DESIGN AND CONSTRUCTION OF ANANDA COLLEGE SWIMMING POOL

by

B M A Balasooriya

Abstract

This paper describes the design and construction of Ananda College Swimming Pool and the ancillary structures : Spectator decks, sumps and tank. Planning and design considerations are explained. Design of Water retaining structures according to BS 8007 is critically looked at in respect of crack widths and service stresses in steel. Importance of joints and their detailing is presented. Testing of the pool is described and occurrence of damp patches and leaks commented on. Good design and detailing, the contractor's ability and technological know-how and the cooperation within the client -consultant - contractor trianagle helped to achieve quality standards.

Design and Construction of Ananda College Swimming Pool

Project Description

Ananda College Swimming Pool was constructed in 1991/92 in the 2 acre land acquired from Mackwoods Ltd by the Ministry of Education for the extension of Ananda Playground. It is bounded on two sides by Ananda Mawatha and Temple Road and faces the cricket ground on the other. The swimming pool is 50 m long x 21 m wide and has 8 lanes.(Fig.1)

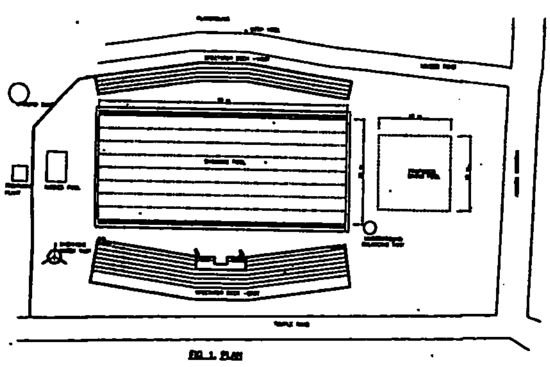
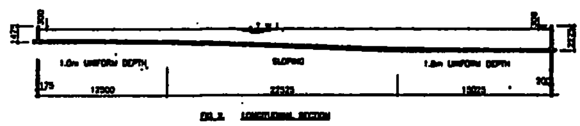
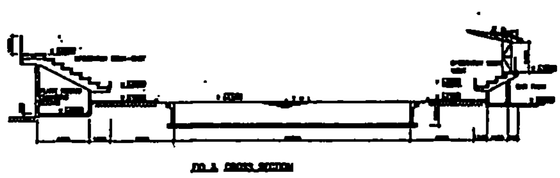


FiG 1, Plan

The depth varies from 1m at the shallow end to 1.8 m at the other. (Fig 2)



In this respect a deviation was made from international competition pool requirement of 1.8 m uniform depth as the primary purpose of this pool is training of school children and therefore, requires shallow depths. The two long walls are designed for water to spill over into two gutters over the top of the wall (Fig.3)



and drain to the deep end and discharge into the Balancing Tank. The ancillary structures include tiered spectator decks on the East and West sides of the pool, an elevated water tank (6000 I), underground balancing water tank(72000 1) a deep well (46 m), a treatment plant for removal of dissolved iron from ground water and a ground sump for storage of treated water. The plant room, changing rooms, toilets and storage space is provided at ground level under the spectator deck on the East. Provision has been

Dr. B M A Balasooriya - BscEng, MSc, phd, CEng, MICE, MistructE, MIE (SL) Consultant Engineer

of the pool [illegible] mechanical equipment is Rs. 16.62 million. The project was financed and executed by the old Boys Association of Ananda College.

This paper describes the design and construction of the pool and the ancillary structures.

2.0 The Swimming Pool

The pool is basically a reinforced concrete open tank 50 m long x 21 m wide placed in the ground. The depth is variable from 1.0 - 1.8 m as shown in Fig. 2. The base slab is ground supported and the walls cantilever off the slab.

The slab and walls were designed as water retaining reinforced concrete elements based on BS 8007; 1987, (1) Movement joints were provided at 12.5 m centres along the length. The pool was waterproofed externally with a continuous preformed bituminous sheet membrane (Fig.5) and internally with Vandex super, a brush applied waterproofing treatment. Grade 30 N/mm^2 readymixed concrete was used ; slump 75-100 mm. Maximum water/cement ratio 0.5, maximum cement content 400 kg/m^3, Pozzolith.300 R retarder and AEA 303 air entraining agent were used in the mix. High yield steel reinforcement was used.

2.1 Base Slab

The base slab of the pool is ground supported. The natural soil is compact, red laterite. The ground water table is very deep at 6.7 m below ground level, and hence there would not develop any uplift on the base. With these favourable conditions it was possible to provide a relatively thin base slab (175 mm). However, in order to guard against cracking due to differential movements caused by local pockets of weak areas, top and bottom layers of mesh reinforcement were provided (Y10 - 250 bw), although a single layer at the top would have been adequate according to BS 8007 for thermal and shrinkage effects. In this particular case local weak areas present were some bricklined deep pits that were found in the ground, which were later filled with gravelly soil and compacted.

After excavation, the grade was prepared according to the longitudinal profile required and it was compacted using vibro rollers. The surface was finished with a 20 mm layer of quarry waste and again rolled over. 75 mm blinding concrete (Grade 20) was then placed [illegible]y topped over with 16 mm [illegible]ed. The external waterproofing [illegible]ane was installed over the screed. It comprised 2 layers of bitumen felt sheets of chinese manufacture bonded to the screed using hot bitumen over the screed and again at the interface of the two layers of bituminous sheets.

A protective screed was applied over the waterproofing membrane over which a slip membrane of gauge 1000 polythene sheet was laid to permit free movement of the concrete slab arising mainly from shrinkage of concrete. The 175 mm structural concrete base slab was cast on it.

2.2 Walls

In the design of the walls, two loading conditions were assumed: (a) Full height water head internally with no earth pressure outside. This condition is obtained during the test fill of the pool before backfilling. (b) Earth pressure externally when the pool is empty. The crack width was limited to 0.2 mm, under "Severe exposure" condition. 40 mm concrete cover was provided.

A wall thickness of 175 mm was provided in the depth range 1.0 - 1.4 m and 200 mm from 1.4 to the 1.8 m deep end. A transition length of 600 mm was provided in increasing the thickness from 175 to 200 mm. The drainage gutters were provided at the top of the walls along the length. (Fig. 4).

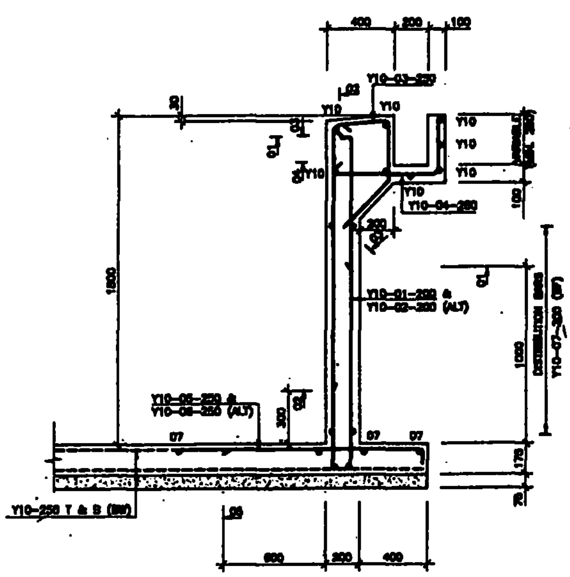


FIG 4. DETAIL OF WALL

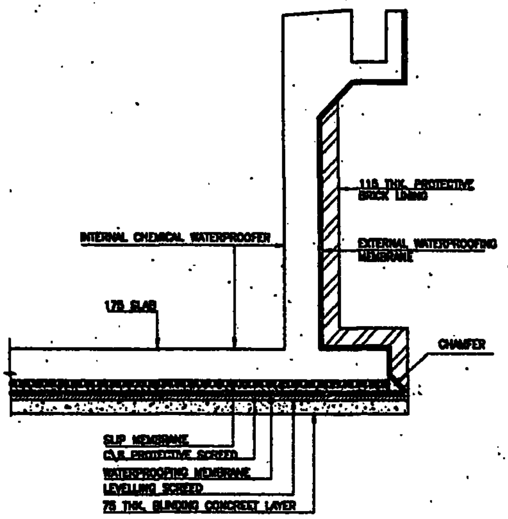


FIG. 5. WATERPROOFING DETAIL

In choosing the wall reinforcement, the working stress in steel was limited to 130 N/mm^2 although higher stresses could be permitted, still controlling the crack width to W < 0.2 mm. the crack width at fs = 130 N/mm^2 was 0.07 mm with Y10 - 100 mm spacing provided on the water face in the wall with 1.8 m depth of water. Here the alternative "deemed to satisfy" provision (C1.3.2.2) was complied with, although knowingly it was a conservative approach. It is pertinent to mention here that at 1.8 m depth of wall (h=200), the crack width w <0.2 mm criterion would have been satisfied even with Y10-200 reinforcement for flexure, but the steel stress would then have been as much as 243 N/mm^2 which is almost equal to the steel stress at working load arising in normal reinforced concrete sections in flexure. For 1 m depth of wall, 175 mm thick with Y10-200 mm spacing on water face, steel stress was 109 N/mm^2.

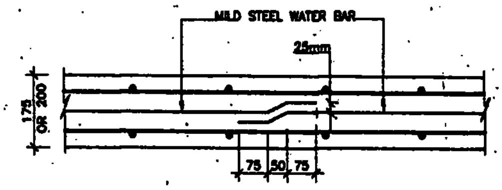
In the absence of confidence gained through previous experience in permitting such comparatively high stress levels in reinforcing steel in water retaining structures at the time, the stresses were deliberately limited to 130 N/mm^2. Other reasons for this decision were that crack width calculations are based on empirical methods; the absence of Quality Assurance Schemes for Ready Mixed Concrete from the few suppliers in Sri Lanka, and the consequent possibility of non-compliance of strength specifications.

R D Anchor (2) states, quote 'the design tensile stress in the reinforcement should be as high as possible for due economy, but relatively low steel ratios are not forgiving if the site workmanship is less than perfect. Anchor states ... not closely controlled, it is not prudent, in the authors' opinion, to permit stresses of the order of 200 / mm^2. They have limited the stresses to generally 160-180 N/mm^2.

2.3 Restrained Shrinkage and Thermal Movement

Early thermal and shrinkage cracking of reinforced concrete walls is a problem frequently met with in construction sites. This is of special concern in water retaining structures. BS 8007 recommends methods for controlling such cracks. There are 3 options available for design.

Semi-continuous construction option was chosen and movement joints (Fig 6) were provided at 12.5 m centres, thus dividing the length of the pool into 4 equal sections. Each movement joint in the base slab was continued up the height of the walls on the two sides, thus making each section completely free of the adjacent one. Reinforcement is discontinued at the joint.



LAPPING DETAIL FOR STEEL WATER BAR AT THE KICKER JOINTS

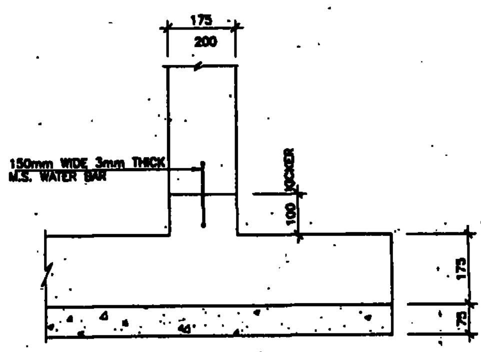


FIG 6. EXPANSION JOINT - ON WALL JOINT DETAILS

Cracking is controlled by means of distribution reinforcement placed longitudinally as close to the surface as possible but complying with cover requirement. The crack width was limited to under 0.2 mm by distributing the cracks by way of distribution reinforcement Y 10-200 and Y 10-250 in the surface zones of walls and the slab respectively which in this case is equivalent to 0.36 percent.

In the base slab (175 mm) the quantity of reinforcement required is 315 mm^2 per metre on each face which was provided by Y10-250 (bw). It should be mentioned here that ideally the choice should have been Y8-150 (bw), since small diameter bars at closer spacing would result in finer cracks more closely distributed.

However, 8 mm dia reinforcement bars are not freely available in Sri Lanka and, therefore, Y10-250 was used although knowingly it was a deviation from BS 8007 where Clause 2.6.2.3 require that spacing of bars should, quote, generally not exceed 300 mm or the thickness of the section (175 mm) which ever is the lesser.

The designers took this decision for the following reasons :

(a) It is not a critical requirement as is seen in the very wording of the clause,

(b) For economy, particularly considering the large area of the slab. If Y10-175 (bw) was provided, it would have meant 43% more steel in the slab,

(c) The minimum steel quantity as required by BS 8007 to control crack width is anyway provided with Y10-250.

It should be noted that although BS 8007 contains empirical formulae for the calculation of minimum reinforcement for control of cracking due to thermal and shrinkage effects, the values to be assigned to several parameters that are included in the formulae are speculative, particularly under Sri Lankan climatic conditions. They are T1, the fall in temperature from the hydration peak to ambient; R, the restraint factor; associated creep strain and shrinkage strain and, the coefficient of thermal expansion of mature concrete produced with local aggregate. In the absence of reliable data based on experimental research in Sri Lanka, the designer needs to exercise judgement in their application.

A surface type preformed flexible PVC waterstop 'Expansion Serviseal 240 (Grace product) was provided externally across the entire length of the joint in the slab and the walls. 20 mm joint width was provided between adjacent faces. 12 mm round mild steel dowel bars at 600 centres debonded on one half were provided to minimize differential movements at the joint. Slab and wall reinforcement bars were terminated on either side of the joint.

The joint gap was filled with microcellular rubber packing and sealed at the top with "Vertiseal" - a two part polysulphide sealant from 'Grace'.

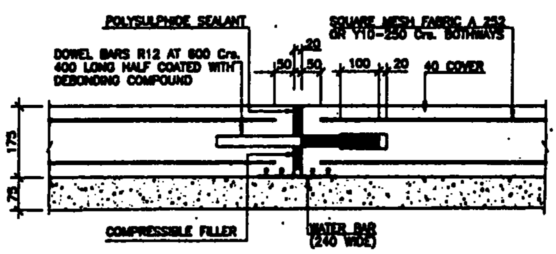
Microcellular rubber (Sri Lankan manufacture) was used as the joint filler material on the recommendation of the CISIR on its suitability with regard to compressibility, non-absorbency and durability in chlorinated water.

The usually specified improted joint filler materials such as Korkpak, and Hydrocell would have been very much more expensive. The movement joint was carried through the finishing tiles.

In hindsight, it is important that the joint line is located to coincide with the tile module line or at least it should be made to be accurately parallel with the tile lines in order to avoid it being oblique resulting in irregular tile lines in the finished pool.

2.4 Kicker Joint on Wall

A 100 mm 'kicker' was provided for construction of the wall with a 3 mm x 150 mm wide mild steel strip used as a waterstop across the joint. (Fig.7) The contractor devised a method of positioning the waterstop accurately and firmly by supporting the m.s. strip with cross bars spot welded to the reinforcement cage.



EXPANSION JOINT - ON BASE SLAB

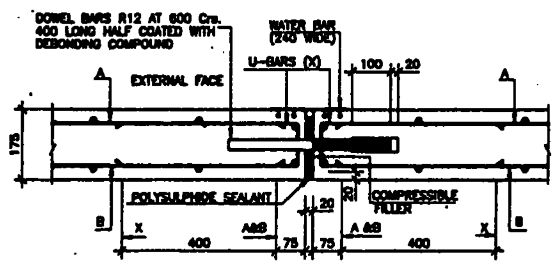


FIG 7. WATER BAR AT BASE SLAB/WALL JOINT

2.5 Placing of Concrete

The base slab concrete was placed in one operation between two adjacent movement joints (12.5 m length). The levels were carefully monitored and the slab finished using a rollerbug. The concreting of walls was done subsequently using plywood formwork. Tie bolts were used to keep the forms rigidly in place. the gutter section and the wall were concreted in one operation in one lift covering the 12.5 m length between joints.

2.6 Curing of Concrete

Within 24 hours after casting of the base slab it was covered with polythene sheets and water was sprayed under the cover at regular intervals to keep the concrete wet continuously for 7 days. The walls were similarly cured.

2.7 Testing of the Pool Structure

Before the application of water proofing membrane externally and backfilling around the walls, the pool was filled for testing the pool structure. It took 208 hours of pumping from the deep well to fill upto 1.75 m level requiring 322,000 gallons of water.

Damp patches were observed on all four walls. They were mostly near the kicker joint. They disappeared in a few days without any corrective treatment. There were definite leaks at two locations on the deep end wall and two on west wall. All of them but one were near the kicker joint. The other was a little above the mid depth of the end wall where an unplanned construction joint had been provided due to suspension of concreting for about 3 hrs as a result of running out of concrete.

These leaks were successfully arrested using 'Thoro' system 'Water plug' externally. The leaks could be correlated to the occurrence of some voids immediately above the kicker joint. This is a known problem and, in fact, at the time of placing concrete, the cement content in concrete was increased a little over a height of about 200 mm from the kicker in order to minimise the problem.

The occurrence of damp patches is a common phenomenon, the reason being the inherent porous nature of concrete. Furthermore, the design philosophy is based on probabilistic theory and there is a statistical chance that crack widths may exceed the design value of 0.2 mm. Dampness and minor leaks often disappear after a few days by the process of autogenous healing and it was the case in this instance.

After an initial period of 4 days for stabilizing, the water level in the pool was measured at the 4 corners of the pool regularly over a continuous period of 9 days. The drop in water level over 24 hour periods was recorded. After slightly erratic 'drops' in the first 5 days, the drop over 24 hours stabilized at 5.25, 5.0, 5.0 and 4.25 mm respectively during the last 4 days. It was reported by the Meteorology Department that the drop in water level due to natural evaporation during the same 4 days as recorded by them was 5 mm per day. Therefore, it was evident that there was no more loss due to any leaks, and consequently, it was concluded that the performance was very good.

However, the Project Committee decided to provide an internal waterproofing, in addition, to make doubly sure of complete water-tightness, in view of the fact that, if any leaks develop later, the remedy would be very expensive after finishing works in the pool are done. "Vandex Super" was applied on the internal surface which seals the concrete by a process of crystallisation filling the pores.

3.0 Spectator Decks

The spectator deck structure on the East is 50 m long and comprises insitu reinforced concrete columns and raker beam spanning 4.65 m between columns and cantilevering out 1.5 m at the top and 1.8 m at the bottom ends. The deck slab having 7 rows of seating was made with precast reinforced concrete L-shaped units spanning 5 m between the raker beams. (Fig 8)

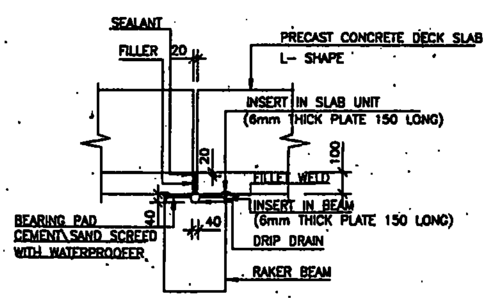


FIG 8. JOINT DETAIL OF DECK SLAB\RAKER BEAM

The joint detail between the precast slab units and the raker beam is shown in Fig 8. A 'drip-drain' was provided along the beam to drain seepage water, if any, at the joint, with an outlet into the deck surface drain under the front cantilever. The slab units were connected to the beam by means of welded joints with mild steel inserts provided on the beam and the slab soffit. The joint was sealed at the top using 'Meycoplast' - a bitumen rubber sealing membrane from Master Builders Technologies, forming a watertight elastic membrane.

The L-shaped slab units were precast at the site on a specially prepared plywood lined platform. The units were cast upside down, so that the smooth surface against the mould would form the final deck surface without the need for any rendering. The Contractor install a gantry hoist to lift the precast units off the platform on which 4 units could be cast simultaneously. they were transported to their final location on a trolley specially made for the purpose and hoisted into place using suitably mounted chain blocks. The cooperation extended by the contractor in developing suitable methods for its construction to meet the designers' requirements enabled the achievement of high quality standards.

Initially, the Technical Committee decided to construct the spectator decks on the East side only, and it was accordingly included in the main contract. However, a decision was taken at a very late stage when the main contract was almost completed to construct the spectator deck on the west of the pool, as well. The reason for this decision was that it would complete the Swimming Pool Project fully and avoid the nuisance and dust to the operation of the pool if it is constructed at a later stage. West side deck, similar to the East deck, is also 50 m long and it provides 3 rows of tired seating. Built by Ranica Engineering Ltd., it was fully institu concrete construction including the terraced deck slab.

A canopy roof was provided over the Western deck. A cantilever steel frame (Fig 3) at 5m centres was used to support the colour bonded profiled steel roof cladding. The frame was fabricated with square hollow steel (SHS) and erected by Isuru Enterprises.

4.0 Water Supply

Water supply is from a deep well (46 m deep 140 mm dia) constructed by the Water Resources Board at the edge of the playground in the vicinity of the pool. No water yield was obtained from the overburden clayey strata. The water yields from deep fractures of the rock starta from 28 - 46 m. Pumping tests indicated a safe yield of 80 litres per minute.

Raw water from the deep well was reported by the Board to be excellent. However, subsequent tests revealed that the iron content was high (2.52 mg/1) and it precipitated as a brown sediment in the pool. Therefore, an iron removal plant (1585 GPH) was designed and constructed by Lanka Enviro Engineers based on their own patented system using crushed dolomite. The treatment includes aeration (via dolomite), flocculation, sedimentation and rapid sand filtration. Dolomite reacts physically and chemically to change the pH value of water and retain dissolved iron particles in the sedimentation tanks.

Water is pumped from the deep well into the iron removal plant and the treated water flows under gravity into a ground sump 54 m^3 (12000 gal) from where it is pumped into the overhead water tank.

5.0 Balancing Tank

The hydraulic system for water circulation required an underground sump 72000 1 (16,000 gal) capacity into which water from the pool flows under gravity, and for the overflow water from the gutters to drain into, from where it is pumped into the filters. A 15 m dia, 4 m deep cylindrical tank was built into the ground with its cover slab at pool deck level near the deep end of the pool.

The ground supported base slab with top and bottom reinforcement mesh was 200 mm thick with a 300 mm thick ring on the outer edge from which the cylindrical wall sprints. The wall is 125 mm thick with a local enhancement to 200 mm near the base to cater for secondary bending moments in the wall. Except in the thickened lower portion of the wall, reinforcement provided is a single layer (Y 10 - 200 bw) placed at mid-depth.

The soil being hard laterite, it was possible to cut down to the required depth with vertical sides needing no lateral support. The base slab was concreted and the earth face lined with brickwork (230 mm) to serve as permanent external shutter for the concrete wall. An inner concentric brick wall (115 mm) was built in stages to serve as the inner permanent shutter and the annular space was concreted in three lifts forming the cylindrical wall. It was plastered internally with cement/sand mortar.

6.0 Overhead Water Tank

An overhead water tank 6000 1(1300 gal) capacity with minimum 6 m head provided to supply water for bathing, toilets and for replenishment of the pool. The Technical Committee required an aesthetically pleasing water tower that would harmonise with the total pool complex. The Architect produced a proposal having a hexagonal bowl held between symmetrical sloping legs. (Fig.9)

FiG 9, Overhead Water Tank

For analysis, the bowl was considered as an assembly of plane plates, 3 alternate plates being directly supported on the 3 legs and the intermediate plates being supported by the former.

The tank base comprising 6 triangular folded plates supported at their periphery on the walls could be considered as a membrane in tension. It was designed according to BS 8007, but controlling the maximum steel stresses to under 130 N/mm^2. Wherever the reinforcement required for strength was small, minimum of 0.35% steel was provided in orthogonal directions.

7.0 Hydraulic System

The hydraulic system to treat the 1,400,000 1 (310 000 gal) of water in the pool with a 4 hour turnover period was designed and installed by Environmental Laboratories Ltd. 3 Nos high rate sand media filters (Italian) having 115 m^3/h capacity each, 3 Nos centric pumps, 100 mm dia 12.5 HP, and a gas chlorination unit (British) 3 kg/h, form the installed plant for the water circulation system, along with the attendant electrical systems.

8.0 Final Cost of Project

The final cost of the project was Rs. 16,624,300 made up as follows : (1992 prices)

Swimming pool	Rs.	7,706,800.00
Spectator decks including facilities for swimmers	Rs.	4,454,100.00
Pool equipment	Rs.	2,480,700.00
Electrical Installations	Rs.	538,000.00
Balancing tank	Rs.	250,000.00
Overhead tank	Rs.	200,000.00
Sump (renovation)	Rs.	92,000.00
Deep well	Rs.	165,000.00
Iron removal plant	Rs.	737,700.00
Total cost	Rs.	16,624,300.00

9.0 Conclusion

It is to the credit of the collaborative efforts of a team of multi-disciplinary consultants, contractors and of course, the 'Client team' which also comprised all professionals' that enabled a well designed and constructed product to be achieved.

The regular progress meetings held at the site where issues were discussed among all parties with openness, frankness and cordiality, and with a positive attitude, helped in delivering to the school a swimming pool and connected facilities of a high standard.

10.0 Credits

Client	:	Ananda College Old Boys Association
Hony. Project Architect	:	Ranjan Gopallawa
Hony. Civil & Structural Engineers	:	Stems Consultants (Pte) Ltd
Hony. Electrical Engineer	:	A T de S Gunasekera
Quantity Surveyors	:	Cost Consultancy Services
Main Contractor	:	Link Engineering Ltd
Plant Installation	:	Environmental Laboratories Ltd
Water Treatment Plant	:	Lanka Enviro Engineers

Acknowledgment

The authors record the invaluable contributions made by other colleagues - too numerous to mention individually, with regard to planning, design, selection of electro mechanical plant, tendering and contract administration. They thank the Old Boys Association for the permission granted to publish the paper.

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2. R D Anchor, The design of liquid retaining concrete structures, Edward Arnold, London, 1992.
3. R Colin Deacon, Water tight concrete construction, Cement and Concrete Association, 1978.