Our Ref: 16038
Morawa Aquatic Centre
Swimming Pool Core Survey

airey taylor consulting
engineers
scientists

Report prepared by	Date	Signature of Author	Approved By	Approved By Signature
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Contents

1. Investigating Personnel

1.1 The entrance to the Morawa Aquatic Centre is located along Croot Street, with the adjacent roads White Avenue and Gill Street to the north and east direction respectively in the Shire of Morawa 6623. Dr Rainier Catubig BEng(Hons) PhD of Airey Taylor Consulting (ATC) attended the site between 23/02/2016 until 25/02/2016 to supervise the core survey of the 50 m pool under the instruction of Dr Anthea Airey BSc(Hons) PhD MBA MRACI CChem (Project Leader – Scientific Services). The report was reviewed by Mr Peter Airey BE GradDipAdmin FIEAust CPEng (Managing Director).

The core survey was divided into three components, the first being the electrolocation of the reinforcing bars by use of ground penetrating radar. The reinforcement detection was performed by Mr Dale Shearsmith from Subtera Subsurface Locating (formerly MP Electrolocation) using a Mala CX 1.6 gHz Ground Penetrating Radar.

The second component corresponded to the coring of samples from the pool floor, walls and lip. Coring of the concrete was conducted by a technician from ConCut Pty Ltd.

The third component corresponded to the sealing of the core holes with repair mortar, which was conducted by Mr Phil Browne from Elite CPR.

2. Inspection and core survey visual observations

2.1. General observations of the pool

The pool was constructed in the year 1969 meaning the pool is approximately 47 years old. There were no diveboards in the dive pool or plastic platforms on the shallow and deep end starter blocks observed during the inspection. Both were removed a few years prior to the inspection by ATC.

The plan view of the pool is shown in Appendix A. There are a set of stairs on both the south east and south west corners of the pool (shallow end). The south east corner of the pool is shown in Figure 1. On the east side of the deep end, there is a dive pool area, shown in Figure 2. Infinity drains are present along the east and west sides of the pool, including the east side of the dive pool. The drains wrap around the stairs on the shallow end (Figure 1). Instead of drains, there are concrete beams that run along the north and south sides of the pool as well as the south wall of the dive pool.

Figure 1: The south east corner of the pool (shallow end) showing the top of the stairs into the pool (solid arrow). The starter block is indicated by the dotted arrow.

Figure 2: The dive pool area on the north east side of the pool.

The drains on the side of the pool had been renovated sometime in the late 80's to early 90's. Figure 3 shows a detail of a drain from the pool drawings dated 1966 where the drain had been relatively close to the edge of the pool. As shown in Figure 1, the renovations involved sealing the top of the original drains and placing a new drain further away from the pool. A void was present behind the pool wall, seemingly beneath the old drain. The void was observed when extracting Core 7 and 13 (Figure 4 shows the void behind core 13). The wall was approximately 150 mm thick and the void was about 130 mm wide. The tiled concrete at the top of the pool wall and at least the shallow end wall did not appear to have a void since core holes at sites 2 and 5 did not have a void behind it.

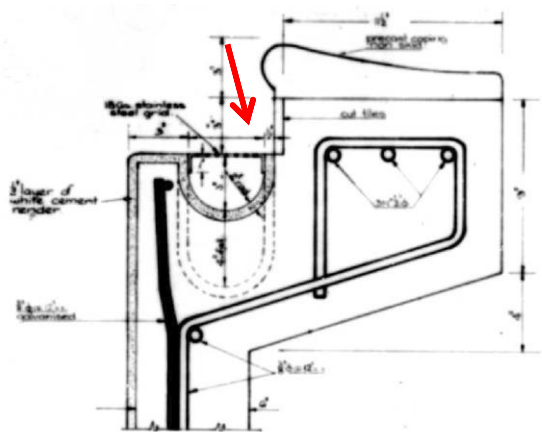


Figure 3: A detail of drains on the side of the pool on drawings dated 1966.

Figure 4: Core hole 13 (Beneath the splash zone) with a void at approximately 150 mm from the surface of the pool wall.

2.2. Typical core samples

To assess the condition of the pool, a core survey was conducted. Figure 5 shows a schematic diagram of where each core sample was obtained with respect to the pool structure. The typical concrete core obtained will be described in the following sections.

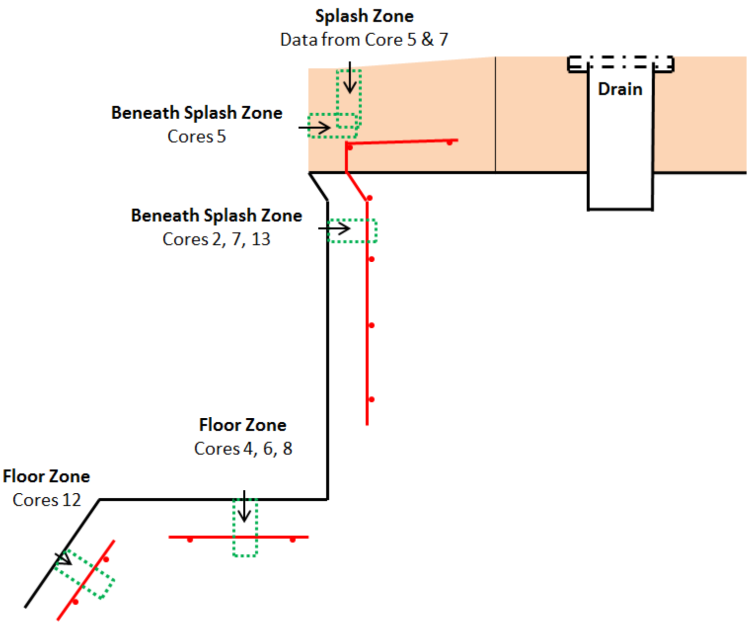


Figure 5: Schematic diagram of the approximate locations of each of the core samples with respect to the pool structure. The positioning of the reinforcement steel are also approximations from the observations during the GPR survey.

2.2.1. Pool floor

The concrete slab of the pool floor had multi-coloured aggregate particles with a white topping of varied thickness (Figure 6). At the tiled floor areas, there was the tile and an intermediate material on top of the concrete instead of the white topping (Figure 7). The cores taken from the main pool floor include Core 4, 6 and 8 while Core 12 was from the sloped surface of the dive pool. The soil was reached beneath Core 4 and 8 at approximately 145 mm depth. No void was observed on site when the cores were extracted.

Figure 6: Core 4 Floor sample showing the white topping over the concrete with multi-coloured aggregates.

Figure 7: Core 6 Floor with a tile and intermediate material over the concrete and multi-coloured aggregates. The orange colour of the core is debris from drilling that had dried onto the core surface.

2.2.2. <u>Beneath the splash zone of the pool wall</u>

The cores taken from the pool below the tiles that line the lip of the pool typically had the white topping and intermediate layers covering concrete with multi-coloured aggregate particles (an example is Core 7 shown in Figure 8). These cores included Core 2, 7 and 13. Cores taken within the tiled area at the lip of the pool wall had a tile and intermediate layer covering concrete with blue coloured aggregate particles and a different type of cement (Core 5 shown in Figure 9).

Figure 8: Core 7 Beneath splash zone sample showing the white topping and intermediate material over the concrete with multi-coloured aggregates.

Figure 9: Core 5 Beneath splash zone was in the tilled area above the first horizontal reinforcement steel on the east side of the pool. A tile and intermediate layer is observed over concrete with blue aggregates and a different type of cement.

2.2.3. <u>Lip of pool adjacent to the drains</u>

The splash zone core samples showed a mixture of different materials. Figure 10 shows Core 1 which was extracted at the lip adjacent to the pool edge of the east side of the pool. Half of the core had a tile over it while the other half had the stone topping (Figure 12). Beneath the tile and the stone topping was an intermediate material and concrete with blue coloured aggregate particles respectively. Beneath those layers was another concrete type.

Core 11 (Figure 11) only had the stone topping on top of the concrete (shown in Figure 13) however, at a certain depth, there were two types of concrete which is different to the concrete above (solid arrow in Figure 11).

A detailed description of the core sections and testing schedule is outlined in Appendix C.

Figure 10: Core 1 Splash zone sample had both a tile (solid arrow) and a stone topping (dotted arrow) over the core. There is an intermediate material and concrete beneath the tile and stone topping respectively. A second type of concrete is observed beneath both.

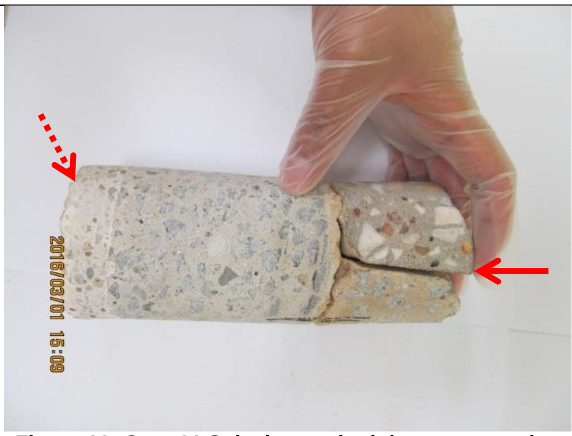


Figure 11: Core 11 Splash zone had the stone topping (dotted arrow) over the concrete. At a certain depth, two different concretes were observed (interface shown by solid arrow) beneath the first concrete material.

Figure 12: Core 1 Splash zone sample showing the tile and stone topping over the core.

Figure 13: Core 11 Splash zone sample showing only the stone topping over the core.

3. Test results

3.1. Density of concrete

The average density for the core samples 1, 3, 7, 8, 10 and 13 is 2265 ± 234 kg/m^3 according to the SGS laboratory results. According to A. M. Neville "*Properties of Concrete*", 4th Edition 2005, the density of normal weight concrete is between 2200 – 2600 kg/m^3. Cores 1, 3, 7 and 8 yielded density values outside this range with the greatest deviation being Core 7 from increment 10-40 mm (density of 2030 kg/m^3).

The density results from SGS Australia are presented in Appendix D. Dry density determinations were also obtained from Compressive Strength tests shown in Appendix M. The Densities are used to convert the % chloride by weight of concrete test results to % chloride by weight of cement.

3.2. Compressive strength

The compressive strength results are summarised in Table 1 and shown in Appendix M. An average compressive strength of 49.3 ± 12.7 MPa was observed. The cores from the floor and beneath the splash zones tended to be relatively high in compressive strength compared to the splash zone cores. Core 3 was extracted from the top of the west steps at the shallow end of the pool and yielded the lowest compressive strength of 31.5 MPa.

Table 1: Compressive strength results for core samples 3, 8, 10 and 13. The laboratory report is shown in Appendix M.

Core Number	Mass/Unit Volume (kg/m^3)	Compressive Strength (MPa)
3 – Splash	2140	31.5
8 – Floor	2640	60.5
10 – Splash	2300	49.5
13 – Beneath Splash	2600	55.5

3.3. Cement content

Table 2 shows a summary of the cement content results for Core 1, 3, 4, 5 and 7. The corresponding laboratory reports are shown in Appendix N.

Core 4 yielded the highest cement content as it had the lowest aggregate: cement ratio compared to the other cores tested. In contrast, Core 1 had the lowest cement content as it was observed to have a significantly greater number of aggregates compared to the other cores (eg. Observations of aggregate density, Appendix C) revealed the presence of 126 individual aggregates between 5-10 mm in size).

Table 2: Cement content results for Cores 1, 3, 4, 5 and 7. The laboratory report is presented in Appendix N. Note that only the top half of Core 5 and 7 were tested.

Core Number	Depth (mm)	CaO content (%wt Sample)	Cement content (%wt Sample)	Aggregate: Cement ratio (:1)
1 – Splash	109-124	5.6	8.8	10.1
3 – Splash	150-164	8.0	12.5	6.8
4 – Floor	105-120	11.1	17.4	4.5
5 – Beneath Splash	60-75 Top	7.1	11	7.8
7 – Beneath Splash	55-70 Top	7.1	11.2	7.7

3.4. Chloride concentration

Chloride testing was performed in sections of concrete by SGS Australia according to the testing schedule request presented in Appendix C. A detailed discussion is outlined in Section 5.2.

3.5. Carbonation of concrete

Carbonation is the ingress of carbon dioxide into concrete over time which causes a reaction, lowering the pH of the concrete from a high of about 12, down to around 9. At this lower pH, corrosion initiation can occur on any reinforcement steel present. The process of carbonation generally occurs as a front parallel to any concrete surface exposed to air and is revealed by spraying with phenolphthalein dye that stains pink in high pH areas or is colourless in carbonated areas. The carbonation test results are presented in Appendix L. The majority of the cores showed no carbonation on all layers.

Cores 4 and 12 showed carbonation on the topping layer, with the former being carbonated up to a depth of 8 mm. While this indicates the ingress of carbon dioxide through the topping of Core 4 and 12, there was no carbonation of the concrete itself. Therefore Core 4 and 12 are not considered to be carbonated. Core 8, a floor sample from the deep end, was carbonated up to a depth of 7 mm from both the topping and the bottom face. Once again the carbonation of the topping layer is ignored as the concrete of the pool side was not carbonated. Therefore Core 8 was only considered to be carbonated on the bottom face up to a depth of 7 mm. Core 6, having no carbonation, was extracted from the floor at the middle of the pool and had a tile over it.

Core 10b, extracted from the deep end splash zone, is carbonated only on the tile/topping layer. Therefore the concrete for Core 10b is considered to be free of carbonation. All other splash zone cores (Cores 1, 3, 9 and 11) had no carbonation observed.

Core 13 was a beneath splash zone core, extracted from the west pool wall and had a carbonation depth of 10 mm on the bottom side. Core 7 is beginning to carbonate at both the topping and bottom face as the pink colouring from the phenolphthalein spray was lighter than the rest of the core. However as a pink colour was still observed, no carbonation was reported on the laboratory report (Appendix L). All other beneath the splash zone cores (Cores 2 and 5) had no carbonation observed.

4. Durability assessment from common mechanisms

Durability assessments were calculated from the test results, for the common mechanisms of reinforcement deterioration including chloride attack and carbonation.

4.1. Background

Metal items embedded in concrete have the capability of rusting in the presence of oxygen and water, but generally, this reaction is slow in the high pH environment of young concrete. This is since a stabilised layer of rust occurs on the outside of the metal known as the "passivating layer". To commence corrosion some other agent is required to destabilise this layer.

In a swimming pool, limited oxygen is present underwater thus in submerged concrete reinforcement corrosion is retarded.

The principal environmental hazard to reinforced concrete of a swimming pool is chloride attack (chloride being the major anion of sea salt) resulting from the use of swimming pool chemicals plus a comparatively minor amount deposited from the atmosphere (blown in from the ocean). Diffusion underwater or through repeated wetting ultimately transports the salt to the reinforcement. Owing to the nature of the reaction with the surface of the steel, chloride is a catalyst for rusting. A probabilistic threshold for corrosion initiation is of the order of 0.29 % by weight of cement, in air; and approximately 0.78 % by weight of cement under water.

A second hazard to reinforcement in concrete is carbonation. This is an insidious invisible form of degradation of concrete which occurs as a result of gaseous intrusion into concrete by ordinary atmospheric carbon dioxide which causes the initial high pH of the concrete to progressively reduce from about 12 to 9. This can be seen as a line or "front" parallel to the surface progressing into the depth of the concrete by using the indicator phenolphthalein which shows a pink colour in basic areas that have yet to be carbonated and appears colourless in more acidic carbonated areas. The net result of lower pH at the reinforcement level is to depassivate (destabilise) the surface of the steel predisposing it to rusting. Carbonation is relevant if there are voids beneath the pool, in the splash zone and surrounds exposed to air.

4.2. Remaining service life from chloride attack

The SGS test results for chloride content is shown in Appendix E. The testing regime was carried out in increments of 15 mm, some at reinforcement depth where possible. Due to the relatively deep cover to the reinforcement and the different concrete types observable within some cores, the chloride testing increments were typically taken from the bottom end of the cores, with some having an increment close to the top of the core.

Fick's Law modelling was carried out according to the approach advocated in the recently published "Durability" guideline of the Concrete Institute of Australia (2014).

Probabilistic thresholds for corrosion activation at the reinforcement were assumed to be 0.29 % Cl by weight of cement for splash zone samples and 0.78 % Cl by weight of cement for beneath the splash zone and floor samples (Paramasivam, Lim and Ong, Performance of Reinforced Concrete Piles Exposed to Marine Environment, 2001).

Chloride diffusion coefficients were calculated according to the inverse of the following equation using a Newton-Rhapson style approach to calculate for D:

$$C_i(x,t) = C_0 + (C_S - C_0) erfc \frac{x}{2\sqrt{Dt}} \qquad \text{Equation 1}$$

Where *x* is the depth (mm)

C_i = concentration of chloride ions (%Cl by weight of cement) at depth x

C_S =concentration at the surface of the concrete (%Cl by weight of cement)

C_0 = initial historical chloride concentration of concrete element (%Cl by weight of cement)

D = diffusion coefficient (mm^2/year)

t = time (years)

$erfc$ = complementary error function

The method is sensitive to selection of C_s *and* C_o parameters. C_0 was determined experimentally from the chloride result of each core at 120 mm depth or the deepest tested increment. The C_S value was determined in two ways: both experimentally and theoretically as follows.

Experimentally: The chloride concentration data was fitted with an exponential trendline using the built in feature from Microsoft Excel 2010. The trendline equation was used to extrapolate the chloride concentration when the depth x = 0 mm. This concentration value is C_S and was calculated for each core. A linear trendline was fitted to Core 1 as an exponential trendline was not suitable.

Theoretically: Fitting the data with a Fick's Law curve (Equation 1) is the more usual approach to this work and provides an estimate of both the C_S value (% Cl by weight of cement) and the D (mm^2/year) value. Once both values are incorporated into the data, an estimate of the remaining service life can be obtained. The remaining service life is determined when time is increased to effect the intersection of the Fick's Law curve to the appropriate % Cl threshold and the shortest reinforcement depth. The shortest reinforcement depth is used instead of the detected reinforcement depth for each core sample to estimate the "worst case scenario".

The typical cover to the pool within the splash and floor zones was greater than 90 mm which is evident in many aquatic centre pools. However, beneath the splash zone cores below the tiled pool lip (Cores 2, 7 and 13) had horizontal covers of 50-60 mm. Core 5 was also within the beneath the splash zone but was extracted higher up the pool wall than the other beneath the splash zone cores (the approximate locations of extraction for each core type is shown in Figure 5, Section 2).

4.2.1. Fick's Law Projections of service life

The Fick's Law Projections of remaining service life is presented in Appendix H (% Cl by weight of cement) and Appendix K (% Cl by weight of concrete). Table 3 summarises the projections for nine cores tested for chloride content. Three cores from each zone (splash, beneath splash and floor) were tested for chloride content across the core lengths and fitted with Fick's Law in order to predict the remaining service life (the results of the analysis are summarised in Table 3a). From this fit, there was a relatively large variation in surface chloride content C_S and the maximum observed is 1.40 % Cl by weight of cement (Core 3, highlighted in yellow). Table 3b calculates the projection when C_S = 1.40 % for all nine core samples to provide projections for the "worst case scenario". The graphs for these projections were not included in this report but can be provided upon request.

Table 3: A summary of projections a) as fitted to Fick's Law with variable D and C_S values. b) as fitted to Fick's Law with variable *D* and C_S = 1.40% (1.40% is the maximum C_S value observed in (a) and is highlighted in yellow. The values highlighted in red correspond to Cl concentration exceeding their respective Cl threshold while values highlighted in green have not exceeded their respective Cl threshold. A dash corresponds to the Chloride concentration not being exceeded due to the C_S value being below the respective Cl threshold. Note that these projections apply only when the surface is the pool side.

Core	Cover (mm)	Concrete type	**a)** Fick's Law Projection - variable D & C_S				**b)** Fick's Law Projection - variable D, C_S=1.4%Cl wt cement			
			D (mm²/ year)	C_S (% Cl wt of cement)	Years to reach Low Cl Threshold (0.29 % Cl by weight of cement)	Years to reach High Cl Threshold (0.78 % Cl by weight of cement)	D (mm²/ year)	C_S (% Cl by wt of cement)	Years to reach Low Cl Threshold (0.29 % Cl by weight of cement)	Years to reach High Cl Threshold (0.78 % Cl by weight of cement)
1 – Splash	200	2	30	0.34	0	-	15	1.40	0	800
3 – Splash	180	3	35	1.40	40	500	35	1.40	40	500
4 – Floor	110	3	30	0.71	73	-	18	1.40	60	490
5 Top – Beneath Splash	120	2	30	1.10	0	50	20	1.40	0	20
5 Bottom – Beneath Splash	120	2	30	0.65	0	-	10	1.40	0	130
6 – Floor	110	3	30	0.50	110	-	15	1.40	50	520
7 Top – Beneath Splash	60	3	30	0.87	0	500	15	1.40	0	50
9b – Splash	130	2	30	0.70	0	-	10	1.40	0	900
12 – Sloped Floor	90	3	35	0.55	20	-	16	1.40	20	430

The Low Cl Threshold (0.29 % Cl by weight of cement) represents the chloride concentration limit, above which reinforcement steel is expected to corrode within the splash zone. From the Fick's Law projections (Table 3), the splash zone Core 1 and 9b had chloride concentrations greater than the Low Cl Threshold, therefore had zero years remaining service life as the embedded reinforcement is expected to be corroding at the time of the core survey. Core 3 had the highest C_S value at 1.40 % Cl by weight of cement but had not exceeded the Low Cl Threshold and had a projected service life of 40 years. This variation in projection is probably due to Core 1 and 9b being from the pool side while Core 3 is from the stairs.

The High Cl Threshold (0.78 % Cl by weight of cement) represents the chloride concentration limit for all submerged zones (beneath the splash and floor core samples). Of the cores tested for chloride content within these zones, the shortest projected service life is 20 years (Core 5 Top half considering the projection when C_S = 1.40 % Cl by weight of cement). Core 7 bottom half (beneath the splash zone) had embedded reinforcement steel with no evidence of corrosion. Core 7 top half is projected for 50 years (when C_S = 1.40 % Cl by weight of cement). The lack of corrosion is therefore in agreement with the significant remaining service life at least for beneath the splash zone around Core 7.

The beneath splash and floor projections represented by a dash in Table 3a correspond to Fick's Law Projections not being able to exceed the High Cl Threshold since the corresponding C_S value is less than the High Cl Threshold (Core 4, 5 Bottom half, 6 and 12). Considering the age of the pool (approximately 47 years at the time of the core survey), C_S is assumed to have reached equilibrium and will not increase over time. According to Fick's Law Projections, this suggests that the chloride content will not reach the concentration necessary for corrosion initiation at these areas. When C_S is increased to 1.40 % Cl by weight of cement (Table 3b), projections are observed for these cores, with the shortest projection being 130 years for Core 5 Bottom half. Even when C_S is increased to the maximum observed value of 1.40 % Cl by weight of cement, there is still a significant projected service life.

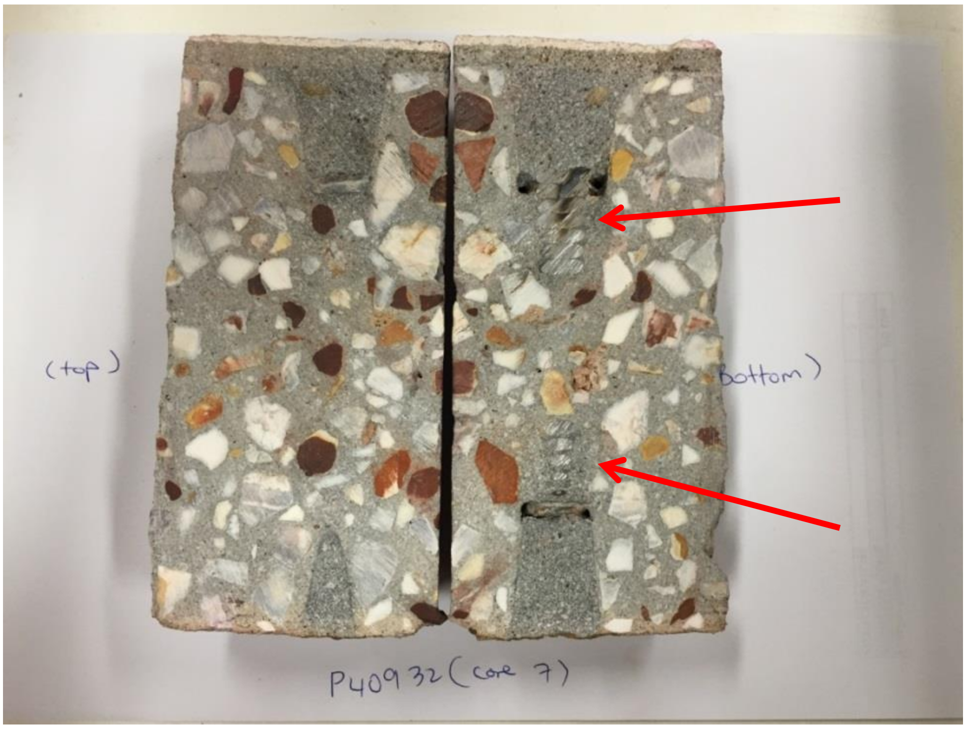


Figure 14: Core 7 (beneath the splash zone) was found to have reinforcement steel within the bottom half of the core (as indicated by the arrows). No evidence of corrosion on the steel was observed.

4.2.2. The influence of the pool wall void

It must be remembered that the projections in Table 3 does not consider the presence of voids or air pockets on the other side of the concrete (soil side). As described in Section 2.1, a void was observed behind Core 7 and 13 (beneath the splash zone cores on the east and west sides of the pool respectively). A schematic showing the location of the void is shown in Figure 15. If the void was completely filled with air, all surfaces in contact with the void would be considered as splash zone surfaces. Core 13 is carbonated 10 mm on the void side according to the carbonation report (Appendix L), suggesting the air (at least on the west pool wall behind Core 13) is being replenished and the susceptibility to carbonation (ie. Corrosion of reinforcement) is increased.

While Core 7 and 13 are beneath the splash zone samples on the pool, they would be considered as splash zone samples on the void side. Figure 16 shows the Fick's Law fit (% Cl by weight of cement) for Core 7. From the void side, the chloride concentration is greater than the Low Cl Threshold and therefore the reinforcement is expected to already be corroding. Although no corrosion was observed within Core 7 (Figure 14), corrosion may have initiated elsewhere along the void. Figure 15 shows a second layer of reinforcement within the pool wall closer to the floor with approximately 50.8 mm (2 inch) cover on the void side. With less cover on the void side the second layer of reinforcement (that on the void side) is more susceptible to corrosion.

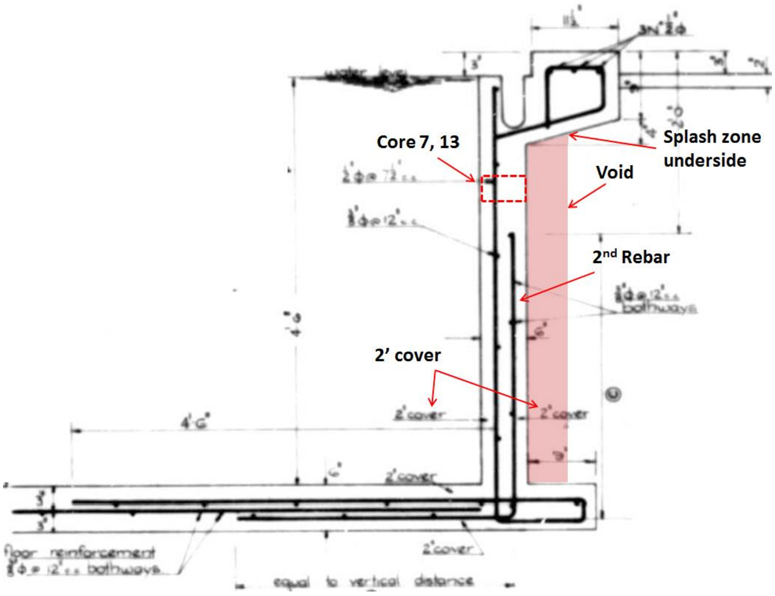


Figure 15: A schematic detail of the pool wall showing the location of Core 7 and 13 with respect to the pool. The cover of rebar in the pool wall is 2 inches according to the drawings (approximately 50.8 mm) on both the pool side and the void side. The void is assumed to run along the whole length of the pool walls and the full height (as indicated in red).

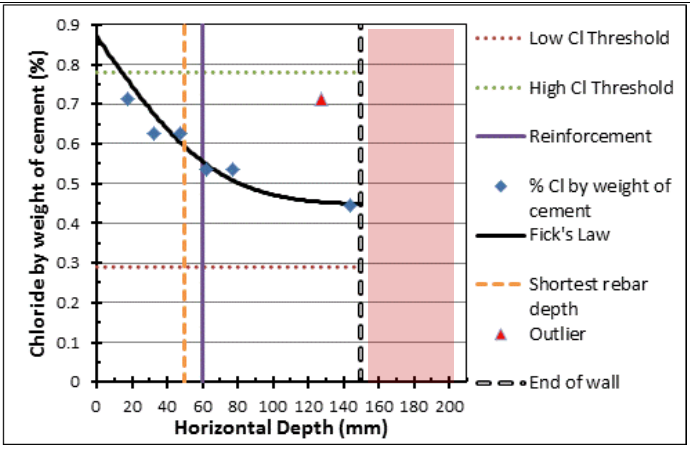


Figure 16: Fick's Law fitting (% Cl by weight of cement) for Core 7 top half. Classified as a beneath the splash zone core from pool side and therefore below the High Cl Threshold (green dotted line). From void side, it is a splash zone and had exceeded the Low Cl Threshold (red dotted line). The void is highlighted in red.

The least cover on the pool side for splash zone cores was at Core 9b with 130 mm cover. The underside of the splash zone (void side) would remain a splash zone but with the lesser cover to reinforcement of approximately 50.8 mm (2 inches similar to the cover for the pool wall). The chloride concentration of Core 9b exceeded the Low Cl Threshold and therefore corrosion is expected on the reinforcement. The lesser cover on the void side makes the susceptibility of reinforcement to corrosion greater on the void side of the splash zone.

4.2.3. Fitting Core 5 and 7 Chloride content data as a splash zone sample

Fick's Law Projections are one dimensional and do not represent the rate of chloride penetration from multiple directions. Core 7 was extracted directly beneath Core 5 and the top and bottom half tested for both cores to determine if a chloride gradient was present within the height of the pool wall beneath splash zone (The bottom half of Core 7 could not be tested due to the presence of embedded reinforcement steel). Figure 17 shows the approximate locations from which chloride content data was gathered from Core 5 and 7 (the cores shown by the green dotted lines) to emulate the change in chloride content as a splash zone core (shown by the purple dotted line). The blue diamonds and red triangles represent the approximate location of the core increment tested for chloride content.

Figure 18 shows this data fitted with Fick's Law. All data points were greater than the Low Cl Threshold, therefore would have a projected service life of 0 years (since it is considered as a splash zone). There appeared to be a decreasing gradient of chloride content from the top half to the bottom half of Core 5. Deeper in the model core, the data from Core 7 was greater than the expected chloride content according to Fick's Law. It is not clear why this is the case as there are a number of factors which can influence the chloride content in Core 7. This includes the presence of a void behind Core 7 and the pool side surface of Core 5 was tiled as compared to the rendered surface of Core 7. Nevertheless, the exceedance of the Low Cl Threshold is in agreement with the splash zone Cores 1 and 9, which are all adjacent to the pool wall.

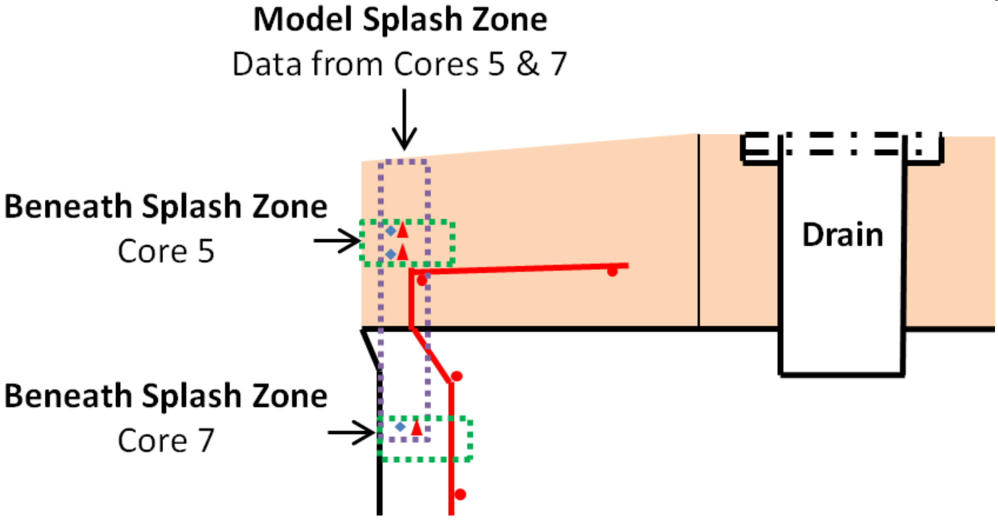


Figure 17: Schematic showing the location of Core 5 and 7 with respect to the pool wall (dotted green line). The purple dotted line represents the model splash zone core being represented by the select chloride concentration data from both Core 5 and 7. The blue set of data is from the 60-75mm increment of Core 5 (top and bottom half) and the 55-70mm increment from Core 7. The red set of data is from the 75-90mm increment of Core 5 (top and bottom half) and the 70-85mm increment from Core 7.

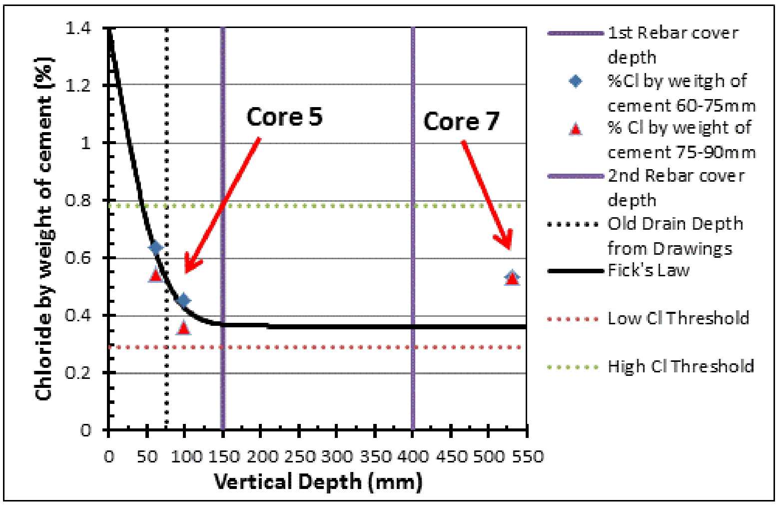


Figure 18: Fitting Fick's Law for the chloride concentration data for Core 5 and 7. The blue set of data is from the 60-75mm increment of Core 5 (top and bottom half) and the 55-70mm increment from Core 7. The red set of data is from the 75-90mm increment of Core 5 (top and bottom half) and the 70-85mm increment from Core 7.

4.3. The effect of carbonation

4.3.1. Calculation of carbonation projection

Table 4 shows the calculations for the expected carbonation projection towards the reinforcement steel using the simplified Fick's Second Law formula:

$$d = k\sqrt{t} \qquad \text{Equation 2}$$

where d = the penetration distance (mm)

k = constant dependent on concrete environment

t = time (years)

A publication of the Swedish Concrete Research Institute “Carbon dioxide uptake during concrete life cycle – State of the Art 2005” provides *k* values for different concrete strengths and exposure zones.

Table 4 shows the carbonation projection (in years) for the shortest cover depth from each zone. Although carbonation was observed on a number of core samples (Cores 4, 8, 10b, 12 and 13), the reinforcement steel is considered to be safe from carbonation related mechanisms of corrosion attack.

The pool side of the floor zone Core 8 is relatively safe from carbonation with a carbonation projection greater than 500 years, however on the soil side the cover is only 37 mm (145 mm subtract 90 mm pool side cover and 18 mm assumed reinforcement diameter, according to observations on site and Appendix O). The cover for the soil side of Core 4 is even shorter at 17 mm (145 mm subtract 110 mm pool side cover and 18 mm assumed reinforcement diameter, according to site observations and Appendix O). If there were no voids between the slab and the soil, the carbonation projection is 514 years. Due to carbonation on the bottom side of Core 8 (floor, deep end), a pocket of air/void (although not observed on site) was likely present, resulting in a projection of 289 years if the air pocket is beneath Core 4.

Similarly the void observed behind the beneath the splash zone cores 7 and 13, can also significantly reduce the carbonation projection down to 25 % of the projection on the pool side, but in this case both sides is still projected for more than 500 years (beneath splash – pool side and formwork void). The cover for any splash zones in contact with the void (referred to as Splash – formwork void) is approximately 50 mm according to the drawings. This will be identical to the void side of the beneath the splash zones, both will act as splash zone areas when in contact with the void. Therefore the projection will be the same (greater than 500 years). However if the void was present beneath Core 3, the carbonation projection on the void side is reduced to 44 % of other splash zone cores on the void side. This is due to both the compressive strength of the concrete being 31.5 MPa (less than 35 MPa) and the cover depth is approximated to be 50 mm.

The shortest carbonation projection is still a relatively long service life at 289 years. The significant projections are considered due to the compression strength of the concrete being relatively high, the majority of samples being greater than 35 MPa (compressive strength results presented in Appendix M). The splash zone Core 3 did result in a compression strength of 31.5 MPa (Core 3 in Table 1) but the concrete strength is high enough to yield a projected carbonation time of greater than 500 years. This clearly indicates that carbonation of the pool is not the critical factor in terms of the failure of the swimming pool.

Table 4: Calculations for the projection of carbonation reaching the reinforcement steel. Unless stated, all calculations assumed the concrete had a compression strength greater than 35 MPa. The k constants were referenced from Bjorn Lagerblad "*Carbon dioxide uptake during concrete life cycle – State of the art*", Swedish Cement and Concrete Research Institute 2005.

Location	Environment	Shortest reinforcement depth (mm)	k constant	Carbonation Projection to reach reinforcement (years) $t = (d / k)^2$
Splash – pool side Concrete strength 31.5 MPa (Core 3)	Exposed	130	1.5	> 500
Splash – formwork void Concrete strength 31.5 MPa (Core 3)	Exposed	50	1.5	> 500
Splash – pool side	Exposed	130	1	> 500
Floor – pool side	Wet / Submerged	90	0.5	> 500
Floor – soil side	Buried	17	0.75	514
Floor – air pocket	Exposed	17	1	289
Beneath the splash zone – pool side	Wet / Submerged	50	0.5	> 500
Splash / Beneath splash – formwork void	Exposed	50	1	> 500

4.3.2. Estimation of Environment using Fick's Second Law

The surfaces in contact with the void behind Core 7 and 13 were assumed to be splash zone concrete. Splash zone environments are classified as an "Exposed" environment from Bjorn Lagerblad "*Carbon dioxide uptake during concrete life cycle – State of the art*", Swedish Cement and Concrete Research Institute 2005.

To confirm this, calculations for determining the k constant from Equation 2 were performed and presented in Table 5 by assuming d (mm) = carbonation depth and t = 47 years. The back side of Core 13 was found to be in an exposed environment which is in agreement with the assumption that surfaces in contact with the void are considered to be splash zone concrete.

Although no voids were observed between the floor slab and the soil, carbonation was observed on the soil side of Core 8. From Table 5, the soil side of Core 8 was found to be within an exposed environment supporting the presence of air pockets beneath the slab.

For both Core 8 and 13, the ingress of the carbonation front on the back side of the cores suggest the air within the void/air pocket is being replenished.

Table 5: Reverse calculations of Fick's Second Law to determine the expected environment in the concrete cores which were carbonated on the back side. d (mm) is the carbonated depth according to the SGS report (Appendix L) and t is the age of the pool being 47 years.

Core	Back side Carbonation of core (mm)	k = d / √t	Expected Environment
8 – Floor deep end	0-7	0 – 1.02	Exposed
13 – Beneath Splash mid pool	0-10	0 – 1.46	Exposed

5. Comment

5.1. The carbonation on the bottom side of Core 13 suggests the air within the void is being replenished (this is supported by the findings in Section 5.3.2.), which increases the risk of carbonation of all concrete in contact with the void.

Ingress of carbon dioxide through the render of floor samples (Core 4, 8 and 12) was observed, some samples were even carbonated on the bottom side of the core. However, the cover to the reinforcement and the high strength of the concrete is still sufficient to provide resistance to the detrimental effects of carbonation.

If a void is present behind the pool wall or floor, the shortest carbonation projection is 289 years. These projections suggest that the pool is safe from carbonation-based mechanisms of corrosion attack for a significant length of time (assuming that the concrete is free of cracks).

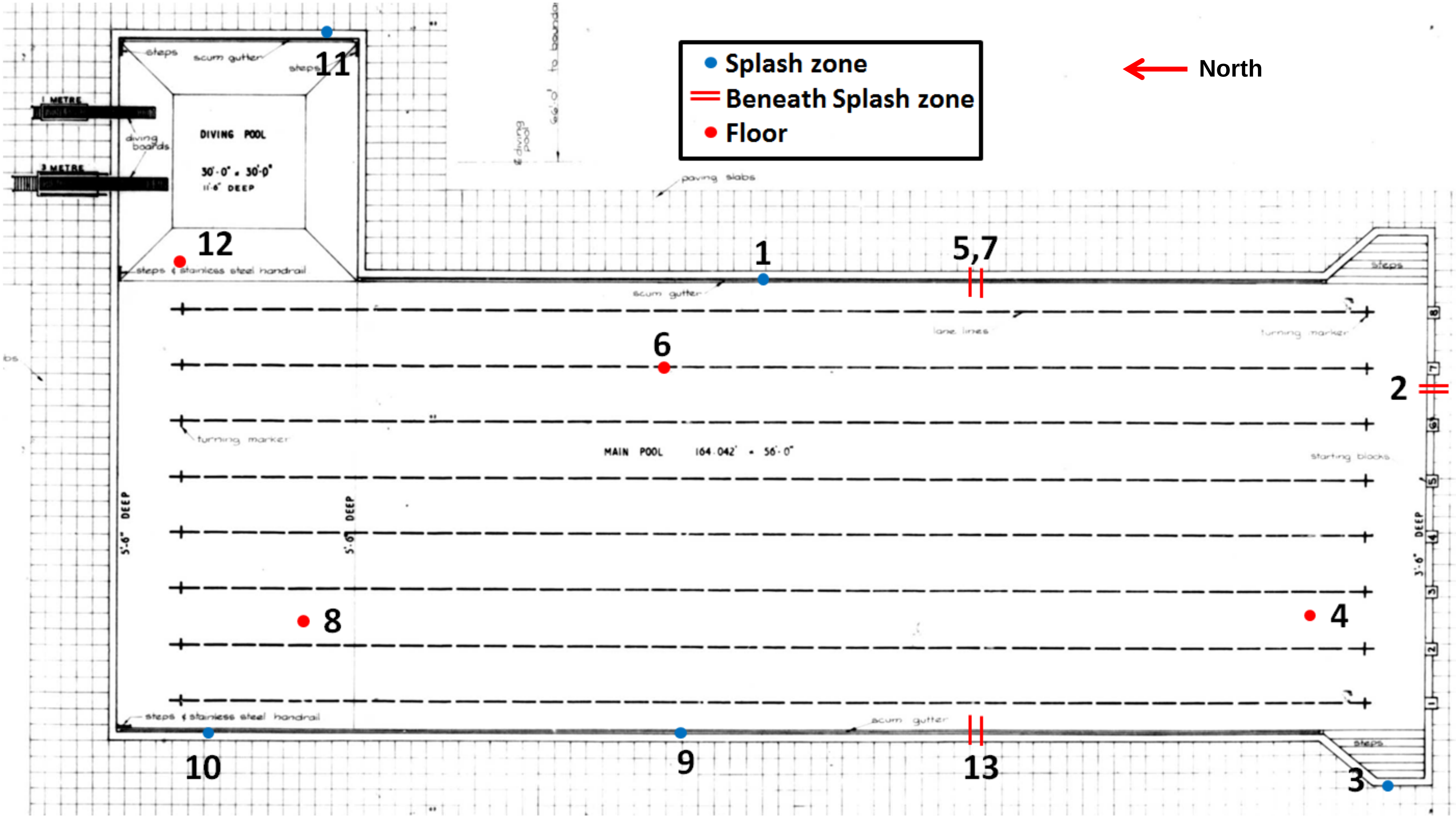
5.2. Our interpretation of the chloride data is that reinforcement steel in areas adjacent to the pool drain on the top side of the lip of the pool, or areas exposed to air during the operation of the pool (referred to as the splash zone) are at risk of corrosion initiation and have a projected service life of zero years.

5.3. The areas of the pool wall which are submerged during the operation of the pool (referred to as beneath the splash zone) had chloride content less than the discovered High Cl Threshold of 0.78 % Cl by weight of cement. While this would normally mean that the chloride concentration at these areas had not reached the critical concentration for reinforcement steel to corrode, the presence of an air-filled void behind the east and west pool walls means the back side can no longer be considered as beneath the splash zone concrete. As they are exposed to air, they are considered as splash zone concrete. Being splash zone concrete when in contact with the void and the chloride content data exceeding the Low Cl Threshold; the projected service life is reduced to zero years as the possibility of corrosion on the reinforcement (particularly close to the back side of wall having a cover of approximately 50 mm) is increased.

5.4. The pool floor generally had chloride concentrations less than the High Cl Threshold (0.78 % Cl by weight of cement) indicating that the onset of corrosion will not have occurred. While no void was observed between the floor and the concrete slab floor, the 7 mm depth of carbonation observed on the bottom side of Core 8 suggests there is a void or at least a pocket of air beneath that particular site.

The presence of an air pocket or void beneath the slab would cause the soil side of the concrete to be classified as a splash zone concrete. The cover on the soil side would be shorter at about 17 mm (Core 4 - 145 mm subtract 110 mm pool side cover and 18 mm assumed reinforcement diameter, according to observations on site and Appendix O). A shallow reinforcement cover of 17 mm will reduce the resistance to corrosion initiation. The condition of the floor on the soil side is therefore in question and it dependent on the presence, size and quantity of air pockets beneath the slab.

Appendix A: Core survey locations



Appendix B: Photographs of the core survey and repair

Figure B.1: View of the pool from the south east corner.

Figure B.2: View of the dive pool from the east side.

Figure B.3: View of the pool from the north east corner.

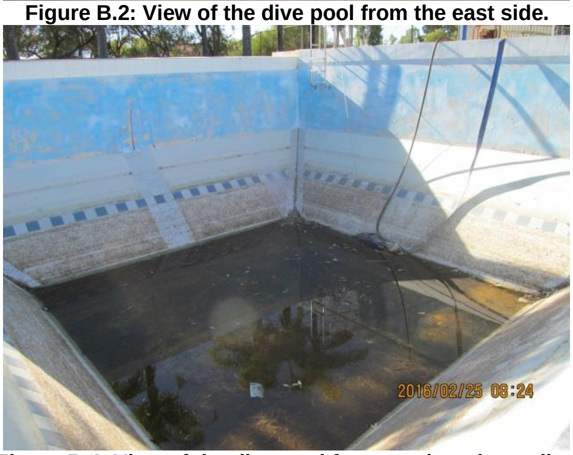


Figure B.4: View of the dive pool from north end standing inside the pool.

Figure B.5: View of the pool from the close to the north west corner.

Figure B.6: View of the pool standing inside the pool at the north west corner.

Figure B.7: The core hole at Location 1 on the east side of the pool.

Figure B.8: Photograph of Core 1.

Figure B.9: Repaired core hole 1 after curing overnight.

Figure B.10: Repaired core hole 1 taped over with polythene sheet.

Figure B.11: The core hole at Location 2 on the southend of the pool.

Figure B.12: Photograph of Core 2.

Figure B.13: Repaired core hole 2 after curing overnight.

Figure B.14: Repaired core hole 2 taped over with polythene sheet.

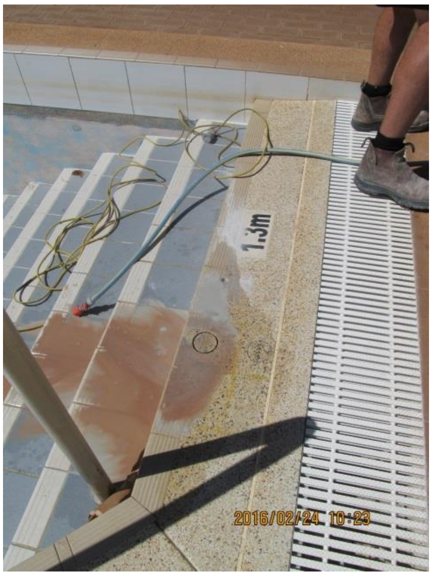


Figure B.15: The core hole at Location 3 on the south west corner of the pool.

Figure B.16: Photograph of Core 3.

Figure B.17: Repaired core hole 3 after curing overnight.

Figure B.18: Repaired core hole 3 taped over with polythene sheet.

Figure B.19: The core hole at Location 4 on the south west of the pool.

Figure B.20: Photograph of Core 4.

Figure B.21: Repaired core hole 4 after curing overnight.

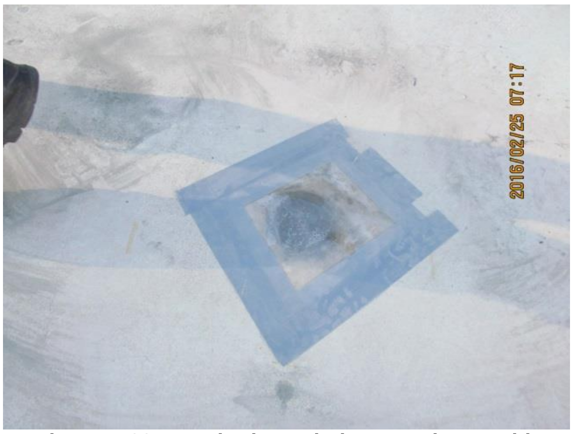


Figure B.22: Repaired core hole 4 taped over with polythene sheet.

Figure B.23: The core hole at Location 5 on the east side of the pool.

Figure B.24: Photograph of Core 5.

Figure B.25: Repaired core hole 5 after curing overnight.

Figure B.26: Repaired core hole 5 taped over with polythene sheet.

Figure B.27: The core hole at Location 6 close to the east side of the pool.

Figure B.28: Photograph of Core 6.

Figure B.29: Repaired core hole 6 after curing overnight.

Figure B.30: Repaired core hole 6 taped over with polythene sheet.

Figure B.31: The core hole at Location 7 on the east side of the pool.

Figure B.32: Photograph of Core 7.

Figure B.33: Repaired core hole 7 after curing overnight.

Figure B.34: Repaired core hole 7 taped over with polythene sheet.

Figure B.35: The core hole at Location 8 close to the north west corner of the pool.

Figure B.36: Photograph of Core 8.

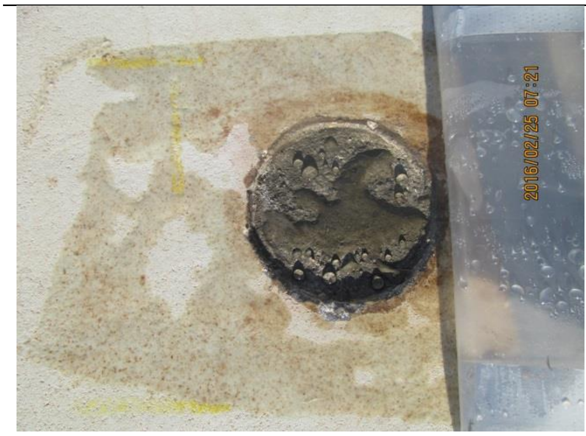


Figure B.37: Repaired core hole 8 after curing overnight.

Figure B.38: Repaired core hole 8 taped over with polythene sheet.

Figure B.39: The core hole at Location 9 on the west side of the pool.

Figure B.40: Photograph of Core 9.

Figure B.41: Repaired core hole 9 after curing overnight.

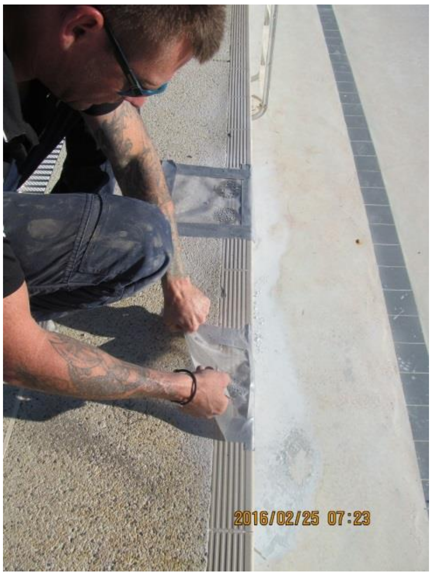


Figure B.42: Repaired core hole 9 taped over with polythene sheet.

Figure B.43: The core hole at Location 10 on the north west corner of the pool.

Figure B.44: Photograph of Core 10b.

Figure B.45: Repaired core hole 10 after curing overnight.

Figure B.46: Repaired core hole 10 taped over with polythene sheet.

Figure B.47: The core hole at Location 11 on the east side of the dive pool.

Figure B.48: Photograph of Core 11.

Figure B.49: Repaired core hole 11 after curing overnight.

Figure B.50: Repaired core hole 11 taped over with polythene sheet.

Figure B.51: The core hole at Location 12 on the sloped floor of the dive pool.

Figure B.52: Photograph of Core 12.

Figure B.53: Repaired core hole 12 after curing overnight.

Figure B.54: Repaired core hole 12 taped over with polythene sheet.

Figure B.55: The core hole at Location 13 on the west side of the pool.

Figure B.56: Photograph of Core 13.

Figure B.57: Repaired core hole 13 after curing overnight.

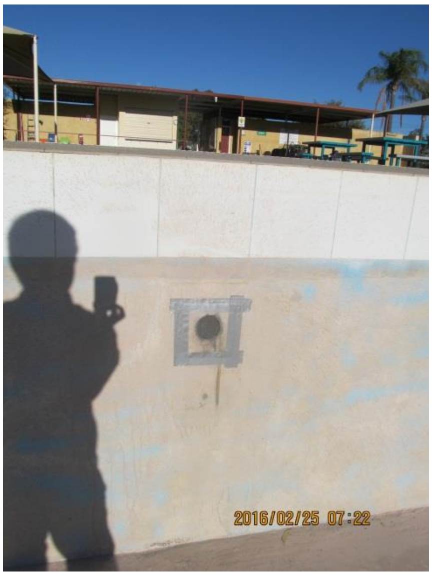


Figure B.58: Repaired core hole 13 taped over with polythene sheet.

Appendix C: Testing schedule sent to SGS Australia on 9/03/2016

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Our Ref: 16038

9 March 2016

Attention: Nhu Nguyen
SGS Australia Pty Ltd
5 Yelland Way
Bassendean WA 6054

Via Email: nhu.nguyen@sgs.com

Dear Nhu,

Re: Morawa Aquatic Centre Investigation

Please review for reasonableness and confirm the following testing schedule before any tests are conducted. We have sent to your laboratory 13 core samples. Information on each core sample, including location, orientation of the core, reinforcement cover, tests to be conducted and the increments for the samples are presented in the table on page 3 onwards of this letter.

Variations in the increments are due to the presence of tiles, intermediate material, render toppings and different types of concrete within each core. All Cores are to be tested for carbonation as soon as possible and accompanied by photographic record.

Please hold Cores 2b and 11b subsequent to the carbonation testing and don't test until further notice.

Cores 3, 8, 10 and 13 are to be tested for compression strength. For core 3, only the concrete type adjacent to the topping will be tested for compression strength while the second half is to be tested for Density and chloride content. Please advise if this is possible.

Cores 5 and 7 are to be cut in half along the length of the core prior to chloride testing. Details of this are presented in page 2.

Please do not hesitate to contact me should you have any question on this.

Yours sincerely

Dr Anthea Airey BSc(Hons) PhD MBA MRACI CChem
Senior Scientist
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AUSTRALIAN ENGINEERING EXCELLENCE AWARDS 2011 WINNER

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D:\Projects\16xxx\16038\Admin\Letters\rc-2016-03-04 SGS Lab Test Request - Morawa Swimming Pool.docx Page | 1

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Cutting Core 5 and 7

Subsequent to carbonation testing, Cores 5 and 7 are to be cut in half along the lengths of their respective cores (along the red dotted line in Figure 1). Both the top and the bottom halves are to be tested for chloride content separately according to the increments detailed in Table overleaf.

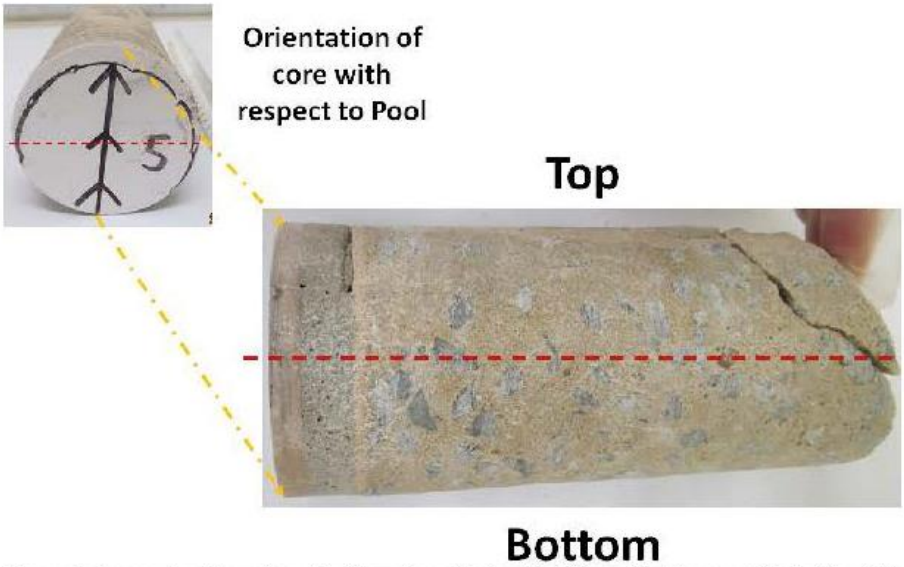

Figure 1: Approximate location of cutting along the length of Core 5 is shown on the bottom left photograph. Testing is to be done on both the top and bottom halves of the core. The orientation of the core is shown by the photograph on the top left (the approximate line for cutting is also shown).

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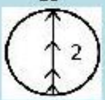
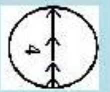
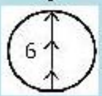
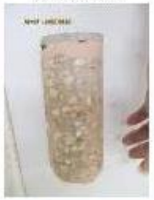
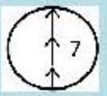
Core & Orientation	Zone & Core Photograph	Core diameter (mm)	Vertical cover (mm)	Horizontal cover (mm)	Notes	Increment Material	Observations of aggregate density	Carbonation	Increment depth (mm)	Density	Chloride test increments (mm)	Other tests to be performed (mm)
1 	Splash 	68	200	120	Middle east side of pool Core depth 169mm	Tile - Stone Topping		✓	0-8	Retain 0-64, Don't test		
						Intermediate Material + Stone Topping	Stone topping Evenly distributed, mainly stones <5mm		8-22			
						Intermediate Material + Concrete 1	Concrete 1: 1x 12mm, 44x <10mm, balance <5mm		22-64			
						Concrete 2	Evenly distributed, 2x 15mm, 9x 12mm, 126x <10mm, balance <5mm		64-169	109-124	64-79 Retain 79-109, Don't test 109-124 124-139 139-154 154-169	**Cement Content.** Report Cement: aggregate ratio 109-124
2b 	Beneath splash 	74	340	60	Beneath shallow end starter block Core depth 135mm	Topping		✓	0-5	Hold core after carbonation test		
						Intermediate Material			5-10			
						Concrete 3	Evenly distributed, 8x <20mm, 28x <15mm, 33x <10mm, balance <5mm		10-135			

Core & Orientation	Zone & Core Photograph	Core diameter (mm)	Vertical cover (mm)	Horizontal cover (mm)	Notes	Increment Material	Observations of aggregate density	Carbonation	Increment depth (mm)	Density	Chloride test increments (mm)	Other tests to be performed (mm)
3 	Splash 	68	180	120	Top of west stairs Core depth 164mm	Tile - Stone Topping			0-9	Retain 0-90, Don't test		
						Intermediate Material + Stone Topping + Concrete 1			9-13			
						Intermediate Material + Concrete 1	Evenly distributed, mainly stones <5mm	✓	13-35			**Compressive strength 13-90** Retain crushed material after test
						Concrete 1	Segregation towards stone top side Stone top side: 6x <6mm, 26x <10mm, balance <5mm Tile side: 5x <15mm, 10x <10mm, balance <5mm		35-72			
						Intermediate Material 2 + Concrete 1	Evenly Distributed, 1x <25mm, 2x <20mm, 14x <15mm, 22x <10mm, balance <5mm		72-90			
						Concrete 3			90-164	90-164	90-105 105-120 120-135 135-150 150-164	

Core & Orientation	Zone & Core Photograph	Core diameter (mm)	Vertical cover (mm)	Horizontal cover (mm)	Notes	Increment Material	Observations of aggregate density	Carbonation	Increment depth (mm)	Density	Chloride test increments (mm)	Other tests to be performed (mm)
4 	Floor 	74	110	-	Shallow end Core depth 144mm No Void between slab and soil	Topping		✓	0-9	Retain 0-14, Don't test		
						Topping + Concrete 3			9-14			
						Concrete 3	Evenly distributed, 2x <25mm, 12x <20mm, 29x <15mm, 22x <10mm, balance <5mm		14-144		14-29 Retain 29-75, Don't test 75-90 90-105 105-120 120-135 Retain 135-144, Don't test	
5 	Beneath splash 	74	150	120	Above first rebar on pool wall Core depth 120mm	Tile		✓	0-6	Retain 0-18, Don't test		
						Intermediate Material			6-18			
						Concrete 2	Segregation towards bottom 1/3 of core: Bottom: 7x <15mm, 46x <10mm, balance <5mm top: 1x <30mm, 12x <10mm, balance <5mm **Test both top and bottom**		18-120		18-33 Retain 33-60, don't test 60-75 75-90 90-105 105-120	**Cement content 60-75.** Report Cement: aggregate ratio

Core & Orientation	Zone & Core Photograph	Core diameter (mm)	Vertical cover (mm)	Horizontal cover (mm)	Notes	Increment Material	Observations of aggregate density	Carbonation	Increment depth (mm)	Density	Chloride test increments (mm)	Other tests to be performed (mm)
6 	Floor tiled 	74	110		Middle of pool through tile Still drilling up to 170 mm depth Core depth 158mm	Tile			0-8	Retain 0-27, don't test		
						Intermediate Material			8-19			
						Intermediate Material + Concrete 3			19-27			
						Concrete 3	Evenly distributed, 1x <25mm, 9x <20mm, 22x <15mm, 40x <10mm, balance <5mm	✓	27-158		27-42 Retain 42-75, don't test 75-90 90-105 105-120 120-135 Retain 135-158, Don't test	
7 	Beneath splash 	74	150	60	Beneath first rebar and Core 5 Core depth 153mm	Topping			0-3	Retain 0-10, don't test		
						Intermediate Material			3-10			
						Concrete 3	Evenly distributed, 3x25mm, 10x <20mm, 26x <15mm, 63x <10mm, balance <5mm **Test both top and bottom**	✓	10-153		10-25 25-40 40-55 55-70 70-85 Retain 85-120, don't test 120-135 Retain 135-153, don't test	**Cement content 120-135.** Report Cement: aggregate ratio

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Core & Orientation	Zone & Core Photograph	Core diameter (mm)	Vertical cover (mm)	Horizontal cover (mm)	Notes	Increment Material	Observations of aggregate density	Carbonation	Increment depth (mm)	Density	Chloride test increments (mm)	Other tests to be performed (mm)
8 	Floor 	74	90	-	Deep end Core depth 136mm No void between slab and soil	Topping			0-16		Retain 0-22, Don't test	
						Topping + Concrete 3			16-22			
						Concrete 3	Evenly distributed, 1x <30mm, 2x <25mm, 6x <20mm, 22x <15mm, 42x <10mm, balance <5mm	✓	22-136	22-136		**Compression strength, cement content 22-136.** Report Cement: aggregate ratio
9b 	Splash 	68	130	120	Middle west side of pool Core depth 165mm	Tile - Stone Topping			0-7		Retain 0-35, Don't test	
						Intermediate Material + Stone topping			7-11			
						Intermediate Material + Stone Topping + Concrete 1			11-25			
						Concrete 1 + Intermediate Material	Concrete 1: Evenly distributed, 11x <10mm, balance <5mm	✓	25-30			
						Concrete 1 + Concrete 2			30-35			
						Concrete 2	Evenly distributed, 3x <20mm, 10x <15mm, 62x <10mm, balance <5mm		35-165		35-50 Retain 50-90, Don't test 90-105 105-120 120-135 135-150	

Core & Orientation	Zone & Core Photograph	Core diameter (mm)	Vertical cover (mm)	Horizontal cover (mm)	Notes	Increment Material	Observations of aggregate density	Carbonation	Increment depth (mm)	Density	Chloride test increments (mm)	Other tests to be performed (mm)
											Retain 150-165, Don't test	
10b 	Splash 	68	200	120	Deep west side corner Core depth 165mm	Tile + Stone Topping	Stone topping: evenly distributed, 37x <10mm, balance <5mm	✓	0-7		Retain 0-38, Don't test	
						Intermediate Material + Stone Topping			7-13			
						Intermediate Material + Concrete 2	Concrete 2: Evenly distributed, 2x <15mm, 13x <10mm, balance <5mm		13-28			
						Concrete 2 + Concrete 1			28-38			
						Concrete 1	3x <25mm, 12x <20mm, 14x <15mm, 26x <10mm, balance <5mm		38-165			**Compressive strength 38-165,** Retain crushed material after test

Our Ref: 16038
Morawa Aquatic Centre
Swimming Pool Core Survey

Core & Orientation	Zone & Core Photograph	Core diameter (mm)	Vertical cover (mm)	Horizontal cover (mm)	Notes	Increment Material	Observations of aggregate density	Carbonation	Increment depth (mm)	Density	Chloride test Increments (mm)	Other tests to be performed (mm)
11b 	Splash 	68	150	120	Dive pool Core depth 153mm	Stone Topping	Evenly distributed, 8x <10mm, balance < 5mm		0-18		Hold core after carbonation test	
						Stone topping + Concrete 1			18-21			
						Concrete 1	Evenly distributed, 9x <15mm, 45x <10mm, balance <5mm		21-103			
						Intermediate Material		✓	103-105			
						Intermediate Material + Concrete 1 (pool side)	Concrete 2: Segregated towards shallow end side of core, Shallow end - 3x <15mm, 9x <10mm, balance <5mm Deep end-1x <15mm, 9x <10mm, balance <5mm		105-110			
						Concrete 2 (Pool side) + Concrete 3 (drain side)	Concrete 3: Evenly distributed, 8x <15mm, 11x <10mm, balance <5mm		110-153			

Core & Orientation	Zone & Core Photograph	Core diameter (mm)	Vertical cover (mm)	Horizontal cover (mm)	Notes	Increment Material	Observations of aggregate density	Carbonation	Increment depth (mm)	Density	Chloride test increments (mm)	Other tests to be performed (mm)
12 	Floor 	74	90	-	Dive pool Core depth 132mm	Topping			0-12		Retain 0-15, Don't test	
						Topping + Intermediate Material			12-13			
						Intermediate Material			13-15			
						Concrete 3	Evenly distributed, 2x <25mm, 9x <20mm, 19x <15mm, 16x <10mm, balance <5mm	✓	15-132		15-30 Retain 30-57, Don't test 57-72 72-87 87-102 102-117 Retain 117-132, Don't test	
13 	Beneath Splash 	74	150	50	Beneath first rebar same level as Core 7 but on opposite side Core depth 150mm	Topping			0-3		Retain 0-13, Don't test	
						Intermediate Material			3-13			
						Concrete 3	Evenly distributed, 1x <25mm, 12x <20mm, 17x <15mm, 31x <10mm, balance <5mm	✓	13-150	13-150		**Compression strength** **Cement content 13-150** Report Cement : Aggregate ratio

------------------------ End of Brief ------------------------

Appendix D: Density test results from SGS Australia

SGS

Client:	Airey Taylor Consulting Pty Ltd 18 Harvest Terrace West Perth WA 6005
Your Reference:	16038 – Morawa Aquatic Centre Investigation
Our Reference:	JN 16-06-62

Certificate of Test No. 11356

Sample:	Concrete Core Samples
Date Received:	10th March 2016
Date Tested:	21st & 22nd March 2016
From:	Morawa Aquatic Centre
Description & Condition:	2 –off nominal 70 mm diameter concrete core samples 1 –off nominal 75 mm diameter concrete core sample

Test Description: **Density**

Sample Preparation:

Ends squared by wet diamond saw prior to measurements.

Test Method:

Density values calculated using geometric values obtained by measurement.

Tested By A. Luobikis, Technical Officer	22/03/2016 Date	Authorised By N. Nguyen, Chemist	06/04/2016 Date

SGS Australia Pty Ltd | Industrial Division, 5 Yelland Way, Bassendean WA 6054 t + 1300 781 744 f + 61 (8) 9458 3700 www.sgs.com

SGS

Certificate No. 11356

Test Results:

SGS Lab No.	Client No.	Depth (mm)	Density (kg/m^3)
P40926	Core 1, Splash – Middle East Side of Pool	64-154 mm	2,060
P40928	Core 3, Splash – Top of West Stairs	105-164 mm	2,200
P40932 (Top Section)	Core 7, Beneath Splash – Beneath First Rebar & Core 5	10-40 mm 40-135 mm	2,030 2,150

Appendix E: Chloride content test results from SGS Australia

Client:	Airey Taylor Consulting Pty Ltd 18 Harvest Terrace West Perth WA 6005
Your Reference:	16038 – Morawa Aquatic Centre Investigation
Our Reference:	JN 16-06-62

Certificate of Test No. 11358

Sample:	Concrete Core Samples
Date Received:	10th March 2016
Date Tested:	31st March 2016
From:	Morawa Aquatic Centre
Description & Condition:	3 –off nominal 70 mm diameter concrete core samples 5 –off nominal 75 mm diameter concrete core samples

Test Description: **Acid Soluble Chloride Content**

Sample Preparation:

Sub-samples removed from cores by dry diamond saw, pulverised to pass 150 µm sieve prior to analysis.

Test Method:

Chloride content in accordance with BS 1881:Part 124:1988 "Methods for Analysis of Hardened Concrete" Section 10.2, except titration by potentiometric method.

	31/03/2016		06/04/2016
Tested By F. Juwono, Senior Technical Officer	Date	Authorised Signatory N. Nguyen, Chemist	Date

NATA Accredited Laboratory No. 2418.
Accredited for compliance with ISO/IEC 17025. This document shall not be reproduced except in full.

Page 1 of 3

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Certificate No. 11358

Test Results:

SGS Lab No.	Client No.	Sample Location	Depth (mm)	% Cl$^-$ by Weight of Sample
P40926	Core 1	Splash – Middle East Side of Pool	64-79	0.03
			109-124	0.03
			124-139	0.03
			139-154	0.03
			154-169	0.03
P40928	Core 3	Splash – Top of West Stairs	90-105	0.03
			105-120	0.03
			120-135	0.03
			135-150	0.02
			150-164	0.02
P40929	Core 4	Floor – Shallow End	14-29	0.09
			75-90	0.03
			90-105	0.03
			105-120	0.02
			120-135	0.02
P40930	Core 5	Beneath Splash – Above first Rebar on Pool Wall	18-33T	0.08
			60-75T	0.07
			75-90T	0.06
			90-105T	0.06
			105-120T	0.05
			18-33B	0.05
			60-75B	0.05
			75-90B	0.04
			90-105B	0.04
			105-120B	0.04
P40931	Core 6	Floor Tiled – Middle of Pool Through Tile	27-42	0.05
			75-90	0.04
			90-105	0.03
			105-120	0.03
			120-135	0.03

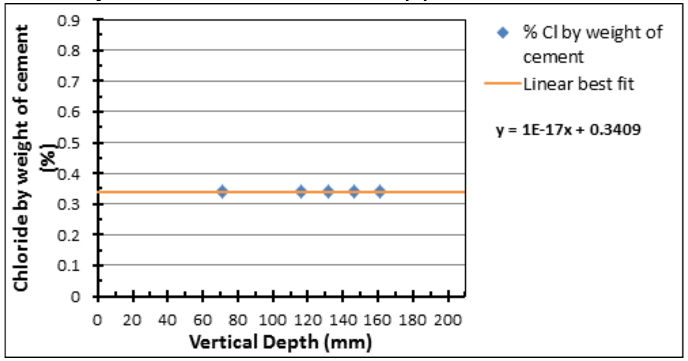
Certificate No. 11358

Test Results:

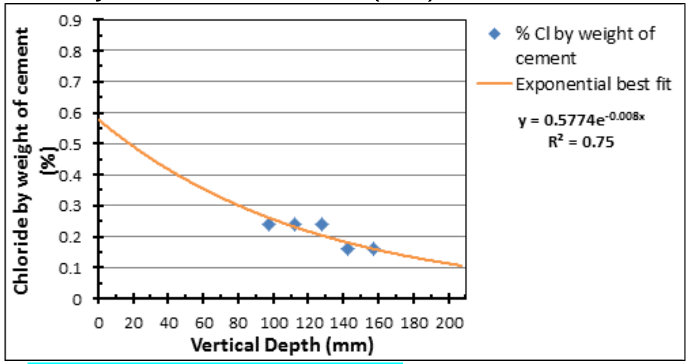
SGS Lab No.	Client No.	Sample Location	Depth (mm)	% Cl^- by Weight of Sample
P40932	Core 7	Beneath Splash – Beneath First Rebar & Core 5	10-25T 25-40T 40-55T 55-70T 70-85T 120-135T 135-153T	0.08 0.07 0.07 0.06 0.06 0.08 0.05
P40934	Core 9B	Splash – Middle West Side of Pool	35-50 90-105 105-120 120-135 135-150	0.05 0.04 0.04 0.04 0.04
P40937	Core 12	Floor – Dive Pool	15-30 57-72 72-87 87-102 102-117	0.07 0.05 0.05 0.04 0.05

Appendix F: Chloride concentration fitted with an Excel Trendline to estimate Cs (% Cl by weight of cement)

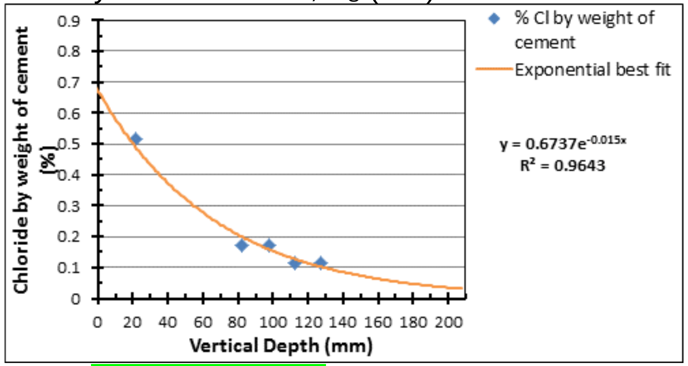
Core 1 Splash zone, middle of east wall
$y = 10^{-17}x + 0.3409$, $C_S\ (x) = 0.3409$ %



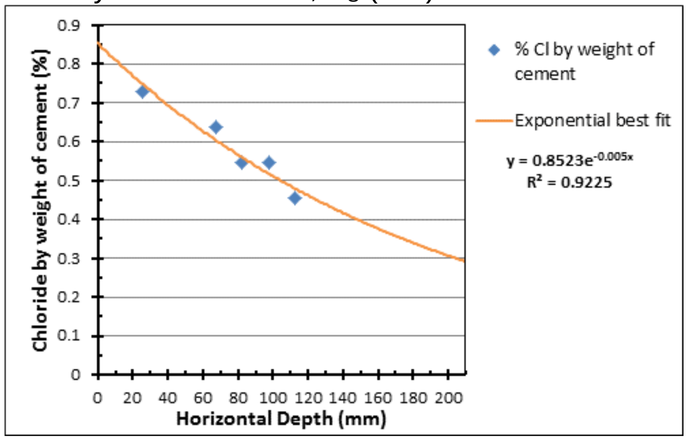
Core 3 Splash zone, top of west steps
$y = 0.5774e^{-0.008x}$, $C_S\ (x=0) = 0.5774$ %



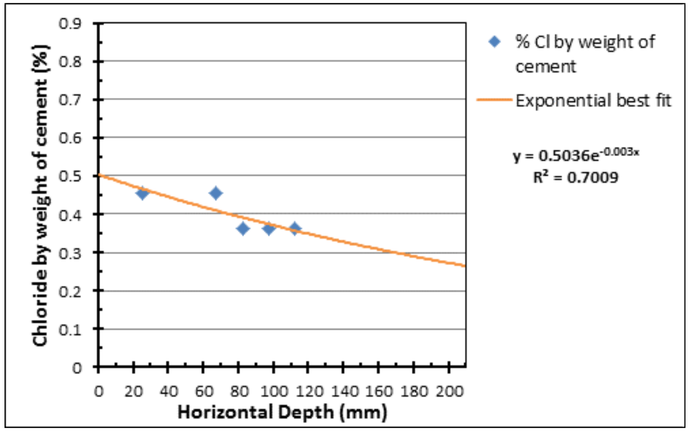
Core 4 Floor zone, shallow end
$y = 0.6737e^{-0.015x}$, $C_S\ (x=0) = 0.6737$ %



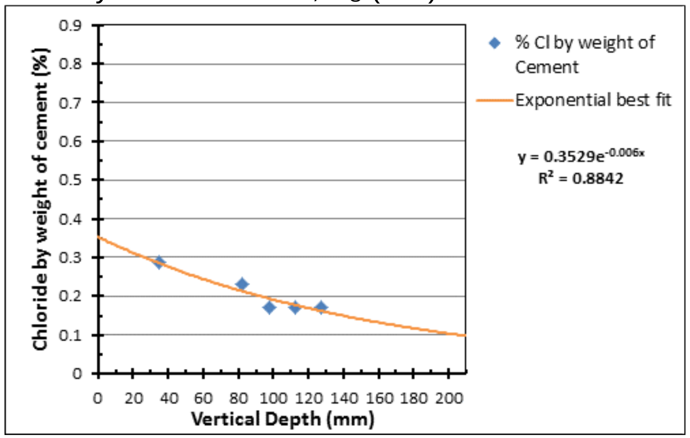
Core 5 Beneath Splash zone, top half of core
$y = 0.8523e^{-0.005x}$, $C_S\ (x=0) = 0.8523$ %



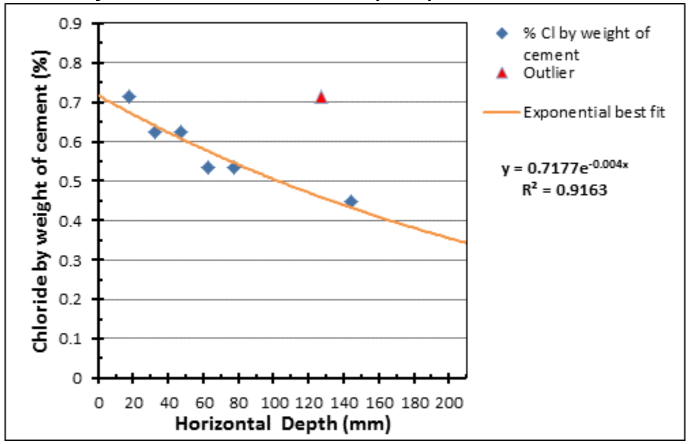
Core 5 Beneath Splash zone, bottom half of core
$y = 0.5036e^{-0.003x}$, $C_S\ (x=0) = 0.5036$ %



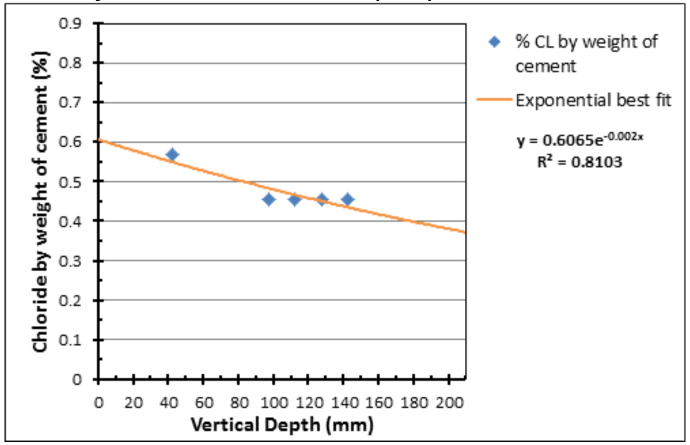
Core 6 Floor zone, Tiled middle of pool
$y = 0.3529e^{-0.006x}$, $C_S\ (x=0) = 0.3529$ %



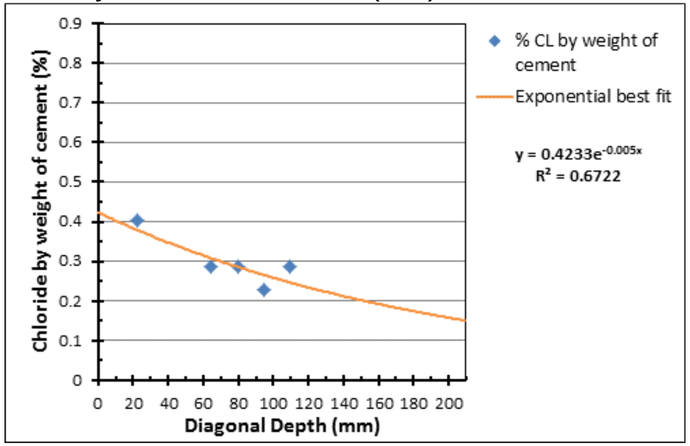
Core 7 Beneath Splash zone, top half of core
$y = 0.7177e^{-0.004x}$, C_S (x=0) = 0.7177 %



Core 9b Splash zone, middle of west wall
$y = 0.5012e^{-0.002x}$, C_S (x=0) = 0.5012 %

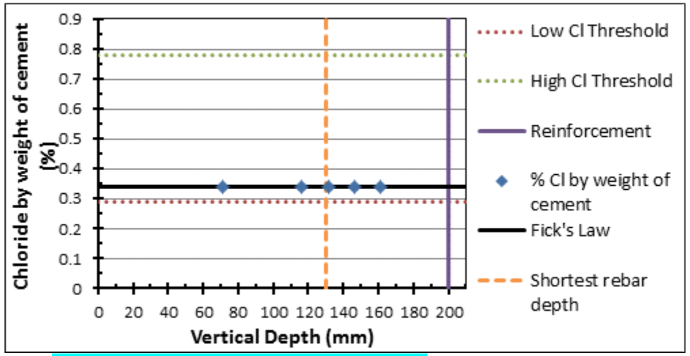


Core 12 Floor zone, slope in dive pool
$y = 0.4233e^{-0.005x}$, C_S (x=0) = 0.4233 %

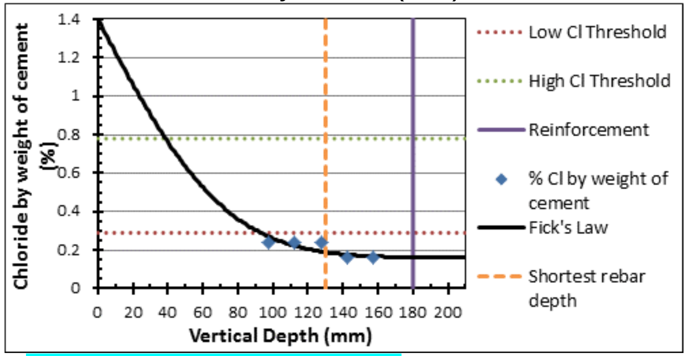


Appendix G: Service Life Prediction with Fick's Law (% Cl by weight of cement)

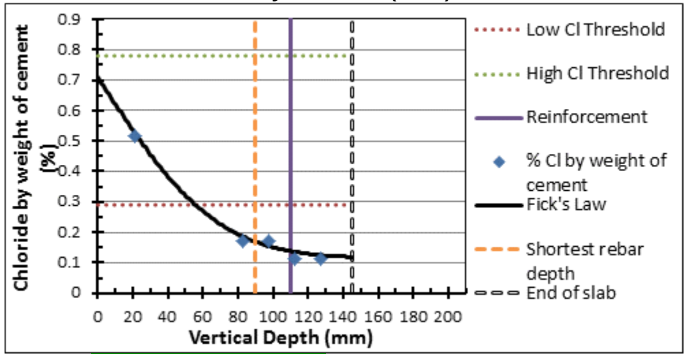
Core 1 Splash zone, middle of east wall
Poor Fit to Fick's Law



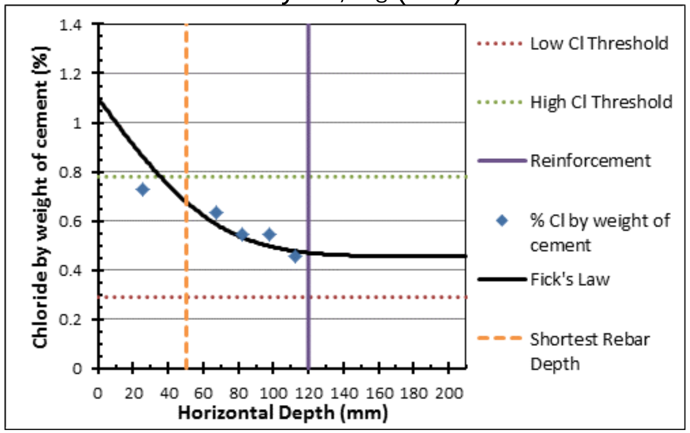
Core 3 Splash zone, top of west steps
D = 35 mm^2/year, C_S (x=0) = 1.4 %



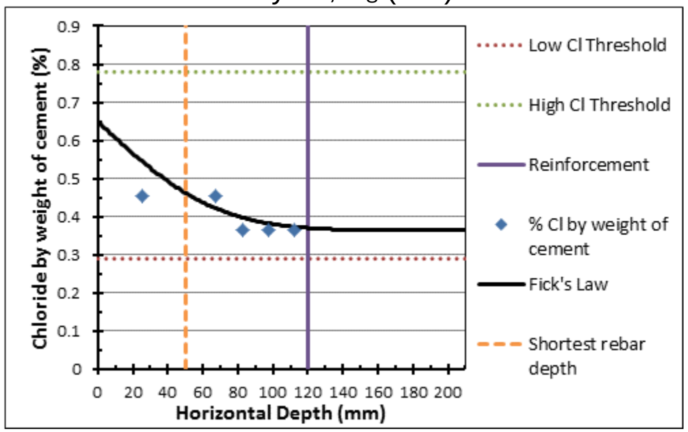
Core 4 Floor zone, shallow end
D = 30 mm^2/year, C_S (x=0) = 0.71 %



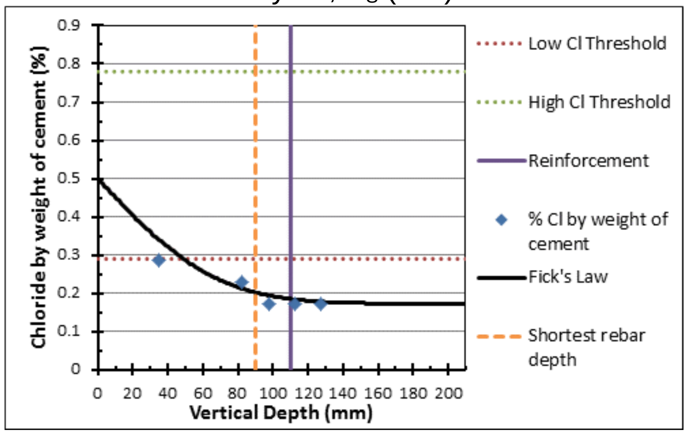
Core 5 Beneath Splash zone, top half of core
D = 30 mm^2/year, C_S (x=0) = 1.1 %



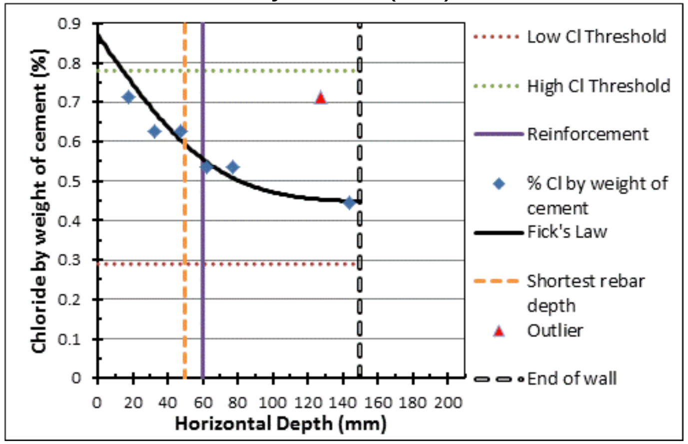
Core 5 Beneath Splash zone, bottom half of core
D = 30 mm^2/year, C_S (x=0) = 0.65 %



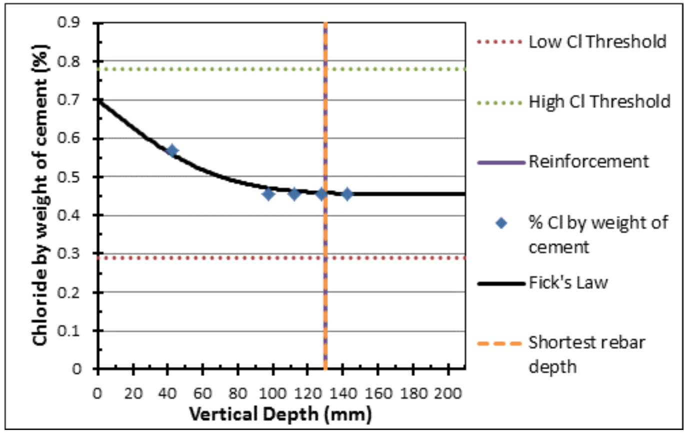
Core 6 Floor zone, Tiled middle of pool
D = 30 mm^2/year, C_S (x=0) = 0.50 %



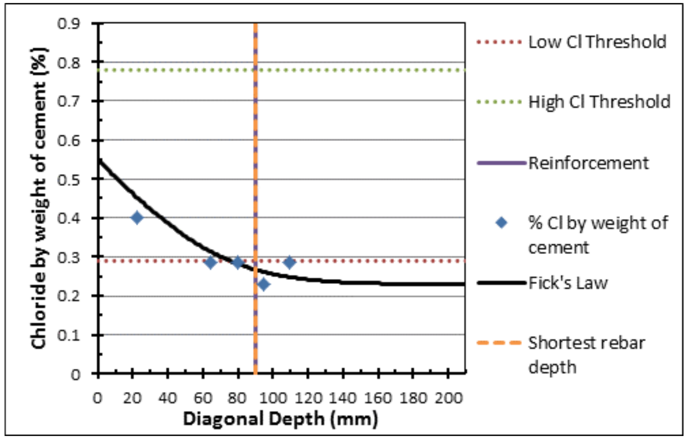
Core 7 Beneath Splash zone, top half of core
D = 30 mm^2/year, C_S (x=0) = 0.87 %



Core 9b Splash zone, middle of west wall
D = 30 mm^2/year, C_S (x=0) = 0.70 %

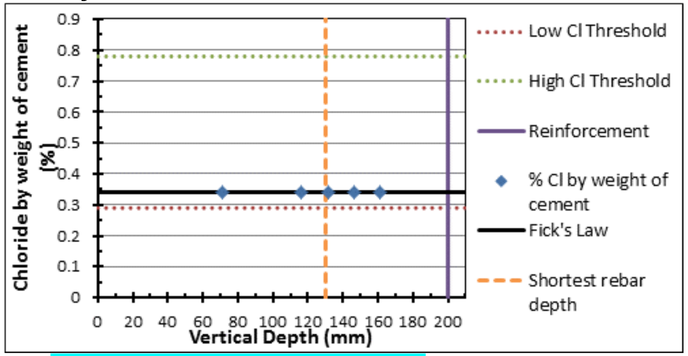


Core 12 Floor zone, slope in dive pool
D = 35 mm^2/year, C_S (x=0) = 0.55 %

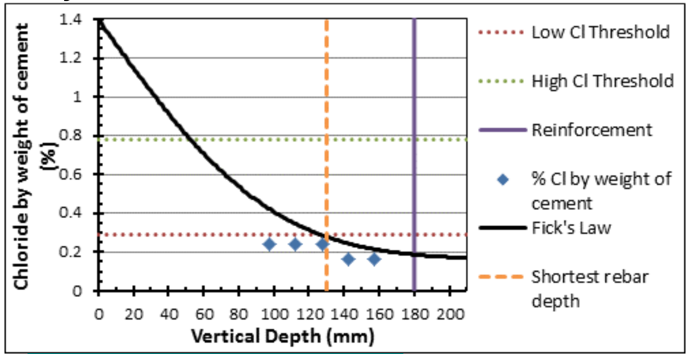


Appendix H: Projection of Remaining Service Life with Fick's Law (% Cl by weight of cement)

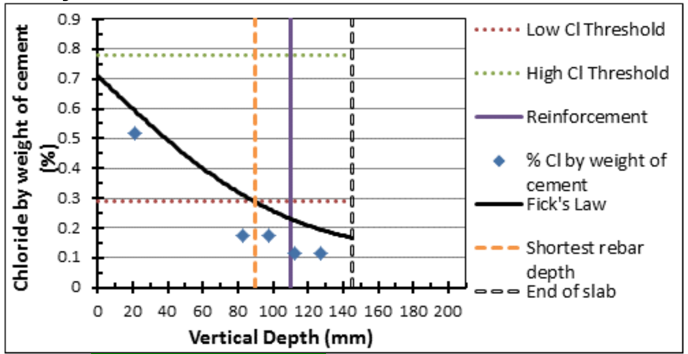
Core 1 Splash zone, middle of east wall
Projection: 0 Years, above Low Cl Threshold



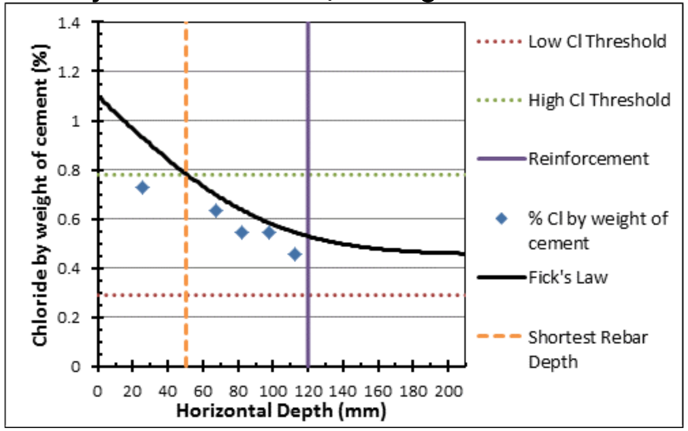
Core 3 Splash zone, top of west steps
Projection: 40 Years to reach Low Cl Threshold



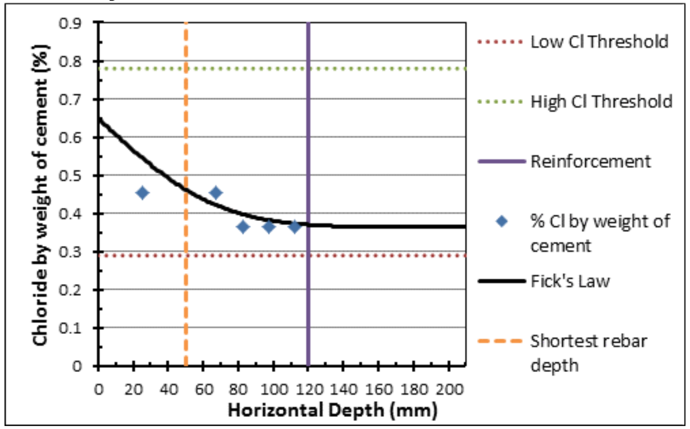
Core 4 Floor zone, shallow end
Projection: 73 Years to reach Low Cl Threshold



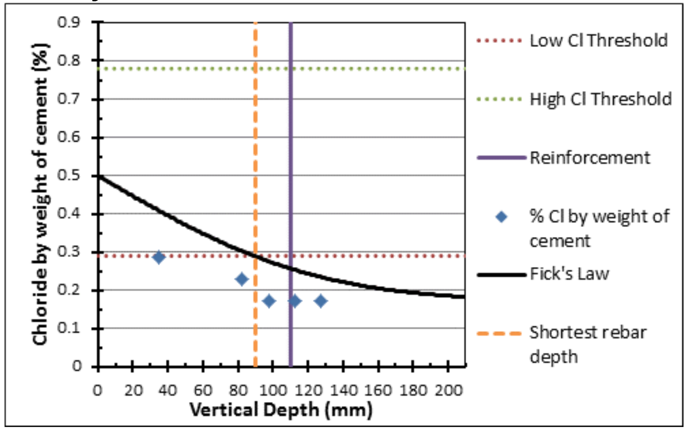
Core 5 Beneath Splash zone, top half of core
Projection: 50 Years, for High Cl Threshold



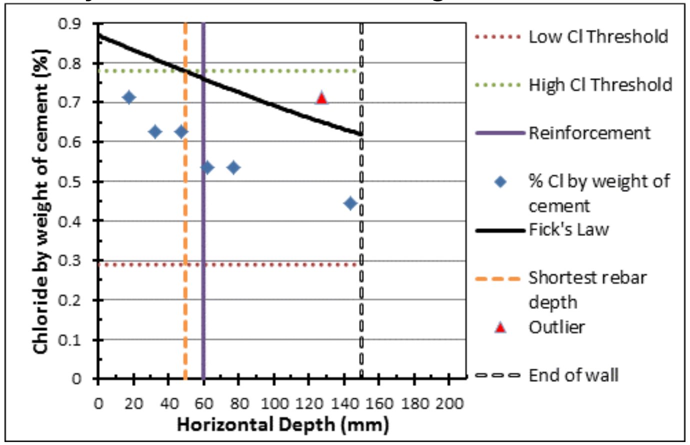
Core 5 Beneath Splash zone, bottom half of core
Projection: 0 Years for Low Cl Threshold



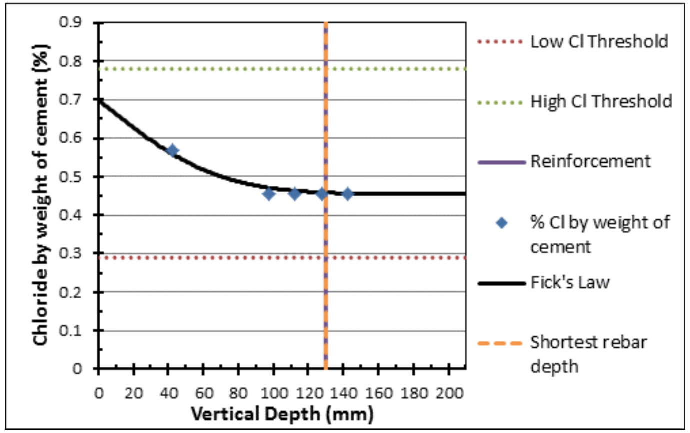
Core 6 Floor zone, Tiled middle of pool
Projection: 110 Years for Low Cl Threshold



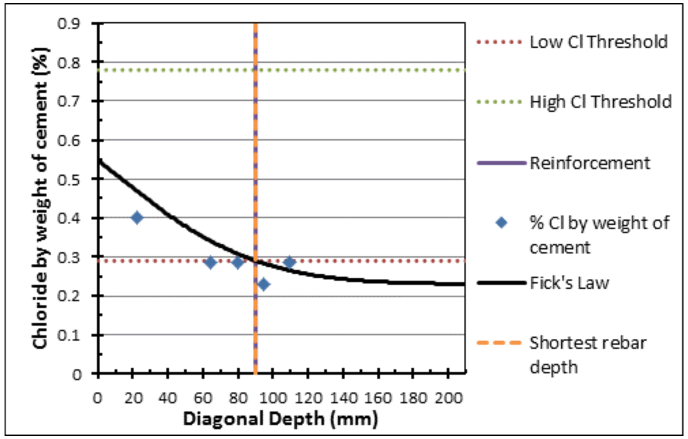
Core 7 Beneath Splash zone, top half of core
Projection: 500 Years, for High Cl Threshold



Core 9b Splash zone, middle of west wall
Projection: 0 Years, above Low Cl Threshold

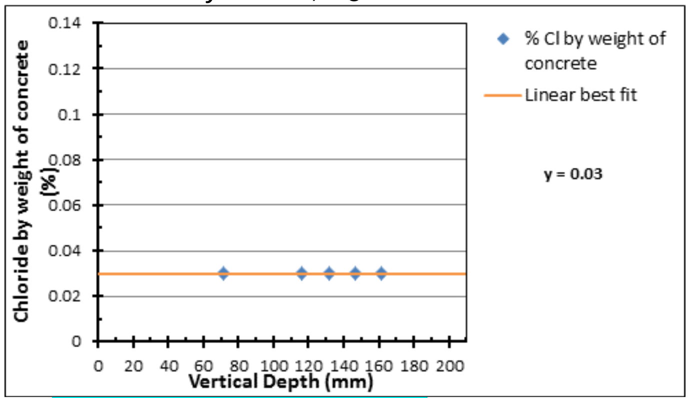


Core 12 Floor zone, slope in dive pool
Projection: 20 Years, for Low Cl Threshold

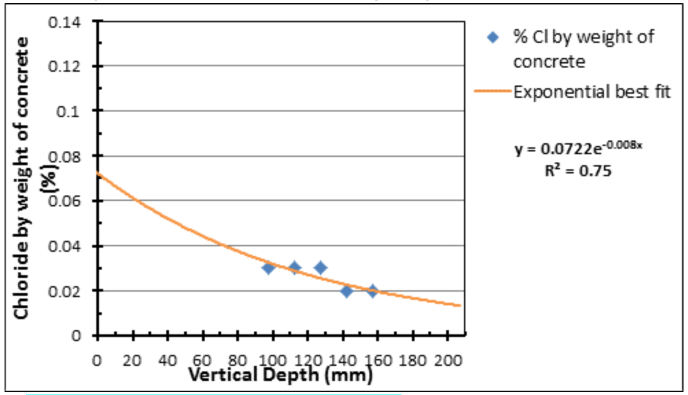


Appendix I: Chlorine concentration fitted with an Excel Trendline to estimate Cs (% Cl by weight of concrete)

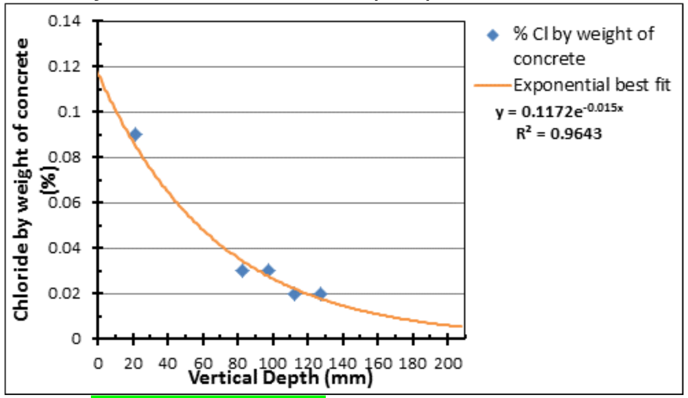
Core 1 Splash zone, middle of east wall
$y = 0.03$, $C_S = 0.03$ %



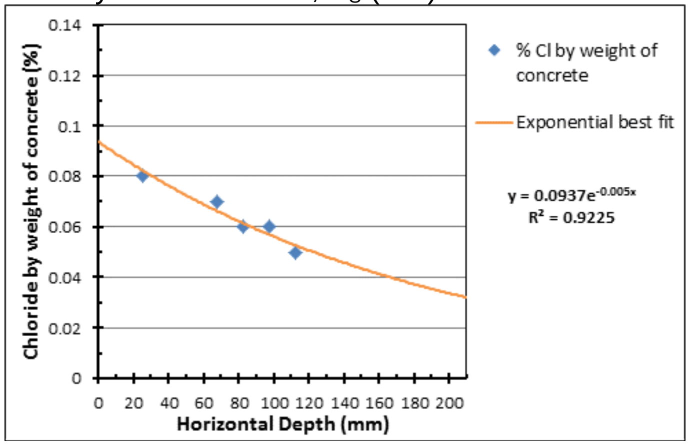
Core 3 Splash zone, top of west steps
$y = 0.0722e^{-0.008x}$, $C_S\ (x=0) = 0.0722$ %



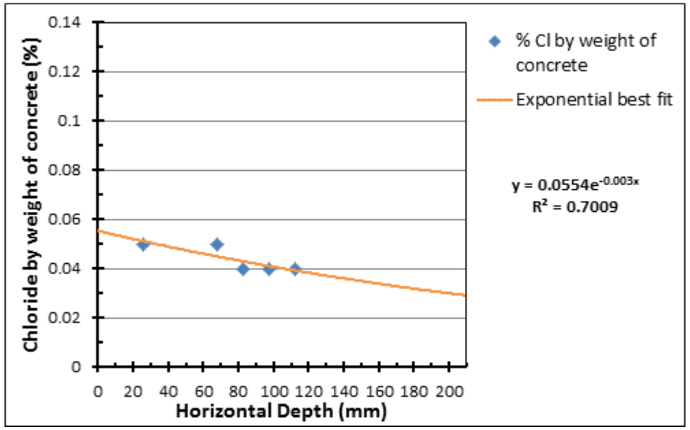
Core 4 Floor zone, shallow end
$y = 0.1172e^{-0.015x}$, $C_S\ (x=0) = 0.1172$ %



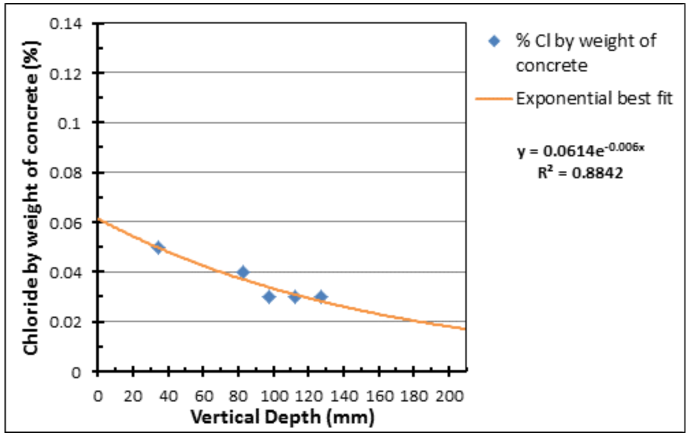
Core 5 Beneath Splash zone, top half of core
$y = 0.0937e^{-0.005x}$, $C_S\ (x=0) = 0.0937$ %



Core 5 Beneath Splash zone, bottom half of core
$y = 0.0554e^{-0.003x}$, $C_S\ (x=0) = 0.0554$ %

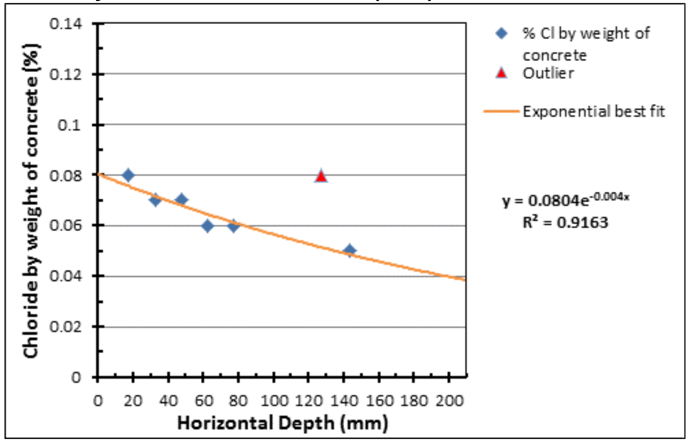


Core 6 Floor zone, Tiled middle of pool
$y = 0.0614e^{-0.006x}$, $C_S\ (x=0) = 0.0614$ %

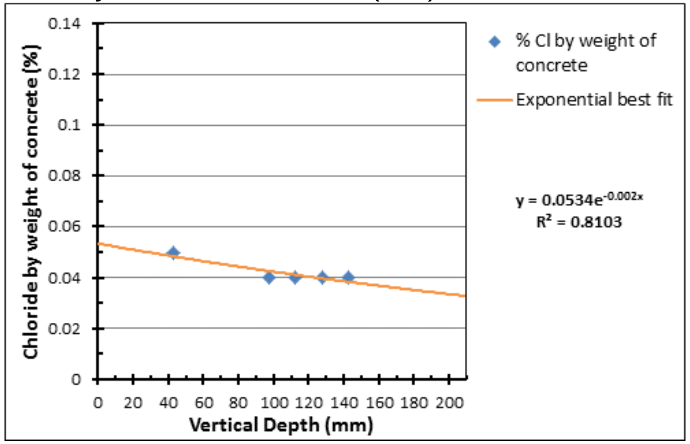


Our Ref: 16038
Morawa Aquatic Centre
Swimming Pool Core Survey

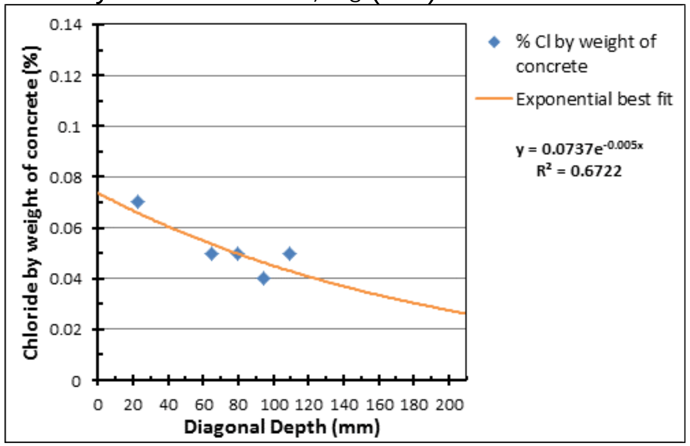
Core 7 Beneath Splash zone, top half of core
$y = 0.0804e^{-0.004x}$, C_S (x=0) = 0.0804 %



Core 9b Splash zone, middle of west wall
$y = 0.0534e^{-0.002x}$, C_S (x=0) = 0.0534 %

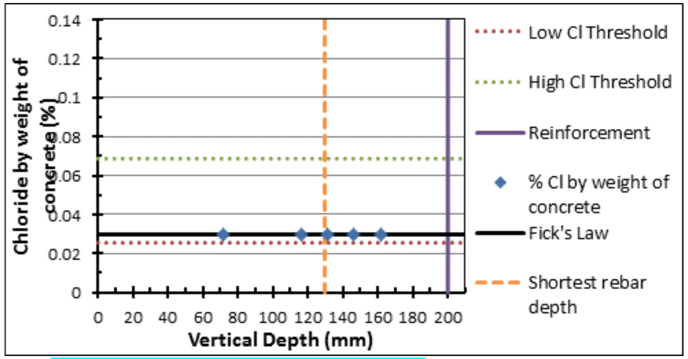


Core 12 Floor zone, slope in dive pool
$y = 0.0737e^{-0.005x}$, C_S (x=0) = 0.0737 %

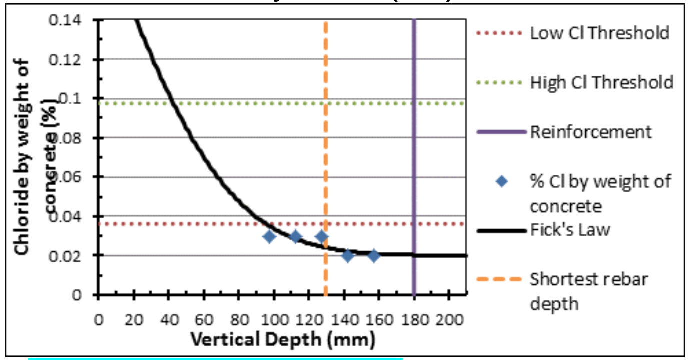


Appendix J: Service Life Prediction with Fick's Law (% Cl by weight of concrete)

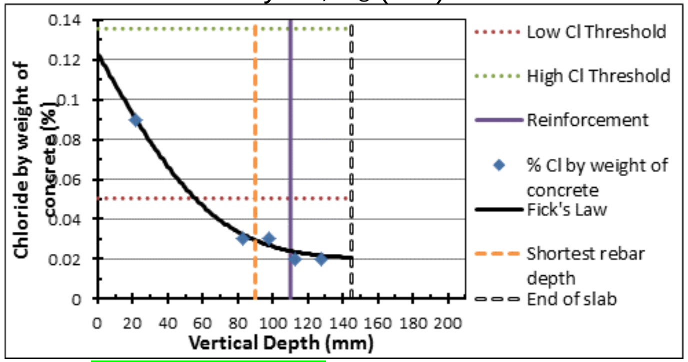
Core 1 Splash zone, middle of east wall
Poor Fit to Fick's Law



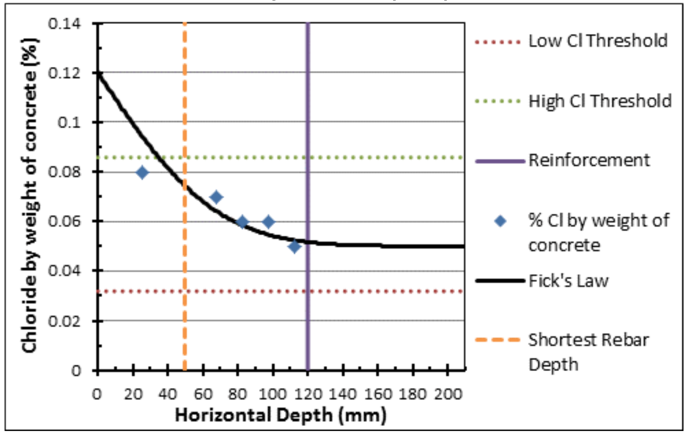
Core 3 Splash zone, top of west steps
D = 35 mm^2/year, C_S (x=0) = 0.19 %



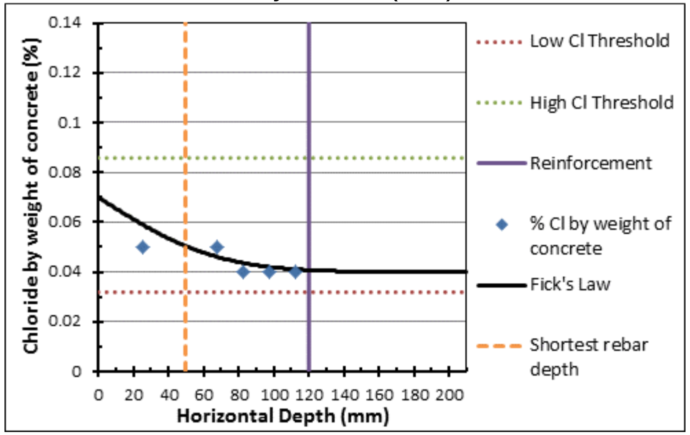
Core 4 Floor zone, shallow end
D = 30 mm^2/year, C_S (x=0) = 0.123 %



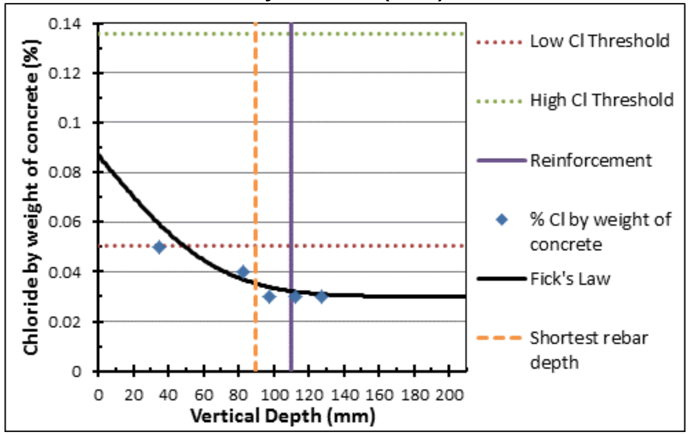
Core 5 Beneath Splash zone, top half of core
D = 30 mm^2/year, C_S (x=0) = 0.12 %



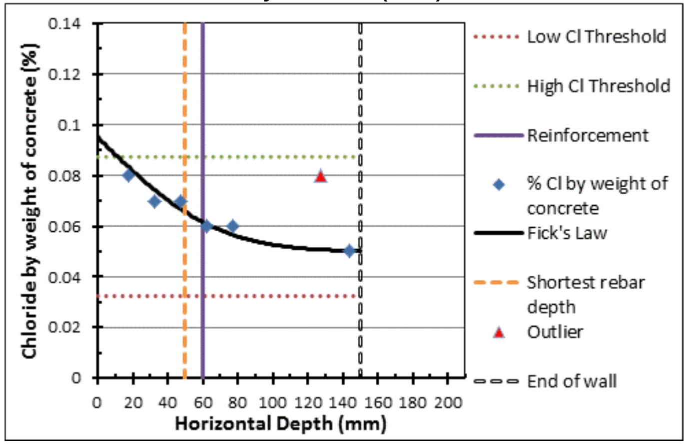
Core 5 Beneath Splash zone, bottom half of core
D = 30 mm^2/year, C_S (x=0) = 0.07 %



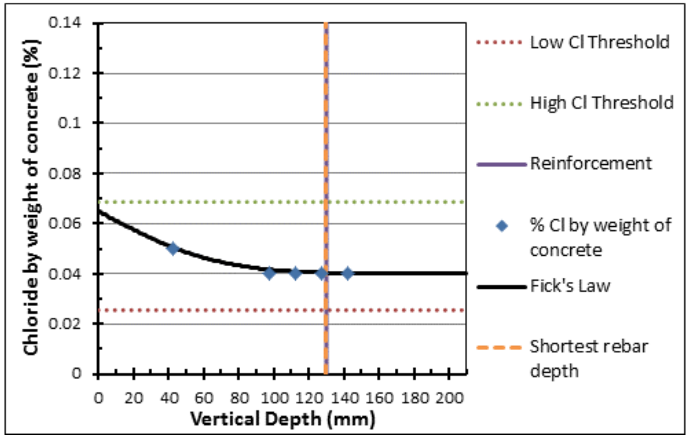
Core 6 Floor zone, Tiled middle of pool
D = 30 mm^2/year, C_S (x=0) = 0.087 %



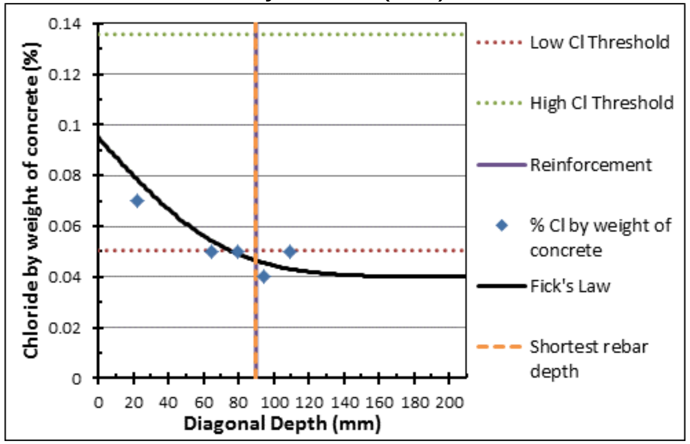
Core 7 Beneath Splash zone, top half of core
D = 30 mm^2/year, C_S (x=0) = 0.095 %



Core 9b Splash zone, middle of west wall
D = 30 mm^2/year, C_S (x=0) = 0.065 %

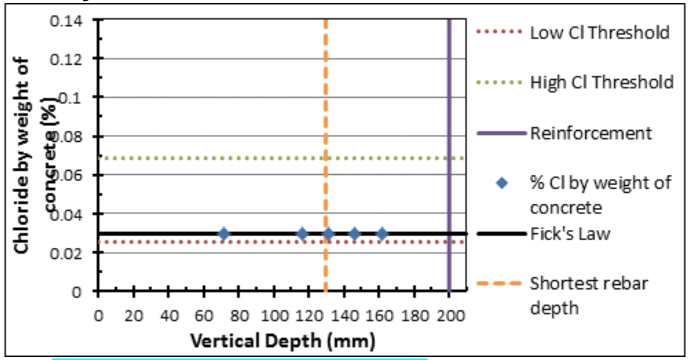


Core 12 Floor zone, slope in dive pool
D = 35 mm^2/year, C_S (x=0) = 0.095 %

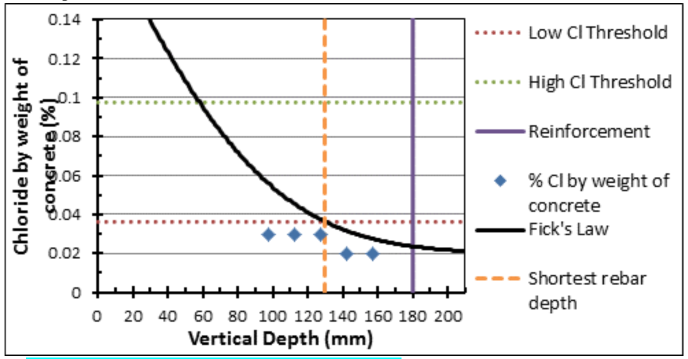


Appendix K: Projection of Remaining Service Life with Fick's Law (% Cl by weight of concrete)

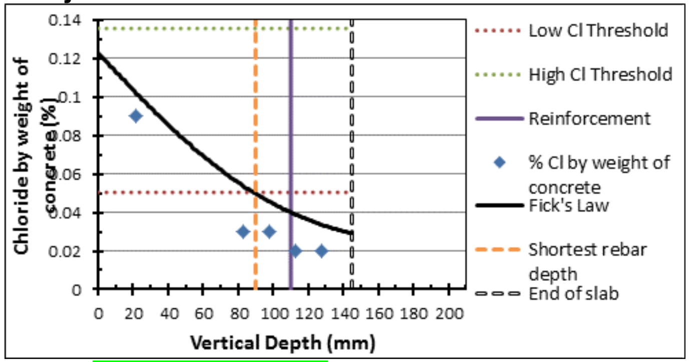
Core 1 Splash zone, middle of east wall
Projection: 0 Years, above Low Cl Threshold



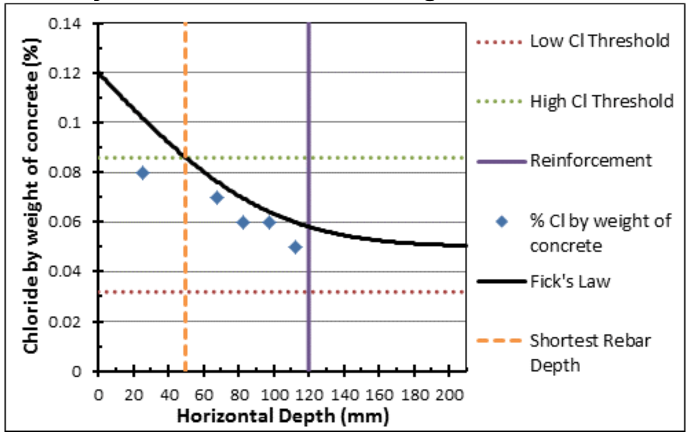
Core 3 Splash zone, top of west steps
Projection: 40 Years to reach Low Cl Threshold



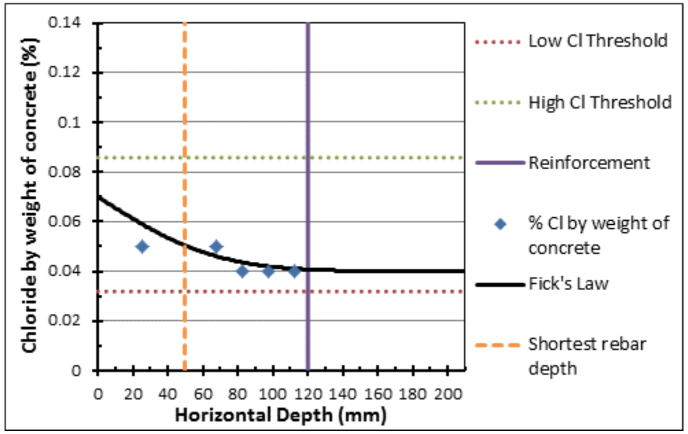
Core 4 Floor zone, shallow end
Projection: 73 Years to reach Low Cl Threshold



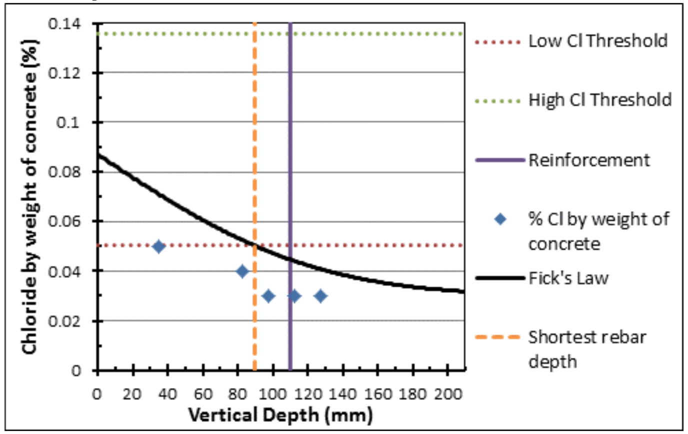
Core 5 Beneath Splash zone, top half of core
Projection: 50 Years, for High Cl Threshold



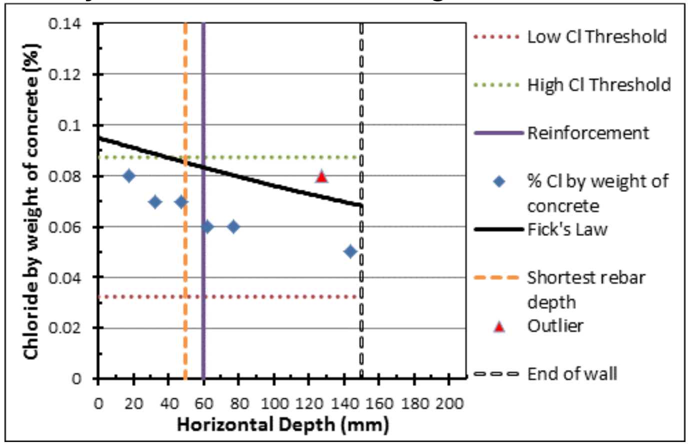
Core 5 Beneath Splash zone, bottom half of core
Projection: 0 Years for Low Cl Threshold



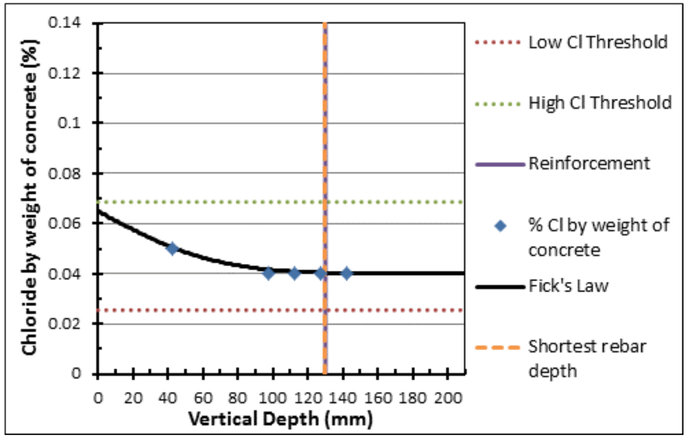
Core 6 Floor zone, Tiled middle of pool
Projection: 110 Years for Low Cl Threshold



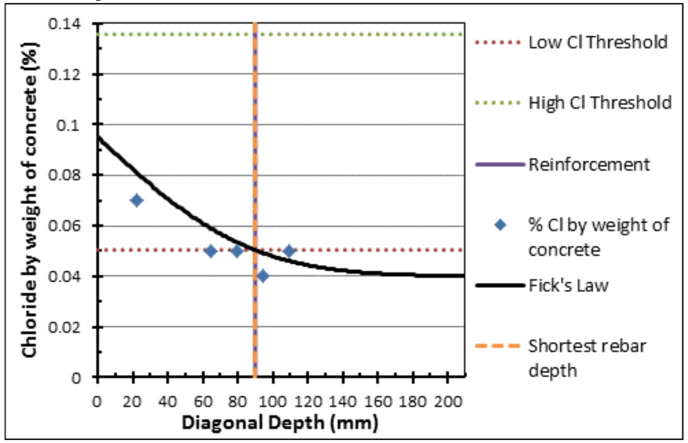
Core 7 Beneath Splash zone, top half of core
Projection: 500 Years, for High Cl Threshold



Core 9b Splash zone, middle of west wall
Projection: 0 Years, above Low Cl Threshold



Core 12 Floor zone, slope in dive pool
Projection: 20 Years, for Low Cl Threshold



Appendix L: Carbonation test results from SGS Australia

SGS

Client:	Airey Taylor Consulting Pty Ltd 18 Harvest Terrace West Perth WA 6005
Your Reference:	16038 – Morawa Aquatic Centre Investigation
Our Reference:	JN 16-06-62

Certificate of Test No. 11312

Sample:	Concrete Core Samples
Date Received:	10th March 2016
Date Tested:	14th March 2016
From:	Morawa Aquatic Centre
Description & Condition:	5 –off nominal 70 mm diameter concrete core samples 8 –off nominal 75 mm diameter concrete core samples

Test Description: **Depth of Carbonation**

Sample Preparation:

Samples tested as received.

Test Method:

Main Roads WA test method WA 620.1 "Carbonation of Concrete".

14/03/2016		06/04/2016	
Tested By F. Juwono, Senior Technical Officer	Date	Authorised By N. Nguyen, Chemist	Date

Certificate No. 11312

Test Results:

SGS Lab No.: P40926
Client No.: Core 1, Splash – Middle East side of pool
Length of Core: 170 mm
Type of Core: Partial Core
Depth of Carbonation: 0 mm in all layers

SGS Lab No.: P40927
Client No.: Core 2B, Beneath Splash – Beneath shallow end starter block
Length of Core: 145 mm
Type of Core: Partial Core
Depth of Carbonation: 0 mm in all layers

SGS Lab No.: P40928
Client No.: Core 3, Splash – Top of west stairs
Length of Core: 170 mm
Type of Core: Partial Core
Depth of Carbonation: 0 mm in all layers

Certificate No. 11312

Test Results:

SGS Lab No.: P40929
Client No.: Core 4, Floor – Shallow end
Type of Core: Through Section Core
Length of Core: 145 mm
Depth of Carbonation: Topping: 6-8 mm, Topping/Concrete Interface: 0 mm

SGS Lab No.: P40930
Client No.: Core 5, Beneath Splash – Above first rebar on pool wall
Length of Core: 155 mm
Type of Core: Partial Core
Depth of Carbonation: 0 mm in all layers

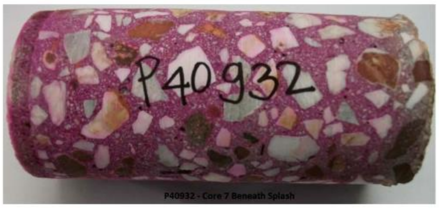
SGS Lab No.: P40931
Client No.: Core 6, Floor Tiled – Middle of pool through tile
Length of Core: 170 mm
Type of Core: Partial Core
Depth of Carbonation: 0 mm in all layers

SGS

Certificate No. 11312

Test Results:

SGS Lab No.: P40932
Client No.: Core 7, Beneath Splash – Beneath First Rebar and Core 5
Length of Core: 160 mm
Type of Core: Through section core
Depth of Carbonation: 0 mm in all layers



SGS Lab No.: P40933
Client No.: Core 8, Floor – Deep End
Length of Core: 140 mm
Type of Core: Through section core
Depth of Carbonation: Topping: 4-7 mm, Topping/Concrete Interface: 0 mm, Bottom Face: 0-7 mm

SGS Lab No.: P40934
Client No.: Core 9b, Splash – Middle West side of pool
Length of Core: 170 mm
Type of Core: Partial Core
Depth of Carbonation: 0 mm in all layers

Certificate No. 11312

Test Results:

SGS Lab No.: P40935
Client No.: Core 10b, Splash – Deep West side corner
Length of Core: 175 mm
Type of Core: Partial Core
Depth of Carbonation: Tile: 5-8 mm, Tile/Concrete Interface: 0 mm

SGS Lab No.: P40936
Client No.: Core 11b, Splash – Dive pool
Length of Core: 160 mm
Type of Core: Partial Core
Depth of Carbonation: 0 mm in all layers

SGS Lab No.: P40937
Client No.: Core 12, Floor – Dive pool
Length of Core: 135 mm
Type of Core: Partial Core
Depth of Carbonation: Topping: 6 mm, Topping/Concrete Interface: 0 mm

Certificate No. 11312

Test Results:

SGS Lab No.: P40938
Client No.: Core 13, Beneath Splash – Beneath first rebar same level as Core 7 but on opposite side
Length of Core: 160 mm
Type of Core: Through Section Core
Depth of Carbonation: Topping: 0 mm, Topping/Concrete Interface: 0 mm, Bottom Face: 0-10 mm

Appendix M: Compressive strength test results from SGS Australia

SGS

TEST CERTIFICATE

au.ind.perth.admin@sgs.com
ABN: 44 000 964 278
ph: 1300 781 744
fx: (08) 9378 0199

SGS Australia Pty Ltd
PO Box 486 Bassendean WA 6934
5 Yelland Way
Bassendean WA 6054

Client:	Airey Taylor Consulting	Client Job No:	JN: 16-06-62
Order No:		Project:	Morawa Aquatic Centre Investigation
Tested Date:	24/03/2016	Location:	
SGS Job Number:	16-01-584	Sample No:	16-MT-2341
Lab:	Bassendean	Sample ID:	Core 3 - Splash (P40928)

COMPRESSIVE STRENGTH of CORES

AS 1012.14 & AS 1012.12.1

Specimen ID:	A
Date Received:	23/03/16
Date Cast:	Unknown
Date Cored:	Unknown
Date Tested:	24-Mar-16
Age at Test (Days):	Not Known
Capping:	End-Polished
Conditioning	As Received - Dry
Days:	1
Average Diameter (mm)	69.0
Length (mm)	73
Mass / Unit Volume (kg/m³)	**2,140**
Uncorrected Compressive Strength (MPa)	36.5
Corrected Compressive Strength (MPa)	**31.5**
Cored By:	Cored by Client

Note: Sample supplied by client.
Deviation from the test method: Diameter is less than 75mm.

Approved Signatory: (Chris.Howard) Date: 4/04/2016

Accredited for compliance with ISO/IEC 17025

Accreditation No.: 2418
Client Address: Suite 12, 18 Harvest Terrace West Perth WA 6005

Site No.: 2411
Cert No.: 16-MT-2341-C302
Form No.PF-(AU)-[IND(MTE)]-TE-C302.LCER/B/17.02.2009

Page 1 of 1

au.ind.perth.admin@sgs.com
ABN: 44 000 964 278
ph: 1300 781 744
fx: (08) 9378 0199

TEST CERTIFICATE

SGS Australia Pty Ltd
PO Box 486 Bassendean WA 6934
5 Yelland Way
Bassendean WA 6054

Client:	Airey Taylor Consulting	Client Job No:	JN: 16-06-62
Order No:		Project:	Morawa Aquatic Centre Investigation
Tested Date:	24/03/2016	Location:	
SGS Job Number:	16-01-584	Sample No:	16-MT-2342
Lab:	Bassendean	Sample ID:	Core 8 - Floor (P40933)

COMPRESSIVE STRENGTH of CORES

AS 1012.14 & AS 1012.12.1

Specimen ID:	A
Date Received:	23/03/16
Date Cast:	Unknown
Date Cored:	Unknown
Date Tested:	24-Mar-16
Age at Test (Days):	Not Known
Capping:	End-Polished
Conditioning	As Received - Dry
Days:	1
Average Diameter (mm)	69.0
Length (mm)	105
Mass / Unit Volume (kg/m³)	**2,640**
Uncorrected Compressive Strength (MPa)	63.0
Corrected Compressive Strength (MPa)	**60.5**
Cored By:	Cored by Client

Note: Sample supplied by client.
Deviation from the test method: Diameter is less than 75mm.

Approved Signatory: (Chris.Howard) Date: 4/04/2016

Accredited for compliance with ISO/IEC 17025

Accreditation No.: 2418
Client Address: Suite 12, 18 Harvest Terrace West Perth WA 6005

Site No.: 2411
Cert No.: 16-MT-2342-C302
Form No.PF-(AU)-[IND(MTE)]-TE-C302.LCER/B/17.02.2009

Page 1 of 1

TEST CERTIFICATE

SGS Australia Pty Ltd
PO Box 486 Bassendean WA 6934
5 Yelland Way
Bassendean WA 6054

au.ind.perth.admin@sgs.com
ABN: 44 000 964 278
ph: 1300 781 744
fx: (08) 9378 0199

Client:	Airey Taylor Consulting	Client Job No:	JN: 16-06-62
Order No:		Project:	Morawa Aquatic Centre Investigation
Tested Date:	24/03/2016	Location:	
SGS Job Number:	16-01-584	Sample No:	16-MT-2343
Lab:	Bassendean	Sample ID:	Core 10B - Splash (P40935)

COMPRESSIVE STRENGTH of CORES

AS 1012.14 & AS 1012.12.1

Specimen ID:	A
Date Received:	23/03/16
Date Cast:	Unknown
Date Cored:	Unknown
Date Tested:	24-Mar-16
Age at Test (Days):	Not Known
Capping:	End-Polished
Conditioning	As Received - Dry
Days:	1
Average Diameter (mm)	69.0
Length (mm)	124
Mass / Unit Volume (kg/m³)	**2,300**
Uncorrected Compressive Strength (MPa)	51.0
Corrected Compressive Strength (MPa)	**49.5**
Cored By:	Cored by Client

Note: Sample supplied by client.
Deviation from the test method: Diameter is less than 75mm.

Approved Signatory: (Chris.Howard) Date: 4/04/2016

Accredited for compliance with ISO/IEC 17025

Accreditation No.: 2418
Client Address: Suite 12, 18 Harvest Terrace West Perth WA 6005

Site No.: 2411
Cert No.: 16-MT-2343-C302
Form No.PF-(AU)-[IND(MTE)]-TE-C302.LCER/B/17.02.2009

Page 1 of 1

au.ind.perth.admin@sgs.com
ABN: 44 000 964 278
ph: 1300 781 744
fx: (08) 9378 0199

TEST CERTIFICATE

SGS Australia Pty Ltd
PO Box 486 Bassendean WA 6934
5 Yelland Way
Bassendean WA 6054

Client:	Airey Taylor Consulting	Client Job No:	JN: 16-06-62
Order No:		Project:	Morawa Aquatic Centre Investigation
Tested Date:	24/03/2016	Location:	
SGS Job Number:	16-01-584	Sample No:	16-MT-2344
Lab:	Bassendean	Sample ID:	Core 13 - Beneath Splash (P40938)

COMPRESSIVE STRENGTH of CORES

AS 1012.14 & AS 1012.12.1

Specimen ID:	A
Date Received:	23/03/16
Date Cast:	Unknown
Date Cored:	Unknown
Date Tested:	24-Mar-16
Age at Test (Days):	Not Known
Capping:	End-Polished
Conditioning	As Received - Dry
Days:	1
Average Diameter (mm)	69.0
Length (mm)	131
Mass / Unit Volume (kg/m³)	**2,600**
Uncorrected Compressive Strength (MPa)	55.5
Corrected **Compressive Strength (MPa)**	**55.5**
Cored By:	Cored by Client

Note: Sample supplied by client.
Deviation from the test method: Diameter is less than 75mm.

Approved Signatory: (Chris.Howard) Date: 4/04/2016

Accredited for compliance with ISO/IEC 17025

Accreditation No.: 2418
Client Address: Suite 12, 18 Harvest Terrace West Perth WA 6005

Site No.: 2411
Cert No.: 16-MT-2344-C302
Form No.PF-(AU)-[IND(MTE)]-TE-C302.LCER/B/17.02.2009

Page 1 of 1

Appendix N: Cement content test results from SGS Australia

SGS

Client: Airey Taylor Consulting Pty Ltd
18 Harvest Terrace
West Perth WA 6005

Your Reference: 16038 – Morawa Aquatic Centre Investigation

Our Reference: JN 16-06-62

Certificate of Test No. 11361

Sample: Concrete Core Samples

Date Received: 10th March 2016

Date Tested: 30th March – 04th April 2016

From: Morawa Aquatic Centre

Description & Condition: 2 –off nominal 70 mm diameter concrete core samples
3 –off nominal 75 mm diameter concrete core samples

Test Description: **Cement Content by Calcium Oxide**

Sample Preparation:

Sub-samples removed from cores by dry diamond saw, pulverised to pass 150 µm sieve prior to analysis.

Test Method:

Cement content by calcium oxide determination in accordance with BS 1881: Part 124: 1988 "Methods for Analysis of Hardened Concrete" Section 5.4.

This Certificate of Test replaces Certificate of Test No. 11357 which is now withdrawn.

	04/04/2016		07/04/2016
Tested By A. Luobikis, Technical Officer	Date	Authorised By N. Nguyen, Chemist	Date

NATA

NATA Accredited Laboratory No. 2418.
Accredited for compliance with ISO/IEC 17025. This document shall not be reproduced except in full.

Page 1 of 2

SGS Australia Pty Ltd | Industrial Division, 5 Yelland Way Bassendean, WA 6054 t + 1300 781 744 f + 61 (8) 9378 0199 www.sgs.com

SGS

Certificate No. 11361

Test Results:

SGS Lab No.	Client No. & Sample Location	Depth mm	CaO Content % Wt Sample	Cement Content % Wt Sample	A/C Ratio (:1)
P40926	Core 1, Splash – Middle East Side of Pool	109-124	5.6	8.8	10.1
P40928	Core 3, Splash – Top of West Stairs	150-164	8.0	12.5	6.8
P40929	Core 4, Floor – Shallow End	105-120	11.1	17.4	4.5
P40930	Core 5, Beneath Splash – Above first Rebar on Pool Wall	60-75 T	7.1	11.0	7.8
P40932	Core 7, Beneath Splash – Beneath First Rebar & Core 5	55-70 T	7.1	11.2	7.7

Note: Assumed 64.0% CaO in cement and 0.0% soluble CaO in aggregates.

Appendix O: Subtera Subsurface Locating GPR report

SUBTERA
subsurface locating

Concrete Investigation

Client: Airey Taylor
Job No: Aire-29 - JN 5386
Address: Morawa Swimming Pool
Date: 23/2/2016

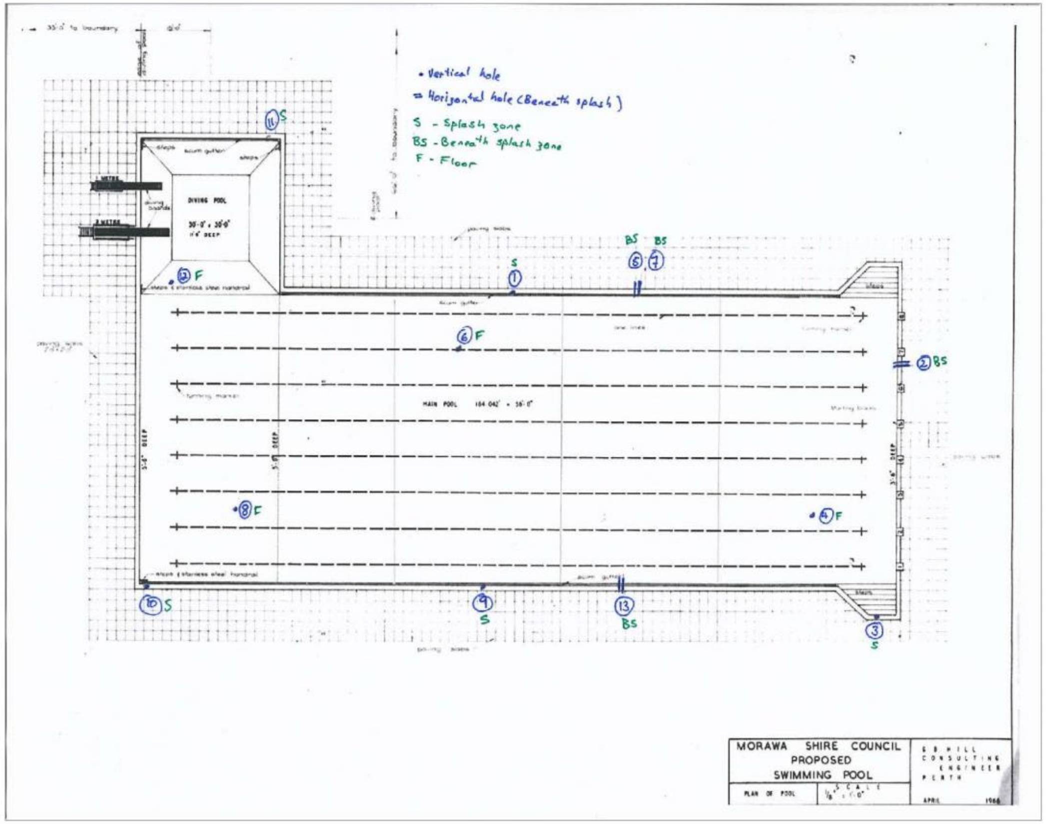
Scope of Works

Investigate swimming pool steel reinforcement structure:

- Steel avoidance when coring for concrete samples
- Check for voids
- General investigation

Equipment Used

- Mala CX 1.6gHz Ground Penetrating Radar specific for concrete scanning
- http://www.malags.com/products/mala-cx-(concrete-imaging)-system
- Mala 500mHz Ground Penetrating Radar specific for locating voids
- http://www.malags.com/products/mala-easy-locator-hdr



Our Ref: 16038
Morawa Aquatic Centre
Swimming Pool Core Survey

SUBTERA subsurface locating

Concrete Investigation

Client: Airey Taylor
Job No: Aire-29 - JN 5386
Address: Morawa Swimming Pool
Date: 23/2/2016

Results

- Voids - A scan was carried out in a grid formation of 1 meter samples using the GPR set to a penetration of 2m
- No voids were located, although penetration was limited due to the steel reinforcement at 150mm centers.
- Destructive testing of the floor slab reveal the slab was sitting tight on the sub soil
- Start end and End blocks were devoid of rebar - No test cores
- In general the bar spacings and covers were consistant overall

Core ID Locations	Zone	Bar Size (mm)	Vertical Centres (mm)	Horizontal Centres (mm)	Slab Thick-ness (mm)	Cover (mm)	Comment
1	Splash	Bar too deep for measurement	300	300		200 From Top	120mm Cover from wall side
2	Below Splash	18	150	300		60	
3	Splash	Bar too deep for measurement	150	150		180 From Top	120mm Cover from wall side
4	Floor	Bar too deep for measurement	150	150	145	110	No Void
5	Below Splash	Bar too deep for measurement	600	200		150 From Top	120mm Cover from wall side
6	Floor	Bar too deep for measurement	150	150		110	Drill 170mm - Didn't go through slab
7	Below Splash	18	200	300		60	150mm Wall Thickness - 280mm of void
8	Floor	Bar too deep for measurement	150	150	145	90	Drill through to earth beneath
9	Splash	Bar too deep for measurement	600	200		130 From Top	120mm Cover from wall side
10	Splash	Bar too deep for measurement	600	200		200 From Top	120mm Cover from wall side
11	Splash	Bar too deep for measurement	600	200		150 From Top	120mm Cover from wall side
12	Slope	Bar too deep for measurement	150	150		90	
13	Below Splash	Bar size recorded at 22 but inconsistant with the other wall readings	200	300		50	150mm Wall Thickness - 280mm of void
Pool Drain			300	300		50	Wall Thickness: 150mm