

FACELIFT FOR AN OLD FRIEND: DISCUSSION ON OCEAN POOL REFURBISHMENT MEASURES AND CHALLENGES

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Ocean pools characteristically dot the eastern coastline of Australia and have generally become a well-established part of their local ocean landscape and community. Typically the pools were constructed in times when materials technology, construction techniques and user safety & access requirements were more rudimentary. It is evident that many have now reached, or exceeded, their life expectancy and are in need of major repairs or refurbishment.

Maintenance of dilapidated ocean pool structures brings a number of interesting challenges to today's asset managers. Common constraints encountered when considering refurbishment are:

- Achieving an equitable balance between cost & durability of materials and longevity of repairs within relatively small budgets.
- Narrow time-windows for construction work (typically during low-season autumn and winter months, in the absence of spring tides and the presence of increased risk of large swell waves).
- Tendering the construction contract within a competitive commercial framework. Many tenderers have little or no experience in working in the unpredictable and unforgiving surf zone (those who do have often gained hard-won insight that renders them commercially uncompetitive in an open-tender situation).
- Managing the construction contract fairly. Work is carried out in an uncontrolled and unpredictable environment, in an economic climate where time and labour are typically more costly than materials.
- Growth of community expectations with respect to aesthetics, safety, accessibility and amenity, compounded by a strong sense of community attachment to these assets.

WorleyParsons (incorporating Patterson Britton and Partners) has been assisting asset managers with assessment, maintenance and upgrade of several ocean pools in NSW. This paper seeks to share some insights regarding successes, lessons learnt, observations and hypotheses resulting from our involvement with these unique structures.

Original Construction

Before attempting repairs, it is helpful to try to understand when and how a structure was built and the mechanisms of decay that are to be combatted. Below is a discussion on some of our findings.

Warringah Council has six ocean pools located along the coast from Collaroy to Queenscliff, constructed between 1912 and 1937. Two of these pools (Queenscliff and North Curl Curl) were constructed under a government-sponsored Unemployment Relief Scheme set up during and following the Great Depression (Mayne-Wilson, 1998 & 1999).

Examples of younger pools outside the Warringah Shire and considered herein are the Ross Jones Memorial Pool at South Coogee, built in 1947 (Coltman, 2002), and Yamba ocean pool at Main Beach in Yamba, built in the 1960s (Hourigan, 2012).

Materials and Techniques

The original design theory behind ocean pool structures is unclear, as construction drawings appear to be non-existent. Rather, it is believed that they were constructed on a trial-and-error basis and evolved in response to need and the availability of funds.

The original construction technique appears to be mass concrete walls (with no expansion joints) and, in some cases, concrete floor slab panels. At Freshwater ocean pool, the floor slabs were a later addition, completed in 1937—some 12 years after the original construction of the pool (Mayne-Wilson, 1999).

At North Curl Curl ocean pool, it appears that the pool's pre-existing southern wall was founded on trenches cut into the natural rock (see Figure 1). This 400mm wide wall was destroyed after 10 years in service, during a storm in 1947, and was replaced by a wall 900mm in width, which was constructed in a revised location. (Mayne-Wilson, 1998).

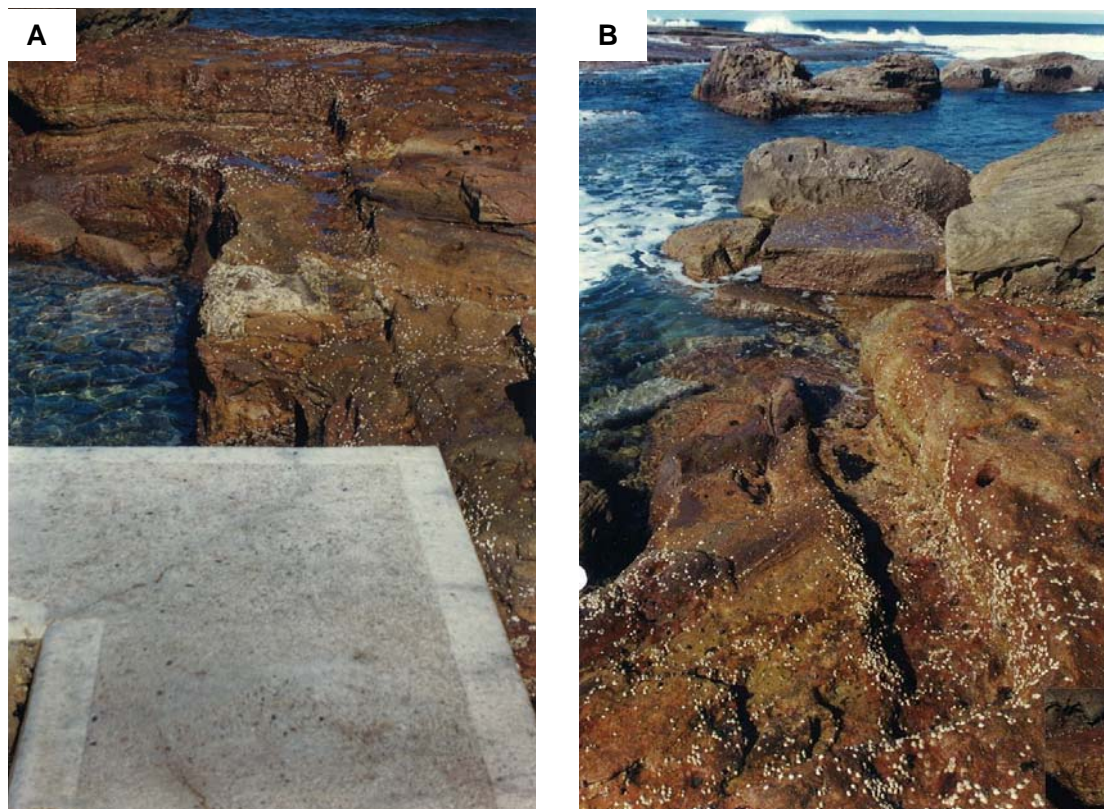


Figure 1: Evidence of trenches cut into the bedrock at North Curl Curl

These are thought to have housed the toe of the pre-existing narrow southern wall. (Source: Mayne-Wilson, 1998)

Finding

Based on our observations, the lower-bound ratio of width to height for walls that have stood the test of time seems to be around 0.5w to 1h. The narrowest walls observed still in service are (i) the eastern wall of the stilling basin at South Curl Curl (the most exposed wall at this site) and (ii) the northern wall of the Ross Jones Memorial Pool in Coogee. Both walls were measured (prior to strengthening works) to be around 500mm wide at the top, but are trapezoidal in section, measuring wider at their base. Nowadays, maximising the width of aprons/walkways appears to be the most important factor when considering wall widths. This is in contrast to design issues of the past, where it would appear that an emphasis was placed on economising on materials, with access requirements of apparent little concern (see Figure 2).

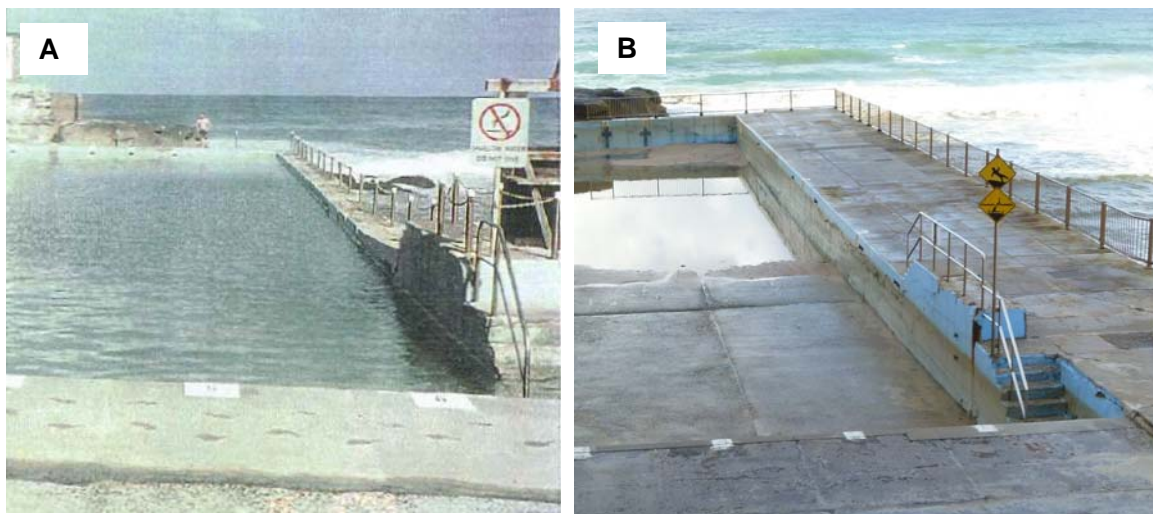


Figure 2: Queenscliff ocean pool

(A) Access along the southern wall apron is poor due to narrow wall width and encroachment of the chain rail. (B) The opportunity was taken to significantly widen the southern apron in 1999 when the Manly Lagoon outflow pipes were extended. (Source: DPWS, 1995; WorleyParsons, 7/2013)

The south-western corner of Freshwater ocean pool was replaced in 2012 as part of a refurbishment and upgrade works package. The walls had sustained considerable damage at this corner, presumably from the stresses associated with changes in temperature and moisture. Upon demolition, it was discovered that the matrix of the wall contained sandstone boulders placed within the original parent concrete. It is likely that these boulders were locally excavated (or collected) and inserted within the concrete forms to economise on construction materials.



Figure 3: Demolition of the SW corner of Freshwater ocean pool

Exposing the materials used in the original construction of the pool wall and numerous subsequent widening and refurbishment works. (Source: WorleyParsons, 3/8/2012)

Core samples taken at South Curl Curl and Coogee show that the concrete used in the construction of these two pools had large coarse aggregate (see Figure 4). Roger Scerri (a Building Materials Research Engineer from SciMat Technologies) proposes that this indicates these concrete mixes were specifically designed for use in the marine environment. Use of large coarse aggregate was an early method of increasing the workability of concrete. It is therefore inferred that the mixes would have a high cement content with a low water:cement ratio. This theory is consistent with the findings made by Scerri (2002) following site testing and laboratory analysis of three core samples from Coogee, as follows:

- $f'_c = 24 \text{ MPa}$
- Cement = 400 kg/m³
- Water/cement ratio = 0.5
- Sulphate intrusion profile = 3 to 7 mm.

Furthermore, Scerri (2002) found that the concrete was of good quality and consistency considering the crude batching and placement methods that would have been used at the time. Extrapolating from Scerri's findings at Coogee, it would appear that the parent concrete generally has the potential to make a suitable base for repairs, providing that the weakened (sulphate attacked) surface is taken into consideration (see Figure 5).



Figure 4: Concrete core samples

(A) From the northern wall of South Curl Curl ocean pool, showing coarse aggregate much larger than that seen today, with an apparent high proportion of fine aggregate, presumably due to the ready availability of beach sand during site batching. (B) Modern concrete with 10mm coarse aggregate. (Source: WorleyParsons, 10/2013)

Deterioration Mechanisms

Serediuk (DPWS 1995) found that the main cause of deterioration of concrete surfaces and joints at Warringah's six ocean pools was sulphate attack. Both copper sulphate (an algaecide that is no longer used) and sulphates occurring naturally in seawater are able to enter the pores of concrete and react with the cement paste. This causes expansion and deterioration of the binder material and subsequent exposure of coarse aggregate. However, studies have found that the presence of chlorides greatly mitigates the expansive forces of this chemical reaction (Verbeck, 1967; Zacarias, 2007; CCAA TN68-2011).

The mechanical forces of mineral crystallisation within the pores of concrete, combined with the abrasive forces of wind, waves and human traffic, are thought to be the key deterioration mechanisms of concrete surfaces. This can be seen on some of the older slab panels and external (unpainted) walls (see Figures 5, 6 and 7). This mechanical degradation can occur rapidly at an ocean pool due to frequent wetting and drying of concrete as well as the wick effect, i.e. transmission of water through walls (due to water pressure inside the pool) to evaporate from a nearby dry surface (BS 6349-1-4:2013).

Serediuk (DPWS, 1995) found that the simple addition of paint affords protection to concrete, as well as inhibiting marine growth (e.g. oysters), which pose a risk to the safety of users. Serendipitously, painting of the internal pool walls is thought to also have provided protection to the apron slab surfaces by reducing moisture transmission through the wall and damage to aprons caused by mechanical sulphate attack as a result of the

wick effect. Warringah Council has had success using a chlorinated rubber paint system inside their pools, which is preferred over an epoxy system as it is quite robust, yet easy to re-apply.



Figure 5: Ross Jones Memorial Pool prior to refurbishment in 2005

It was found that the deterioration mechanism of the concrete was both chemical and mechanical attack from sulphates naturally occurring in seawater, accelerated by the pounding, abrasive action of the surf (Coltman, 2002). (Source: WorleyParsons (inc. PBP), 2002)



Figure 6: Copper sulphate algacidal solution has stained concrete and rock dark green inside Dee Why ocean pool

Copper sulphate has not been used by Warringah Council for over 20 years, but is thought to be responsible for accelerating the deterioration of concrete surfaces during its use (DPWS, 1995). At least two generations of apron topping replacements can be seen, alongside several generations of failed patch repairs. (Source: WorleyParsons, 9/2007)

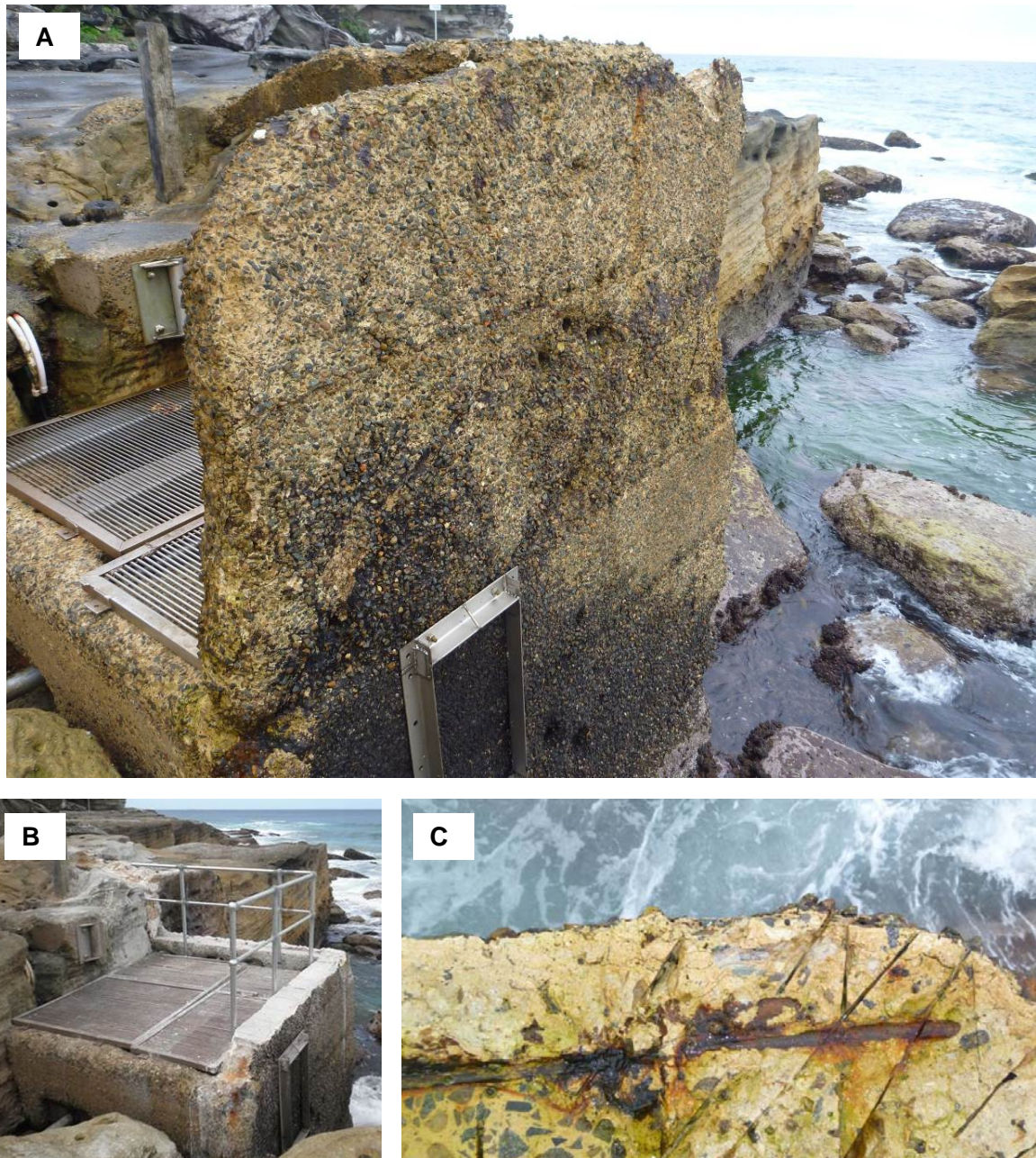


Figure 7: The pump wet at Queenscliff ocean pool

(A) The wave baffle walls in poor condition. The exposed coarse aggregate on the seaward faces of the concrete is a result of the combination of sulphate attack and abrasion from wind and waves. (Source: WorleyParsons, 9/2011) (B) The walls were demolished in April 2013 due to concern over their poor condition. (Source: Warringah Council, 4/2013) (C) A close-up of the concrete wall cross-section, post demolition. Corrosion of reinforcement was not a concern after an estimated 75 years in this severe environment. (Source: WorleyParsons, 7/2013)

Concluding from the above, it is thought that repairs should be detailed to resist mechanical sulphate attack and, if reinforced, to ensure adequate durability of the reinforcement. The main focus would be to optimise impermeability and abrasion resistance of the concrete (to prevent ingress of minerals into the concrete matrix and

surface wear, respectively). This creates a conflicting requirement, as concrete of low permeability, placed in situ in the exposed marine environment, is more susceptible to early age-cracking (from the effects of plastic shrinkage) than a lower-performance concrete that is able to bleed more easily in the plastic state. This is complicated further if the construction crew placing the concrete is inexperienced with high-performance concrete and not intimate with the characteristics of the actual concrete mix being placed.

These issues with in situ construction can be circumvented by the use of precast concrete. However, this introduces a new suite of issues and risks; for example, the practice of precast manufacturers to cure concrete rapidly (using heated moulds or steam curing), so as to strip moulds as quickly as possible, to the detriment of concrete impermeability (Neville, 1973; HB84-2006). Also, there are issues with transporting, lifting, placing and fixing panels without damaging them, especially at a site that has poor access and, potentially, is inundated with destructive waves and water every high tide cycle.

As most of the pools have been constructed from mass concrete, corrosion of reinforcement is not generally of concern when assessing the condition of the original concrete. It is, however, a concern for past or future repairs and modifications. In some cases, it has been found that modifications using reinforced concrete have had a significantly reduced service life when compared with the original structure (refer to Figure 8).



Figure 8: North Curl Curl Ocean Pool prior to repairs in 1998

The slender reinforced concrete scupper lids had sustained considerable damage: one was missing (A), and one other was in an unserviceable condition (B). A potential solution for slender scupper lids is being trialled by Warringah Council at Freshwater ocean pool (refer to Figure 19). (Source: WorleyParsons (inc. PBP), 1998)

Patterson (2006) notes the observation that older reinforced concrete marine structures are generally more durable than those built in the 1970s and afterwards. He proposes that this is due to changes in the manufacture of cement. Cements in older marine structures are thought to be coarse-ground, slowly hydrating, with a high tri-calcium aluminate (C3A) content. In the past, C3A was included in proportions high enough to enable it to bind with free chlorides in the reinforced concrete matrix, thus protecting embedded steel reinforcement from corrosion (Patterson, 2006). Examples that potentially support this theory are shown in Figures 7 and 9.



Figure 9: Core sample taken from the reinforced concrete pool floor slab at Yamba ocean pool

The core includes a segment of reinforcement and a sample of the bedrock foundation beneath. This section of floor slab was around 150mm thick. The reinforcement is measured to be around 4mm in diameter. The steel reinforcement shows no signs of corrosion after nearly 50 years in the marine environment. Patterson (2006) provides a hypothesis that concurs with this finding. (Source: Jim Spencer, 10/2012)

Refurbishment Measures

Some case studies of ocean pool refurbishment measures are shared below. Both successes and “lessons learnt” are discussed.

Resurfacing with In-situ Reinforced Concrete at Coogee

The Ross Jones Memorial Pool at South Coogee was refurbished by Metropolitan Constructions in 2005. The pool walls were resurfaced with a relatively thin reinforced concrete layer, placed in situ. Following an investigation and laboratory testing by Scerri (2002), it was found that despite its poor appearance, the parent concrete was suited to this type of repair (Coltman, 2002). The in situ concrete was reinforced with stainless steel

reinforcement (see Figure 10). The outer walls and pillars were dry-shotcreted. The inner walls were “formed and poured” using a proprietary cementitious grout with 6mm basalt fines added at a 1:1 ratio (by weight). The fines were added to aid dissipation of heat generated during hydration as well as to lower the cement content of the grout mix. Despite these measures, early age-shrinkage cracking was found to be an issue. A seal coat was placed on the face of the inside walls only. The work commenced during winter, however shotcreting of the lower section of the outer walls had to be delayed until summer months, when tides and swell conditions became more favourable.



Figure 10: Ross Jones Memorial Pool

(A) Mid-refurbishment, during the winter of 2005. Note the dense, bright green marine growth on the concrete surface in the background, indicating that surface contaminants had been previously removed. (B) Some 2 years after refurbishment. (Source: WorleyParsons (inc. PBP), 7/2005 & 6/2007)

New Mass Concrete Wall and Apron Widening at Dee Why

Rather than continuing down the path of previous repair scopes and carrying out patch and crack repairs, Warringah Council elected to undertake a more robust refurbishment of the northern wall at Dee Why. S50 mass concrete wall/apron units were cast in situ by

Silver Raven Pty Ltd. Stainless steel reinforcement was used very sparingly for anchors, trimmers and for suspending the apron slab over the top of scuppers. The aprons were widened by moving the wall some 500mm inward. This change in geometry eradicated the pre-existing ledge in the wall (see Figure 11A), formerly used by bathers as a seat. The ledge was missed by pool users, but was a prudent upgrade to comply with the safety requirements of AS2818. Patch repairs were used to repair cracks, but were of limited success (see Figure 12). These types of repairs are thought to be suited to the short term only.



Figure 11: Refurbishment of the deteriorated north wall and apron slabs at Dee Why using mass concrete

(A) Commencement of demolition of pool wall and ledge; (B) completion of demolition; (C) placing the mass concrete units in 2.9m-wide segments; (D) the finished product. (Source: Warringah Council & WorleyParsons, 7 to 9/2009)



Figure 12: Patch repairs to cracked and damaged concrete – a short term solution
 (A) Preparation involved square edge cutting with obtuse angles only, and scabbling back to sound quality substrate. (B) Despite careful attention to detail during preparation and use of light stainless steel mesh reinforcement, early age-cracking of the repair mortar was encountered. (Source: Warringah Council, 7&8/2009)

Refurbishing Using Precast at South Curl Curl

South Curl Curl ocean pool was refurbished by Silver Raven Pty Ltd in 2011. The repair works involved the challenging construction and erection of L-Shaped precast concrete panels. Precast concrete was selected in order to achieve a quality and uniform surface finish and to remove the risks of formwork or reinforcement being lost/damaged and concrete finishes being compromised during in situ repairs. The top of the northern and eastern walls were cut off, and the panels were bolted and grouted in place to provide a renewed finish to internal wall and apron slab surfaces. Following completion of construction work, it was decided by Warringah Council that the risks associated with precast concrete construction in this environment outweighed the benefits.



Figure 13: Refurbishment of pool walls and aprons with precast concrete

(A) Walls in poor condition. (B) L-shaped panel formed and tied in the casting yard. This panel included a formed block-out for a scupper. (C) Finished product. (Source: WorleyParsons, 4/2010, 7&12/2011)

The panels were cast with the apron (the trafficable surface) as an off-form finish. In order to achieve an appropriate slip-resistant surface, Council elected to coat the aprons with a sand-coloured poly-methyl methacrylate flooring product that had previously been successfully trialled in test panels at Dee Why ocean pool. Unfortunately, the exact product trialled was no longer available, so a substitute was used from a different manufacturer. The substitute product did not perform as well as hoped. Due to issues with adhesion, it is unlikely that this system will be used at other sites. The colouring of the topping, however, looks aesthetically pleasing and is more sympathetic to the pool's surrounds than the grey concrete (see Figure 13C).

Around half of the stainless steel posts on the side-mounted chain handrail worked loose at their fixings after less than 12 months in service (refer Figure 13C). The failure plane on the stainless steel chemset anchors was at the bond between the resin and parent concrete. Upon further investigation, the Australian Engineered Fasteners and Anchors Council advised that there is no chemical anchoring product currently available on the