

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

J O'Reilly¹, B Mojsin¹, S Batt¹, M Zed², L Skountzos³, J Spencer⁴

¹WorleyParsons, Ports and Marine Terminals Group, North Sydney, NSW

²WorleyParsons, Coastal and Ocean Engineering Group, Perth, WA

³Warringah Council, Parks Reserves and Foreshores, Cromer NSW

⁴formerly of Clarence Valley Council, Grafton, NSW

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).

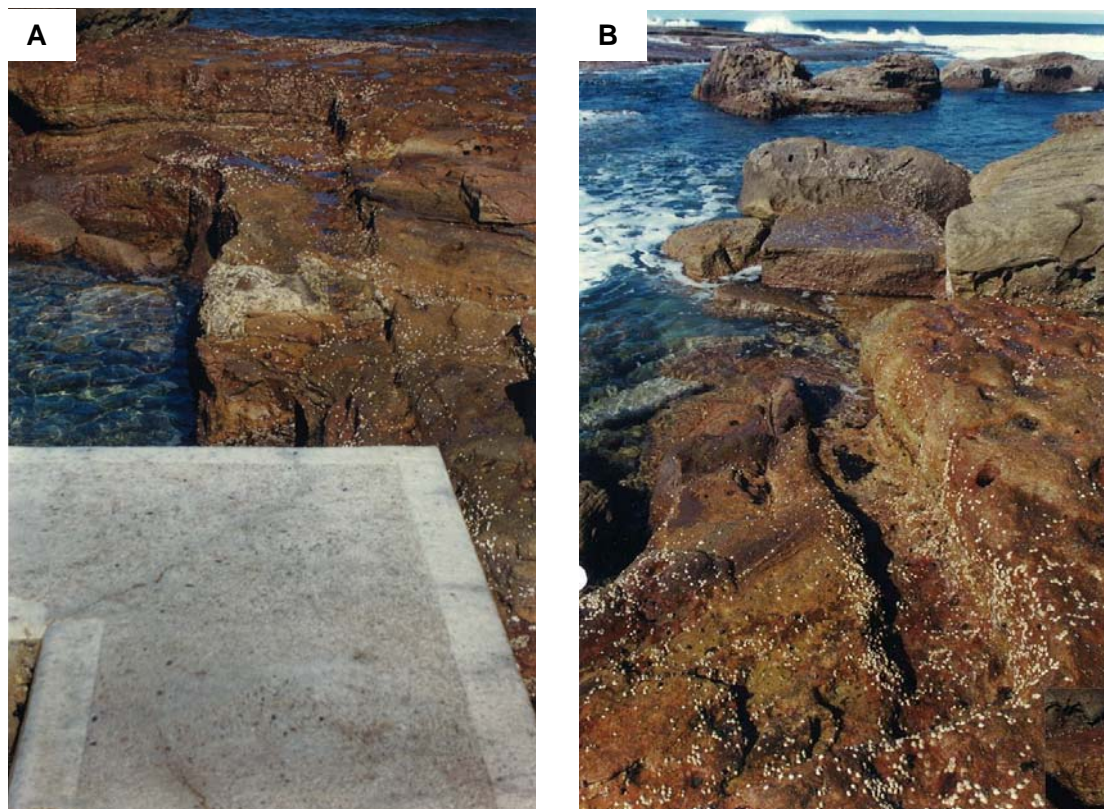


Figure 1: Evidence of trenches cut into the bedrock at North Curl Curl

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).

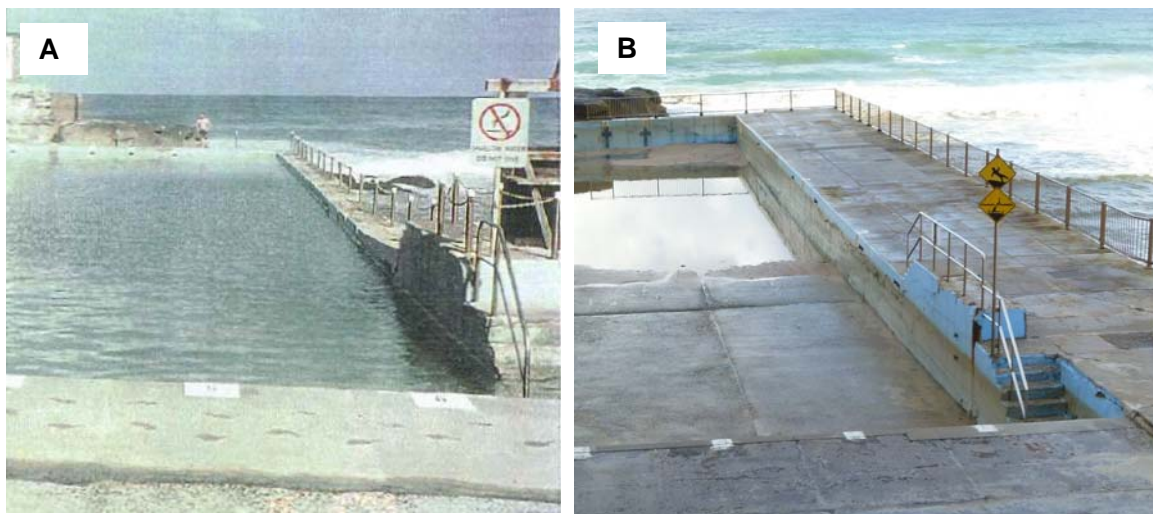


Figure 2: Queenscliff ocean pool

(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)

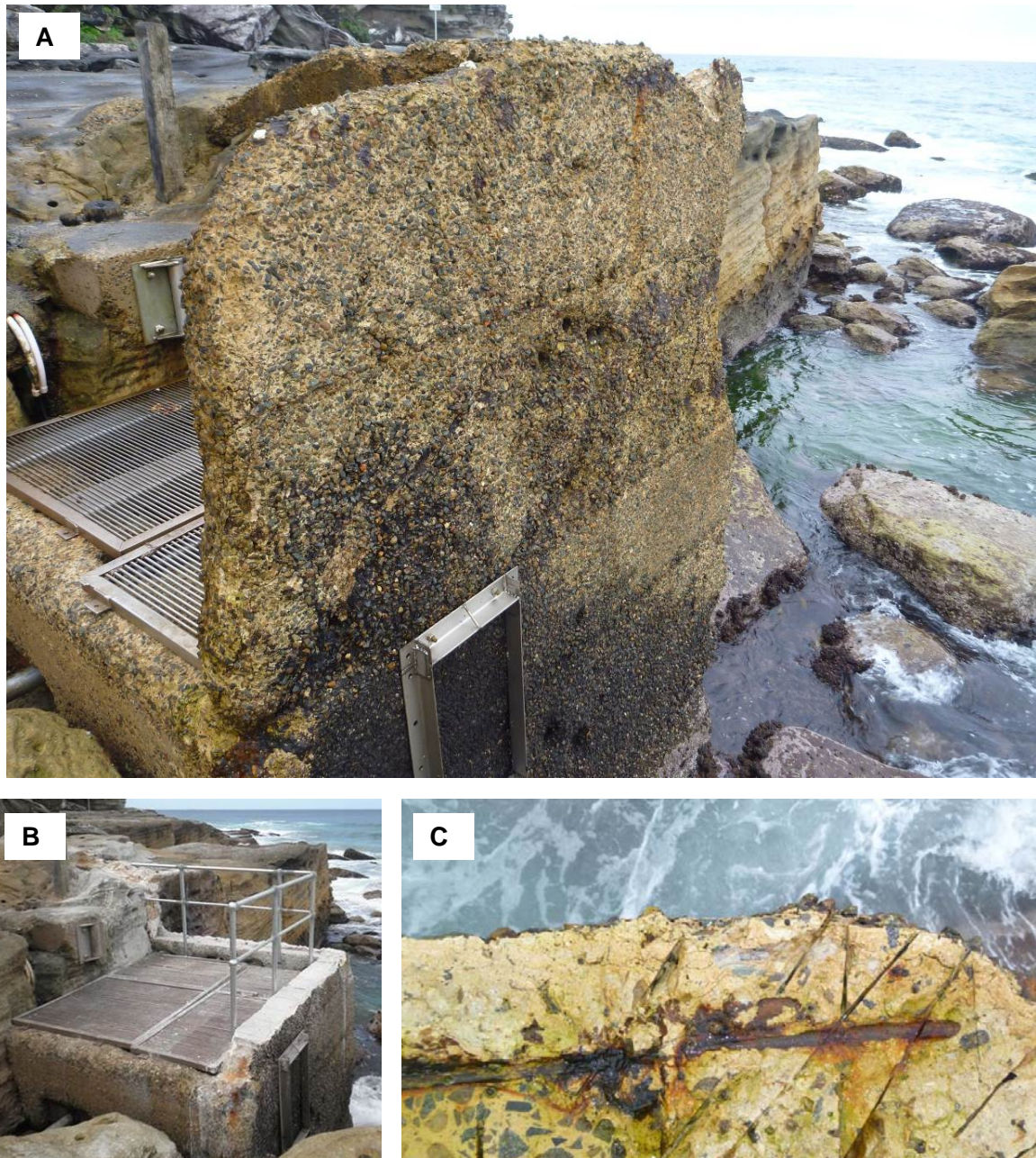


Figure 7: The pump wet at Queenscliff ocean pool

(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

market with ETA or ICC approval for use in holes wet with seawater. This issue could be addressed by use of mechanical anchors, or by ensuring that stresses in chemically anchored fixings are kept to a minimum in these applications.



Figure 14: Erection of precast “L-shaped” units at South Curl Curl

(A), (B) and (C) Silver Raven P/L lifting panels into place – a technically challenging project in a tough environment. (D) Temporary propping of panels in preparation for inundation by the rising tide. (Source: Warringah Council, 10/2011))

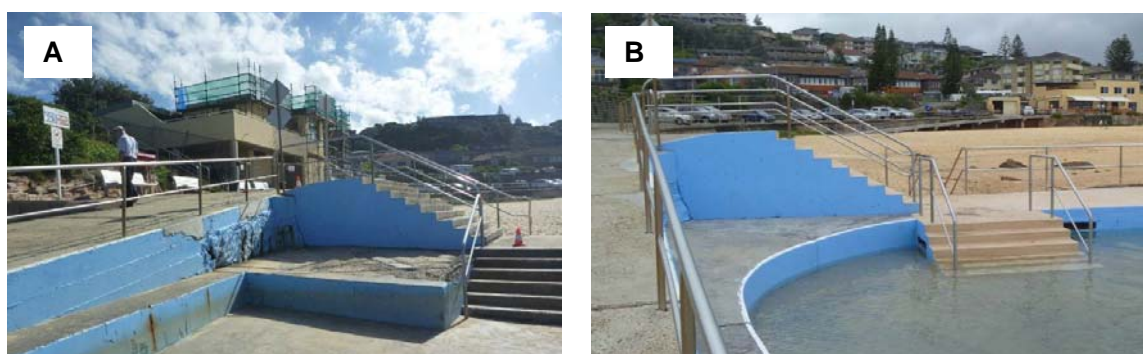


Figure 15: Before & after modifications to the SW corner at South Curl Curl

To improve surface water quality and reduce the accumulation of surface debris, the corner was radiused and a flow-through scupper placed beneath the stair. (Source: WorleyParsons, 4/2010 & 12/2011)



Figure 16: Racing the tide: excavation inside a temporary sand cofferdam

The first attempt at underpinning beneath the valve and pool wall was unsuccessful due to a neap low tide, highlighting that timing and patience is paramount to success in this environment. (Source: Warringah Council, 5/2012)

Deepening the Pool at Freshwater

At the request of local swimming clubs and to comply with Swimming NSW Safe Diving Depths Policy, Warringah Council undertook upgrade works to increase the water depth at Freshwater ocean pool. The “deepening” was undertaken by Corroseal Pty Ltd, by raising scupper invert levels and the coping height around the pool. This approach allowed for concurrent repairs to damaged apron slab surfaces. As this pool was rarely filled naturally by overtopping waves, an increase in wall height would result in a reduction of natural flushing. Measures were undertaken to improve the efficiency and quality of the electric pump system, which is heavily relied upon for water circulation.

The pool’s layout has the drainage valve positioned adjacent to the pump wet well (see Figure 17). Previously, water that had been drained from the pool would be inadvertently pumped back in after the completion of internal cleaning works. This issue was ameliorated by construction of a flushing channel “upstream” of the existing channel (see Figure 18). During the refurbishment work, Council took the opportunity to replace the wet well with a deeper version, to allow operation of the submersible pump during all tidal conditions. In addition, a second pump was installed to facilitate constant and reliable circulation of water. The successful upgrades to improve water quality and maintainability

of the pool were mostly instigated by Warringah Council's veteran Pool Maintenance Engineer, Andrew Prentice. This highlights the valuable input that can be provided by stakeholders that have developed an intimate understanding of these unique structures.



Figure 17: Freshwater: before and after

(A) Narrow southern apron in poor condition. (B) The pool was deepened by raising the coping and scupper invert levels. Warringah Council took the opportunity to slightly widen the narrow southern apron. Useable apron width was maximised by installation of a side-mounted guardrail. (Source: WorleyParsons, 4/2010 & 5/2013)



Figure 18: Modifications to the pool pump system at Freshwater

(A) Replacement pool pump wet well, precast on site. (B) Wet well installed on south side of pool with electropolished stainless steel work platforms and access hatches. (C) New flushing channel (channel through rock on the left) allows circulation of "fresh" water to the pool pump. (D) Close-up of the new flushing channel excavated into rock. (Source: WorleyParsons 9/2012 & 5/2013)



Figure 19: Slender scupper lid being trialled at Freshwater

Fabricated from electro polished stainless steel plate and acting as a step. A potential solution to the issues shown in Figure 8. (Source: WorleyParsons 1/5/2013)

Replacement of a Floor Slab Panel at Yamba

The pool floor slab at Yamba ocean pool has varying foundation conditions. The shallow end is founded on rock and the deep end is founded on back-filled rock and sand. The middle slab panel is half founded on fill and half founded on rock, generally ranging in thickness from 150 to 200mm. After nearly 50 years in service, this lightly reinforced slab panel suffered from significant cracking (see Figure 20C), which was found to propagate from a local highpoint in the bedrock substrate. The cracks allowed water to leak rapidly from the pool, creating a hazard to users due to the water depth varying in direct correlation with the tide.

Local contractor Chambers Constructions was engaged by Clarence Valley Council to replace the middle floor slab panel during the spring tides of 2012. The new slab consisted of a water-proofing membrane and water stops, stainless steel hold-down anchors, galvanised reinforcement, and concrete supplied in a pumpable mix. The local pumping subcontractor was not experienced with high performance concrete, so initial work (underpinning) was carried out using 40 MPa concrete. The new slab was placed with a pumped 50 MPa, binary blend, RMS B80 mix.

Due to program constraints, the floor slab was placed on a rising tide. The high permeability of the substrate beneath the slab, and the failure of previous measures to prevent the flow of water from beneath, resulted in water leaking through the slab joints before it had cured. Local water-proofing specialists, Caps Beta, were called in to rectify the leaks. A temporary foaming hydrophobic polyurethane water-stop was first used,

followed by filling of the excavated joint with an epoxy mortar primer and grout (see Figure 22).

The flow rate of water beneath the floor slab was observed to be very high, with a noticeable influx of water on the incoming tide during the slab underpinning and demolition works, suggesting that water beneath the slabs was tidally connected. This issue is expected at sites where the substrate beneath the slab is of high permeability, e.g. made up of (i) beach sand, (ii) bedrock containing fractures, joint planes, and possibly also eroded seams or dykes which act as conduits for water, or (iii) a mixed foundation consisting of both, as was the case in Yamba.

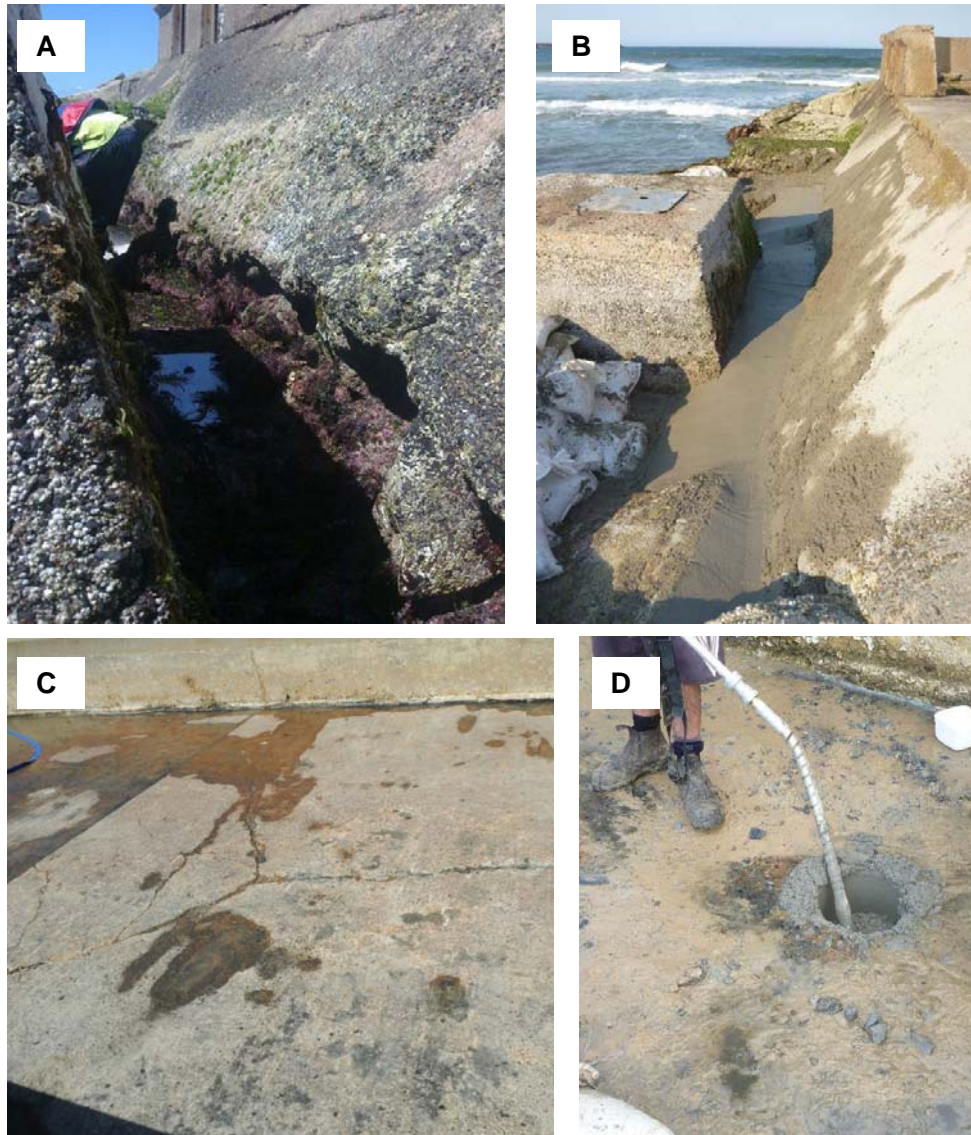


Figure 20: Mass concrete underpinning at Yamba

(A) The toe of the northern wall showing signs of scour and undermining. (B) Mass concrete with stainless steel dowels used to underpin the toe of the northern wall. (C) Central panel shown cracked and leaking. (D) Underpinning the floor slab at the pool's deep end. Worker shown vibrating concrete into a corehole following local dredging of material beneath the slab. (Source: Chambers Constructions & WorleyParsons, 9-10/2012)

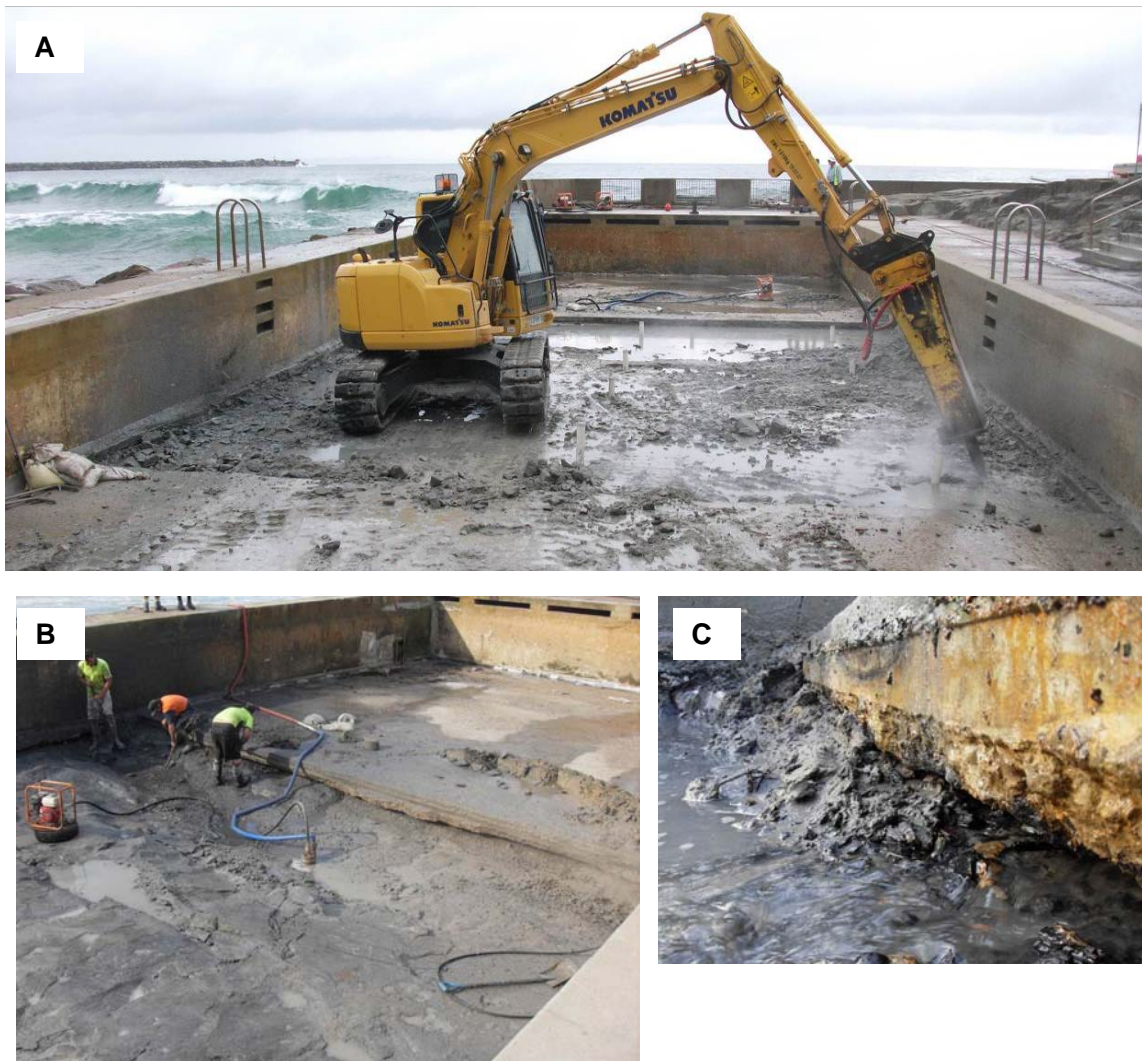


Figure 21: Demolition of the middle floor slab panel at Yamba

(A) Rubber-tracked rock-breaker lowering bedrock levels to allow placement of a floor slab of uniform thickness. (B) Foundation preparation, involving removal of sand and silt and placement of a mass concrete blinding layer. (C) Water flowing freely beneath the floor slab at low tide. (Source: WorleyParsons, 11/2012)



Figure 22: Placement of a new pool floor slab panel

(A) Concrete being pumped and screeded into place. (B) Despite best efforts, delays in placing the concrete meant that the tide rose before the new concrete could set, and the new floor slab began leaking immediately. (C) Specialist repair of leaks by filling the excavated slab joint with epoxy mortar. Note the water pressure relieving holes drilled along the seaward side of the joint, marked with arrows. (Source: WorleyParsons, 11/2012; Jim Spencer, 12/2012)

Robust Handrail at North Curl Curl

North Curl Curl is exposed to heavy seas and is typically inundated by waves each high tide cycle. This pool has a known history of destruction (see Figures 1 & 8). Previous generations of chain handrails at this site were typically not able to stand the test of time (DPWS 1995; Mayne-Wilson, 1998 & 1999). A robust double guardrail was installed in

1998 and remains today at this site, with only minor signs of deformation. It was built using modular components, such that individual items could be removed and replaced on site using hand tools. Rails are $\phi 60\text{mm}$ CHS and posts are 80mm SHS, austenitic 316 stainless steel. The double guardrail format and large diameter rails do not comply with the requirements of the Building Code of Australia (BCA).



Figure 23: Heavy-duty, modularised double guardrail at North Curl Curl

This rail is still performing adequately after 15 years in service at an unforgiving site. (Source: WorleyParsons, 3/2012)

Innovative Balustrade at Queenscliff

The balustrade around Queenscliff ocean pool is similar to the handrail at North Curl Curl in that it was built from 316 stainless steel using modular components. It was fabricated from $\phi 48\text{mm}$ rails and 80mm SHS posts of the thickest wall readily available at the time. (ASSDA, 2005). It is BCA compliant and has removable infill panels made up with 20mm rod balusters. The posts are mounted above 75mm-thick neoprene “shock pads” (see Figure 24C) that are designed to absorb energy in the direction of oncoming waves only. The original design brief for this balustrade was to absorb the impact energy of boulders carried by waves (as these were reported to be found inside the pool from time to time). It was later found, however, that the ultimate load case for the balustrade is the increased drag and inertial forces from wave loading once the rails are covered with weed (see Figure 24D).

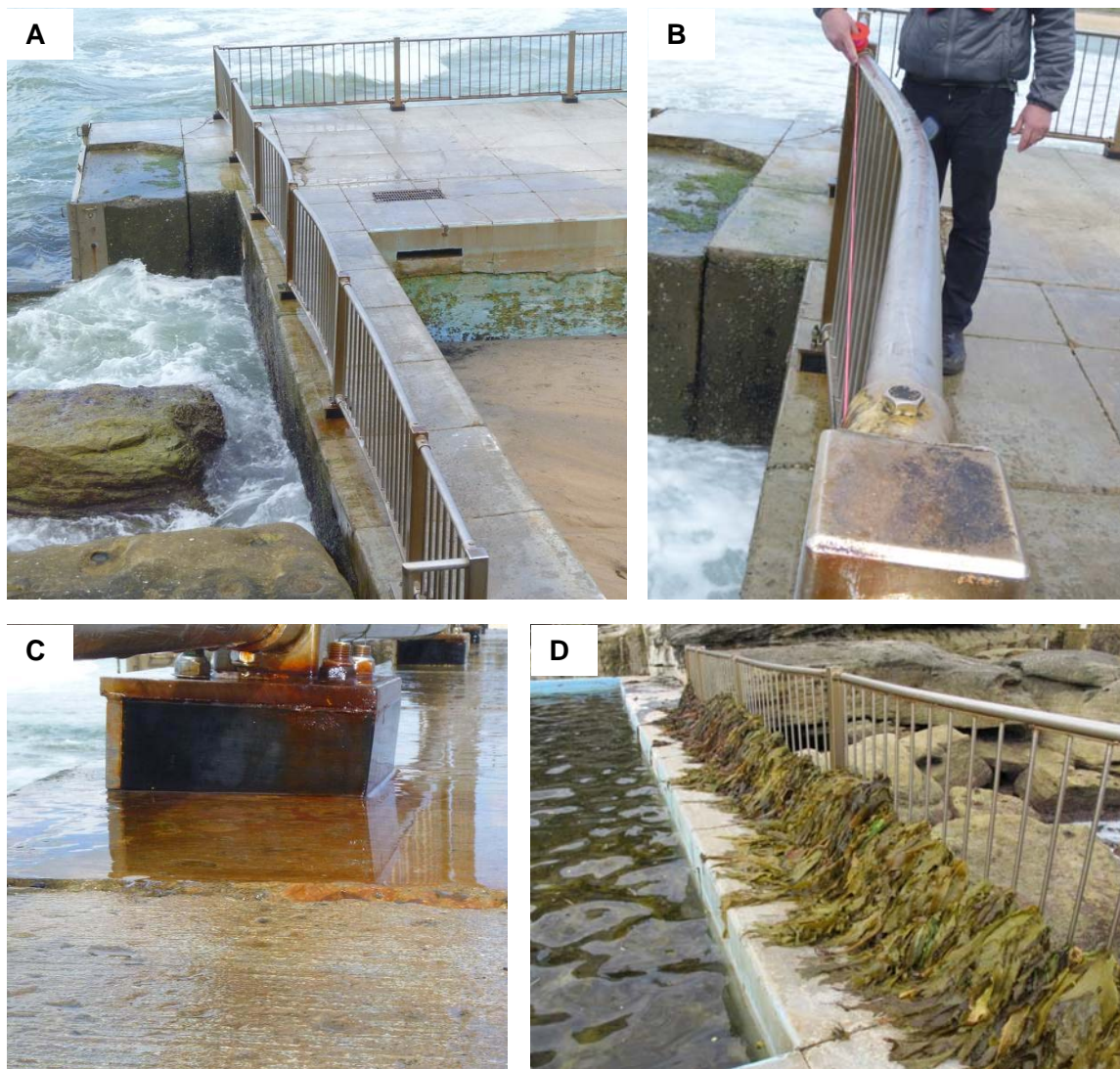


Figure 24: BCA compliant balustrade at Queenscliff ocean pool

(A) After 14 years in service, the balustrade along the eastern wall is ready for replacement. (B) Unacceptably large deformations were measured at the top rail and posts. It now encroaches on the already narrow apron. (C) Neoprene shock-absorbing pads beneath the balustrade posts, designed to absorb energy from rock impacts. (D) Significant quantity of wrack caught on the balusters. (Source: WorleyParsons, 3/2012 & 7/2013)

Concluding Remarks

It is difficult to recommend a universal remedial approach for ocean pools, as solutions rely heavily on several variables; for example, budget, desired service life, skill and experience of the proposed work force, and the quality of available materials.

The literature on durability of reinforced concrete in the marine environment is abundant but confusing, as it is riddled with studies that have contradictory outcomes. This is

frustrating yet understandable, as the reinforced concrete matrix itself is made up of materials that have conflicting requirements. Furthermore, there is no universally accepted method for quantifying the load on these structures for design purposes. As the example in Figure 24 illustrates, it is possible for design criteria to be incorrect and the design loads exceeded in service. In this regard, experience has been found to play a key role in determining repair and upgrade measures appropriate for each scenario, considered on a case-by-case basis.

Achieving economic, durable and successful repairs of ocean pools is a great challenge, from both design and construction perspectives. It is hoped that the discussions and experiences documented herein are of some value to those who face similar challenges ahead in maintaining these unique and valuable community assets.

References

Australian Building Codes Board 2012, *Building Code of Australia*, BCA 2012, Australian Building Codes Board.

Australian Concrete Repair Association, Commonwealth Scientific Industrial Research Organisation & Standards Australia 2006, *Guide to Concrete Repair and Protection*, HB84-2006, 2nd edn, Standards Australia, Sydney, NSW.

Australian Stainless Steel Development Association 2005, *Stainless Steel Stock Guide*, ASSDA 2005, 3rd edn, Australian Stainless Steel Development Association, Brisbane, QLD.

BSI Standards Publication 2013, *Maritime Works – Part 1-4: General – Code of Practice for Materials*, BS 6349-1-4:2013, 3rd edn, The British Standards Institution.

Cement Concrete & Aggregates Australia 2011, *Technical Note 68 – May 2011 – Sulfate-resisting Concrete*, CCAA TN68-2011, Cement Concrete & Aggregates Australia, Sydney, NSW.

Coltman, P. 2002, *Ross Jones Memorial Pool – Condition Assessment and Recommendation for Upgrading*, Patterson Britton and Partners P/L on behalf of Randwick City Council, Sydney, NSW.

Department of Public Works & Services 1995, *Warringah Council – Rock Pools – Structural Investigation and Assessment – Report No. HT 98 R1*, Department of Public Works & Services, Sydney, NSW.

Hourigan, A. 2012, 'Facelift for an old friend', *Coastal Views Newspaper*, 5 October 2012, p. 4.

Mayne-Wilson & Associates 1999, *Heritage Conservation Management Plans for Warringah's Six Rock Pools*, Mayne Wilson & Associates on behalf of Warringah Council, Paddington, NSW.

Mayne-Wilson & Associates 1998, *Heritage Report and Heritage Impact Statement on the North Curl Curl Rock Pool – Prepared on behalf of Patterson Britton & Partners Pty Ltd Consulting Engineers for Warringah Council*, Paddington, NSW.

Neville, A.M. 1973, *Properties of Concrete*, Second Edition, Wiley, New York, USA

Patterson, A. 2006, 'Best Practice in the Design of Maritime Structures', *Lloyds List DCN – Maritime Structures 2006 – Design of Maritime Structures*, Patterson Britton & Partners P/L, Sydney, NSW.

Roads and Maritime Services 2012, *QA Specification B80, Concrete Work for Bridges*, RMS B80, 6th edn, NSW Government Transport Roads and Maritime Services.

Scerri, R. 2002, *Report Prepared by: The Australian Centre For Construction Innovation, The University of New South Wales, on: Investigation of Concrete Condition of Coogee Baths, for: Patterson Britton and Partners*, University of New South Wales, Randwick, NSW.

Standards Australia 1993, *Guide to Swimming Pool Safety*, AS2818-1993, 3rd edn, Standards Australia, Homebush, NSW.

Verbeck, G.J. 1967, 'Field and Laboratory Studies of the Sulphate Resistance of Concrete – Research Department Bulletin 227', Research and Development Laboratories of the Portland Cement Association, Toronto, Canada.

Warringah Council 1999, *Conserving our Rock Pools, Celebrating Warringah Council's Beach Culture Initiatives*, Publication Number: SPPC0899-1, Warringah Council, Cromer, NSW.

Zacarias, P.S. 2007, 'Alternative Cements for Durable Concrete in Offshore Environments', *Offshore Mediterranean Conference and Exhibition*, Ravenna, Italy.