile Installation* directs that:

Mounted tile assemblies shall have sufficient exposure to binding surfaces of the tile body to allow 80% coverage of the bond mortar in dry areas and 95% in wet areas.

Tile manufacturers must specify whether their assemblies are suitable for installation in swimming pools, on exteriors, and other wet area. Paper back-mounted mosaics are not recommended in wet areas.

Clause 2.2.2 of AS 3958.1:1991 similarly cautions:

There are several different types of mosaic tiles available in a variety of shapes and sizes, including glazed and unglazed ceramic mosaics and glass. To facilitate ease of handling, mosaic tiles are assembled as sheets, the separate pieces of tiles being glued either face side down to paper (paper-faced mosaics) or bedding side down to nylon adhesive strips or nylon fabric net (nylon-backed mosaics) or other suitable material.

...When sheets are backed with nylon strip, **[paper net]** nylon fabric net or similar materials, the backing will be embedded in the backing medium, i.e. mortar or adhesive. These forms of

sheeted mosaic tile may be precluded from use externally **[or in immersed conditions]** if the sheet backing adversely affects the development of adequate and permanent adhesion between the mosaic tile and the bedding medium. This situation can arise when –

- (a) the exposed areas of individual mosaic tiles are not sufficient to permit the bedding making contact over an adequate proportion of the area of each mosaic tile;
- (b) the strips of net or the glue used to bond them are of the types that will deteriorate in service or are not compatible with the bedding medium; and
- (c) the glue is spread onto the backs of the individual tiles instead of being confined to the strips or net. ^{NOTE 3}

NOTE: In the absence of any advice from the tile manufacturer, the exposed (glue and mesh-free) areas of individual tiles should be a minimum of 80%.

The words in bold above have been added to the recent revision of AS 3958.1 – *Guide to the installation of ceramic tiles*. Clause 2.2 of AS 3958.1 also recommends that:

...before selecting a particular system, the advice of the mosaic tile suppliers or fixing specialists should be obtained as to the appropriate fixing method and the suitability of a particular type of mosaic for a particular environment.

In November 2001, the tile wholesaler in the recent District Court dispute first asked the importer to confirm, or to forward the unidentified tile manufacturer's confirmation, that the mosaic tiles are suitable for use in swimming pools. The importer, however, declined to do so. Citing commercial reasons, it also refused to divulge the identity of the manufacturer in China until prevailed upon by its own expert witnesses three months before the final hearing in October 2005.

Under the Trade Practices Act, an importer of products from a manufacturer not operating in Australia is deemed to stand in place of the manufacturer. If an importer wishes to keep the origin of its goods confidential, it must bear the ultimate liability for poor performance of those goods. In this case, the importer (or its associated companies) produced a sales brochure illustrated with photographs of swimming pools but, for more than three years, it declined to endorse the tiles for that specific purpose. The source of the tiles appears to have been identified in the context of an affidavit, written in Chinese and incorporated in one of the experts' reports, in which a representative of the alleged manufacturer asserts, not to anyone's surprise, that he is unaware of complaints or accounts of defects wherever the tiles have been used in swimming pools. The judge in the District Court hearing rightly rejected this document as unverifiable hearsay based on a so-called argument from silence: *I know of no problems, therefore there are no problems*. The same line of reasoning was adopted from time to time by the importer's experts on swimming pool tiles: *We and the persons whose opinions we choose to quote know of no failures, therefore the performance of the tiles must be exemplary*.

It is difficult to estimate the incidence of adhesion failures of mosaic tiles in pools in Australia. Tile merchants are understandably reluctant to discuss defects and claims arising from them. The risks of escalating legal and expert witness costs have dissuaded complainants from pursuing seemingly legitimate claims through consumer tribunals and local courts. Magistrates and assessors are obliged to accept expert evidence if it is unchallenged. Some valid claims appear to have been dismissed on the basis of implausible but supposedly expert evidence adduced on behalf of tile suppliers by obliging colleagues. In the dispute at Cronulla, NSW, that prompted me to write *Tiling at the Deep End*, the pool owner received from the tile retailer a *without prejudice* offer to supply new tiles, although from a different source. When the

owner refused the offer, he received a letter from the retailer's self-styled *dispute resolution consultant*. This warned that the consultant had examined the complaint and already determined that it was without merit. It also announced that if the owner proceeded with a formal claim against the retailer, the consultant would give his expert opinion, the claim would inevitably be dismissed and the pool owner would end up paying all parties' legal costs. Similar threats have discouraged at least two claims by pool owners in Byron Bay in northern New South Wales. In the recent dispute, however, the tile importer and its expert witnesses denied knowledge of a single pertinent failure. This gave the unfortunate buyer of the tiles and his advisors – including this writer – an unprecedented incentive to make discreet enquiries around the country and beyond.

Between the preparation of brief written opinions by Davco and BDAP in February and March and the judge's decision in mid-October 2005, I learned of about 25 instances of defective mosaic tiling in swimming pools in New South Wales, Victoria and Queensland and others in Southeast Asia and Hong Kong. Several tile wholesalers and retailers, four reputable adhesive manufacturers, experienced tile-fixers, pool owners, the records of small claims courts and consumer tribunals and, perhaps uniquely, a NSW barrister with years of experience as a full-time tile-fixer, all confirmed the prevalence of adhesion failures of mosaic tiles, most commonly those mounted on backing mesh with haphazardly applied and water-sensitive glues. One major tile distributor, until recently a buyer and seller of unlabelled mesh-mounted glass mosaic tiles, wrote:

We confirm to you that we have had several bad technical and commercial experiences with these types of glass mosaics. They have failed to properly adhere to the sides and bottoms of pools. This has occurred because during the manufacturing process of putting the mesh together with the glass mosaic pieces they have used too much PVA glue which precludes the adhesive being able to get a permanent grip onto the glass mosaics and the substrate. At a later date the tiles simply fall off, or away from the pool. These problems have cost this company in excess of \$60,000 to rectify these pools. We will no longer purchase or use these types of glass mosaics due to their unsuitability...

Another distributor disclosed that it has received seven complaints of similar adhesion failures. The Australian office of an international tile adhesive manufacturer alerted me to an unrelated series of complaints and litigated claims arising from defects in mesh-mounted mosaic tiling in pools as far afield as Alice Springs. An experienced pool tiler operating in northern NSW and southern Queensland reported that his business and reputation had suffered incalculable damage after a small claims tribunal accepted unchallenged expert evidence, adduced on behalf of a tile distributor, that the *only possible explanation* for failure of mesh-mounted glass mosaic tiles in a swimming pool was the tiler's poor workmanship, in particular, allegedly excessive delay in pressing sheets of tiles into ribs of adhesive trowelled onto the pool's rendered shell. I suggest that an honest witness familiar with common techniques of mosaic tile-fixing in pools would appreciate that this explanation is highly improbable.

I have deliberately omitted the identities of the tile importer and its dogged expert witnesses in this account of their District Court debacle, as well as more details of the judge's pithy rejection of their collaborative evidence, in the hope that a sometimes vituperative debate can be depersonalized. Anyone interested in reading the minutiae of the overblown epic will sooner or later find their way to the published judgment without my help. Meanwhile, what has been learned in the five years since *Tile Today* published *Tiling at the Deep End*?

Formulation and selection of adhesive for tiling in swimming pools, spas, ponds, fountains and even on floors and walls occasionally

covered by standing water must assume that water will eventually penetrate grouted joints and saturate both the layer of adhesive and porous substrates such as cement render, screeds and concrete. The adhesive must therefore be water-resistant and dimensionally stable. That is nothing new. In back-mounted mosaic tiling, water will also reach the embedded backing mesh and glue which, ideally, should only coat and flow into bundles of fibres. That glue must also be water-resistant and dimensionally stable when wet.

Backing mesh does not contribute to tile adhesion in service, so its surface area – from both the diameter and proximity of separate fibres – should be no more than whatever is necessary to hold tiles together in sheets during handling and fixing. Dense meshes of fine bundled fibres merely risk entrapping excessive glue and allowing it to dry as thin bubble-like films suspended between fibres, as illustrated in the photographs below. BDAP's tests have demonstrated that films of glue only a few micrometres thick are enough to prevent contact and bonding between tile surfaces and compressed ribs of tiling adhesive.


Backing-mesh glue between strands of mesh and beyond the edges of a sheet of mesh serves no purpose other than to impede direct contact between the solid tile and adhesive. Glues should therefore be formulated and applied so that they cover the fibres and dry quickly without flowing away from or ponding within the mesh. The clear fluid glue on the tiles in the recent dispute appears to have been applied indiscriminately by dipping cut sheets of mesh in a bath of liquid or by flooding the mesh with a roller before lowering it onto grids of 46 x 46 mm tiles. The importer's experts argued that it is impossible to limit the spread of mesh and glue to the 25% recommended since 1989 by BS 5381 and the 20% now recommended in AS 3958.1, let alone to the lower percentages long specified by the Tile Council of America and adhesive manufacturers. Nevertheless, one leading mosaic tile manufacturer has already advised *Tile Today* that it has no difficulty conforming to the 20% limit. BDAP holds mosaic tile samples with single central spots and crosses of water-resistant glue that occupies less than 10% of the rear surface area.

In *Tiling at the Deep End* I concentrated on backing-mesh glues which swell as they become wet at the surface and then slowly absorb water throughout their thickness. In practice, some water-sensitive backing-mesh glues known to cause adhesion failures in pools and spas do not swell noticeably. Some may not swell at all. They simply change from a clear brittle film to a weak translucent or opaque gel that slumps or falls apart when gently probed. Moreover, some unsuitable backing-mesh glues do not soften when wet. They remain relatively stiff, do not change in opacity and still fail to bond permanently to both tiles and tile adhesives in the presence of water. Thus there seems to be three categories of glues to avoid:

1. Glues that soften without noticeable swelling as they absorb water. These are usually clear when dry and white when immersed, similar to PVA-based wood glues. The softened material tends to remain on both the mesh and tile when the two are pulled apart after a few hours in water. With care, very thin films of these glues and embedded mesh can often be peeled away intact.
2. Glues that soften and swell to a gel that eventually forces tiles apart and away from the substrate. When sample tiles and mesh are separated after 24 or more hours in water, the gel tends to fall apart in small pieces rather than stay attached to the mesh. The glue on defective tiles in the residential pool at Cronulla, NSW, illustrated in *Tiling at the Deep End*, swelled so much that it extruded from joints.
3. Glues that do not change in appearance or feel but gradually lose adhesion to the tile. These plastic-like materials remain intact, resilient and clear or slightly translucent, but separate easily from tiles after prolonged immersion in water. Moisture evidently breaks down adhesion at the surface without penetrating far into the film

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of glue. The same phenomenon may occur between the glue and tiling adhesive. These glues do not absorb dyes such as sodium fluorescein and the black glycol-based dye now favoured by BDAP. They have been found in excess on back-mounted glass mosaic, ceramic and tumbled stone tiles, all from southern China. One of the photographs illustrating this article shows a stiff translucent film spread across nylon backing mesh held up to the light. The corresponding tiles came away from the mesh after 48 hours in water.

The advice offered in *Tiling at the Deep End* still applies; soak samples of mesh-mounted mosaic tiles in shallow trays of water and see what happens. If the backing-mesh glue softens and/or changes colour, beware. If the glues does not change in appearance but the mesh comes away easily from the tiles after a day or two, beware. If the glue develops a slimy surface in water, beware. Be prudently skeptical of claims made on behalf of unlabelled tiles from unidentified and uncontactable manufacturers. At every stage of the supply chain, from manufacturer to retailer, seek unequivocal written confirmation that sheets of tiles destined for use in swimming pools are actually fit for that purpose. If you become enmeshed in a dispute that seems to be heading to a court or arbitrator's hearing room, remember that costs can escalate exponentially when one or other party in desperation instigates a war of attrition, for example, by launching volleys of exhaustive evidentiary reports from last-ditch die-hard advocates in the guise of "expert witnesses". In the case recounted above, the tile wholesaler sought to settle the dispute early by offering the importer \$10,000 to retrieve the tiles. When that offer was rejected, he stayed the course long after his likely irrecoverable costs exceeded the sum at issue. He did so knowing that a judgment wholly in his favour – which is what eventuated – might be little more than a pyrrhic victory. On several occasions over two years he was heard to say that he may have made mistakes, for instance, in ordering the tiles without first seeking written confirmation of their fitness for purpose and in selling some while awaiting that confirmation, but at least others in the industry stood to learn from his experience. That opportunity should not now be missed. 

NOTE 1 An inordinate part of the written debate between opposing experts centered on the accurately and appropriateness of dye-staining to accentuate and measure the spread of water-absorbing backing-mesh glue. The importer's team of experts initially rejected dye-staining. They were highly critical of BDAP's use of sodium fluorescein, colour photocopies and photographic enlargements to estimate areas of glue contamination. They preferred to manually probe the perimeter of the glue, using the point of a sharpened dowel viewed under a magnifying glass, to measure coverage to within two decimal places of one percent. Nevertheless, a year later they embraced sodium fluorescein staining, at least as measured by their own method of computer image analysis. They even extolled this combination as *a well-established optical system for quantitative analysis* which would provide the tiling industry with *...an accurate, easy, rapid and inexpensive method of measurement of the degree of coverage*. To counter the initial criticism of the use of fluorescein, BDAP repeated its tests using a range of commercial dyes, food colourants and even a strong solution of freeze-dried instant coffee. We found the best staining agent to be a black glycol-based dye shown in some of the photographs illustrating this article. BDAP's results were remarkably consistent. They also produced averages and maxima consistently higher than those reported by the importer's experts, as did BDAP's computer image analysis. The results of these tests were held in reserve but their submission during the Court hearing was considered

superfluous. These recurring discrepancies invariably favoured each expert's respective client. They have yet to be satisfactorily explained. Doubt remains as to whether the sample of tiles supplied to the importer's experts was ever intended to be representative of the consignment from which it was allegedly taken.

NOTE 2 See also NOTE 1 above. The academic experts' advocacy of their own *quantitative analysis* (i.e. measurement) of coverage of dye-stained backing-mesh and glue by computer image analysis warrants close scrutiny. Such precise measurement is only necessary to demonstrate compliance – or non-compliance – with the percentage coverage limits that the same experts pre-emptively rejected as *unsound, unscientific, arbitrary* and impossible to achieve with current technology. The experts' later preference for case-by-case testing of adhesion tensile strength to the AS 4992.2, as the only reliable measure of long-term performance of backing-mesh glue in conditions of immersion, is also questionable. It assumes that the mosaic tile sample submitted, presumably by a manufacturer or its local distributor, will be representative of all or of a large part of a production batch. The District Court, however, rejected the proposition that the scientists' sample was genuinely representative of the smaller number of sheets in the disputed consignment. BDAP found that glue-and-mesh coverage was highly variable, from carton to carton within one pallet. It should be emphasized that the maximum coverage measured by BDAP was 2.77 times the maximum initially reported by the opposing experts and 54% more than their final maximum. The risk that a small sample will not reveal such high variability is hardly surprising given that the mesh may be manually coated with glue, then lowered onto trays of tiles and stacked in boxes, often before the glue dries, by low-paid semi-skilled workers. I wonder whether any manufacturer, importer or wholesaler would be willing to pay for such precise laboratory measurements when the results cannot be reliably extrapolated across a whole order, shipment or production batch and when the convenient alternative is to soak tiles overnight in water and estimate, by simple conventional methods, whether the coverage of glue and mesh exceeds 20%.

NOTE 3 In this dispute, backing-mesh glue not only covered more than 90% of the rear faces of some mosaic tiles. It also spread over chamfered tile edges, through joints between tiles, across front faces of tiles, onto interlayered paper separating sheets of tiles and down the sides of cartons, effectively gluing tiles to their cardboard packaging. This overflow is strong circumstantial evidence that sheets of tiles were stacked in boxes before the backing-mesh glue could dry. The overflow of glue evidently went unnoticed and was initially denied by the importer's pair of academic expert witnesses. Examples were therefore brought to the Court.

A FINAL FOOTNOTE

The author thanks those in the tiling industry and swimming pool owners who, during the four years that it took to conclude the dispute, were prepared to discuss their experience of tiling defects and failures in swimming pools. The judiciary and others in the New South Wales legal system have recently expressed their alarm and frustration at the antics of expert witnesses who abuse that system. Interested readers are directed to the NSW Law Reform Commission's Report 109 – Expert Witnesses which, was, by coincidence, published in 2005 only weeks before the final hearing of the dispute recounted above.