COST EFFECTIVE STRUCTURAL FORMS FOR SWIMMING POOLS

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by

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Abstract

The use of conventional reinforced concrete type construction for swimming pools has the draw back of excessive capital cost. Therefore, there is a need to develop cost effective structural forms for swimming pools constructed in Sri Lanka. It is shown that gravity wall type swimming pools could be adopted for Sri Lanka with certain modifications to sites with laterite soils. The structural design concepts to be used for the bases, gravity walls and the reinforced concrete lining are described in detail. A cost study was carried out to determine the probable cost savings that could be achieved with the proposed gravity type swimming pools.

1.0 Introduction

Swimming could be considered as a sport or a recreational activity. However, the number of swimming pools available in Sri Lanka is still quite small. For many educational institutions, the availability of a swimming pool is considered as a luxury. This is due to the high capital cost involved in the construction of swimming pools. Once built, the maintenance of a swimming pools is not difficult since the cost could be shared by the users.

The private swimming pools are also gradually becoming popular in Sri Lanka. However, these could be beyond reach of even the wealthy people due to the high capital cost involved. Therefore, it is useful to develop alternative structural forms that could reduce the capital cost associated with the construction of a swimming pool.

The basic requirements for any swimming pool could be summarised as follows (Perkins, 1984):

1. The pool shell must be structurally sound.
2. The pool must be water tight against loss of water when it is full. If constructed below ground level, it should be water tight against infiltration of water from sub-soil when the pool is empty.
3. It must be finished with an attractive, smooth, impermeable surface.
4. The water must be maintained at a proper standard of clarity and purity by means of a correctly designed and operated water treatment plant.
5. A walkway of adequate width and a non-slip surface should be provided around the pool.

The alternative structural forms developed should facilitate the achievement of the above basic requirements. Those should take account of the site conditions and also the provisions of BS 8007: 1987 when reinforced concrete is used. This paper presents a concept that could be adopted for Sri Lanka to reduce the structural cost considerably from the conventional reinforced concrete construction.

2.0 Objectives and Methodology

The main objective of this research is to develop cost effective structural forms for swimming pools so that the capital cost of a swimming pool could be affordable to many institutions and private clients. The following methodology was used to achieve the above objective:

1. A detailed literature review was carried out to determine the various structural concepts and materials adopted in other countries. The alternatives that could be cost effective were identified.
2. These concepts were further investigated to determine the applicability to the soil types and ground water conditions available in Sri Lanka.
3. Detailed structural designs were used to determine the suitability of the proposed concepts.

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3.0 Dimensions for swimming pools

The dimensions used for a swimming pool will depend on whether those are for private houses, clubs and hotels or schools. For public pools, a minimum of 2 m² of pool water area is desirable per person. For proper swimming, a lane of at least 2.0 m in width is required. For the pools intended for swimming, but not for diving, the depth of water need not exceed about 1.5 m. The provision of a depth in excess of this figure serves little useful purpose, but adds significantly to the capital cost and running expenses of the pool. Tables 1, 2 and 3 give some of the recommended dimensions for swimming pools. (Perkins, 1984):

Item No	Length (m)	Width (m)	Minimum water depth	Maximum water depth	Water area (m2)
1	6.00	3.0	0.90	1.10	18
2	10.00	5.0	0.90	1.50	50
3	12.50	5.0	0.90	1.50	62.5
4	16.67	6.0	1.00	1.50	100
5	16.67	6.0	1.00	3.00	100

Table 1: Dimensions recommended for swimming pools in private houses.

Item No	Length (m)	Width (m)	Minimum water depth	Maximum water depth	Water area (m2)
1	12.50	6.0	0.90	1.10	75
2	16.67	8.0	0.90	1.5	133
3	20.00	8.0	0.90	3.00	160
4	25.00	12.50	0.90	3.00	312.5

Table 2: Dimension recommended for swimming pools in clubs and hotels.

Item No	Length (m)	Width (m)	Minimum water depth	Maximum water depth	Water area (m²)
1	10.00	5.0	0.90	1.10	50
2	16.67	8.0	0.90	1.50	133
3	20.00	10.0	0.90	1.50	200
4	25.00	12.5	0.90	1.50	312.5
5	25.00	12.5	0.90	3.00	312.5

Table 3: Dimensions recommended for schools

In all these tables, it can be seen that most of the pools would have a maximum depth of 1.5 m. The largest pool generally recommended for a school is 25.0 m in length x 12.5 m in width. When the depth varies between 0.9 m to 1.5 m, as used for a teaching pool, a section through the pool would be as given in Figure 1. The floor gradient for the shallow part of the pool is about 1:26. In addition to these rectangular pools, there can be free formed pools of various shapes as found in many tourist hotels.

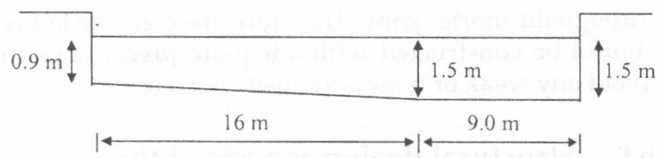

Figure 1: A section through 25 m teaching pool.

4.0 Structural forms for 25 m teaching pools

The structural forms that could be used are briefly highlighted.

4.1 Reinforced concrete structure

Since the pools with a maximum depth of 1.5 m can be quite sufficient in many instances, the attention was focussed on such pools in this research study. The commonly adopted structural forms for such swimming pools are as follows:

1. Designing of vertical walls of the swimming pool as cantilever walls for pool empty and full conditions. When the pool is empty, the soil pressure is considered. When the pool is full, the pressure from the soil is ignored since this could be the situation when the water test is performed. The wall acts as a cantilever since it is rigidly connected to the base slab of sufficient width; it is about 1.5 m for a water depth of 1.5 m. The thickness of the base slab would be 300-350 mm to provide the weight and the rigidity required for stability.

2. The remaining part of the base slab is also generally cast with the same thickness to prevent floatation effects.

Since this structural system relies on the rigidity of joints, generally the service of a specialist contractor is a prerequisite for this type of pools.

4.2 Gravity wall type swimming pool

A swimming pool structure that is quite successfully adopted is gravity walls with an inner lining of reinforced sprayed concrete. The walls of the structure consist of suitable masonry or mass concrete where those should be stable by their own weight when the pool is empty (soil pressure) and also when it is full (water pressure). In this structure, sprayed concrete provides a water tight lining that has certain structural strength.

The walls can be built on independent foundations and the floor can be constructed separately as shown in Figure 2. On the other hand, the floor can be insitu cast reinforced concrete and the wall supported on that as shown in Figure 3. Pools built in this way can be quite successful provided that the water table does not rise much above the floor of the pool.

One of the attractions of this type of a pool is that a considerable part of the construction except the sprayed concrete can be carried out by a contractor who has little or no experience with swimming pool construction.

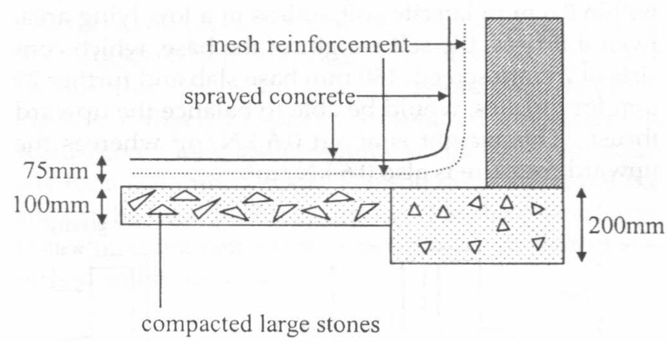

Figure 2: Gravity type wall of pool with reinforced sprayed concrete lining and floor.

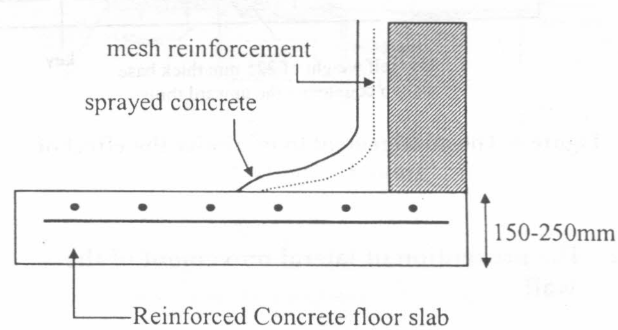

Figure 3: Gravity type wall of pool with reinforced sprayed concrete lining and reinforced insitu cast concrete floor.

5.0 Use of gravity wall type swimming pools for Sri Lanka

When gravity type swimming pools are designed, the following issues should be addressed:

1. The possibility of water table rising outside.
2. The prevention of any lateral (outward or inward) movement of the gravity walls.
3. The type of materials suitable for the gravity walls.

5.1 Solution for the rising water table

In the gravity type swimming pools, the ground floor slab is not designed to withstand the hydrostatic pressure exerted by the high water table. Therefore, it is necessary to ensure that the water table remains sufficiently below the swimming pool floor. This condition can be quite easily satisfied by ensuring that part of the swimming pool in located above the ground as shown in Figure 4. For example, for a depth of 1.5 m, 0.6 m could be below ground. The remainder can be above ground. It is quite unlikely for the water table to rise to within 0.6 m in laterite soil, unless in a low lying area. Even if it rises, the self weight of the base, which consists of 75 mm screed, 150 mm base slab and further 25 mm for finishes, would be able to balance the upward thrust. This weight is about 0.6 kN/m^2 whereas the upward pressure is also 0.6 kN/m^2.

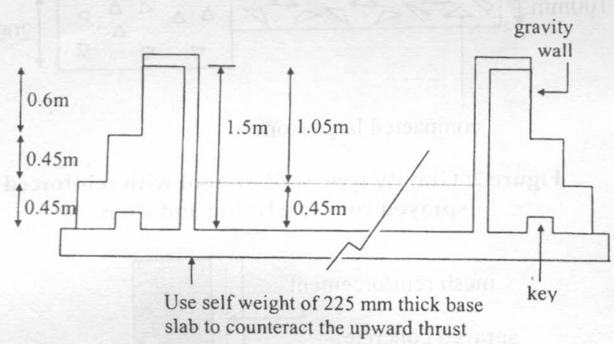

Figure 4: The arrangement to minimise the effect of ground water table.

5.2 The prevention of lateral movement of the wall

Since any minute inward or outward movement of the gravity wall can cause leakage of water, it has to be prevented. The easiest way is to firmly anchor the wall by locating it over the ground concrete slab. The anchoring effect can be further enhanced by having a projecting key below the retaining wall. The starter bars for the concrete walls also can be fixed prior to laying of concrete for the ground floor slab.

5.3 The material for the gravity wall

One material that could become a strong candidate for the gravity wall is random rubble masonry. It is recommended by Chandrakeerthy (1998) that the random rubble masonry walls should be constructed with 1:5 cement sand mortar. The characteristic compressive strength that can be expected is about 2.0 N/mm^2. It is not advisable to rely on the tensile strength. It is also not possible to rely on the random rubble masonry for impermeability since it could be quite permeable through the mortar joint. Therefore, the concrete lining should be constructed with adequate precautions to avoid any weak or honey-combed concrete.

6.0. Structural design aspects of the proposed structure

The main structural components of the proposed arrangement consist of the following:

1. The reinforced concrete ground slab.
2. The random rubble masonry gravity retaining wall.
3. The reinforced concrete sidewalls.

The structural concepts and the additional precautions to be taken for each component are described in detail.

6.1. The reinforced concrete ground slab

The reinforced concrete ground slab need not have any flexural strength since the weight of water can be resisted by the soil below. Therefore, it needs reinforcement only to prevent early thermal cracks in immature concrete. BS 8007: 1987 allows the prevention of early thermal cracks in continuously cast concrete member by the provision of adequate amount of small diameter bars. It also allows the provision of this reinforcement in a single layer. In this type of construction, it is advisable to compact the soil below the ground floor slab thoroughly to avoid any weak pockets of soil prior to laying the screed concrete.

For the design of the reinforcement in the slab, the crack width allowed should be taken as 0.2mm. The maximum spacing of the cracks is given by Equation 1:

$$S_{max} = \frac{f_{ct}}{f_b} \times \frac{\phi}{2p} \qquad \text{Eq. 1}$$

For deformed bars $\frac{f_{ct}}{f_b}$ the ratio of the tensile strength of concrete to average bond strength is equal to 0.67 (Table A.1 of BS 8007: 1987). When a minimum steel ratio, p, of 0.0035 is used with 10mm diameter bars,

$$S_{max} = \frac{0.67 \times 10}{2 \times 0.0035} = 957mm$$

The corresponding maximum crack width can be found from Equation 2.

$$W_{max} = S_{max} \times \frac{\alpha}{2} \times T_1 \qquad \text{Eq. 2}$$

The value of T1 for the ground floor slab is $17^0 + 10^0 = 27^0$C. The value recommended in BS 8007: 1987 for T_1 is 17^0C (Table A.2). An additional 10^0C is allowed for seasonal variations.

$$W_{max} = 957 \times \frac{10 \times 10^{-6}}{2} \times 27^0\,C = 0.129 < 0.2 \text{ mm}$$

Hence, the provision of 0.0035 on the reinforcement ratio is sufficient.

6.2. Design of the random rubble gravity wall

The random rubble gravity wall has to be designed for the lateral pressure due to water. The size of the retaining wall is selected so that no tension will occur in it due to the flexural stresses induced as a result of lateral loads. The dimensions indicated in Figure 5 were selected on this basis.

Random rubble walls require expansion joints when the length is more than 15 m. However, in this wall, the length is 25.0 m. Therefore, it is advisable to have a strategy to prevent any cracks due to shrinkage although it is unlikely in this particular case. One strategy is to construct the wall in lengths of about 12.0 m while keeping gaps of 1.0 m. when the wall is about 2 weeks old, the gaps can be filled up so that a portion of shrinkage has already occurred, thus reducing the chances of cracking. Once the concrete lining in cast, the possibility for shrinkage cracking in extremely remote.

6.3. Design of the wall

The reinforced concrete wall is cast by using the random rubble gravity wall as the formwork on one side. Therefore, the same method adopted for the floor can be used to determine the reinforcement to restrict the crack width in immature concrete. Since plywood formwork would be used as the shuttering on the otherside, the value of T1 should be 25^0C + 10^0C (Table A.2).

In C1.A.3 of BS 8007: Part 1, a restraint factor, R is introduced with R = 0.5 for immature concrete with rigid end restraints. Since concrete is cast against the random rubble wall, it is advisable to use the value of R as 0.5. It was suggested by Fonseka (1995) that the use of the maximum value for R would be beneficial in Sri Lanka since any error in estimating the value of T1 would be adequately compensated. The use of minimum steel ratio of 0.0035 would result in a crack width of 0.167 mm (< 0.2 mm). Therefore, the provision of 0.0035 as the reinforcement ratio is sufficient.

7.0 The structural arrangement of the Swimming pool

On the basis of the calculations described in Section 6, the structural arrangement shown in Figure 5 was selected. The reinforcement details are also given in the same figure. Since, it is necessary to have a walkway of adequate width around the swimming pool, an embankment can be formed by using the excavated soil. This embankment should be paved at the top to ensure that all the water collected will be drained and removed from the location of the swimming pool in order to avoid any build-up of hydrostatic pressure.

The stability of the earth embankment can be further enhanced by using the cement stabilization. It was reported by Jayasinghe & Perera (1999) that it is possible to achieve compressive strengths in excess of 1.0 N/mm2 for blocks when about 2 % cement is used for stabilization of laterite soil. Therefore, the use of cement stabilised properly compacted embankment would give a long lasting solution which is a pre-requisite for a swimming pool. The soil excavated from the site can be used for this purpose. For the cost calculation, this is not considered since the use of cement stabilised soil is optional.

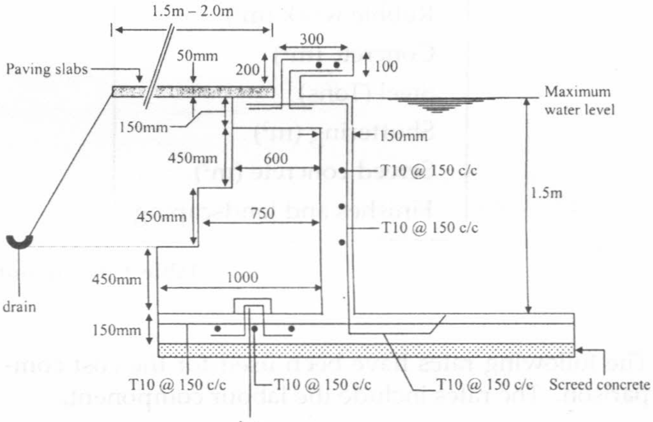

Figure 5: The structural arrangement of the swimming pool.

8.0 The structural cost of the swimming pool

The approximate cost for the swimming pool shown in Figure 1 was evaluated in order to illustrate the cost effectiveness of the proposed concept. It is compared with the structural cost of a conventional solution consisting of a base of 350 mm thickness and walls of 200 mm thickness. The reinforcement arrangement based on a minimum steel ratio of 0.0035 is given in Figure 6 except in the walls subjected to flexure. The material requirement is given in Table 4.

The cost of the conventional swimming pool is estimated as Rs. 2.2 million. The cost of the proposed solution is estimated as 1.4 million. Therefore, a cost saving of about 35 % is possible by adopting the proposed solution. To determine the total cost of the project, the cost of finishes and the treatment plant also should be added.

9.0 Conclusions

The prudent use of available resources could allow the sharing of limited resources among a greater population. In this respect, the development of cost effective solutions for infrastructure would be quite useful. One area available for cost savings is structural optimisation.

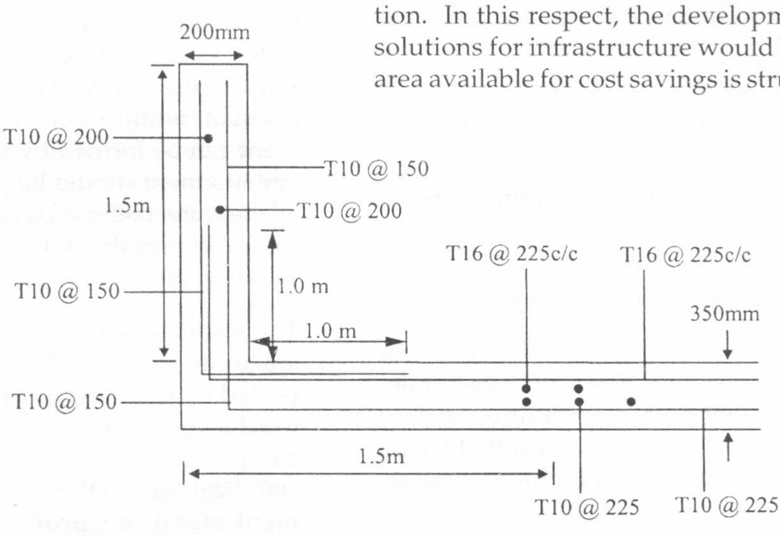

Figure 6: The reinforcement arrangement for a reinforced concrete swimming pool.

	Conventional	Proposed
Excavation (m^3)	650 m^3	250
Rubble work (m^3)	-	80
Concrete (m^3)	120	85
Steel (Tons)	11.0	4.5
Shuttering (m^2)	225	115
Screed concrete (m^2)	340	390
Finishes and landscaping	Same for both	Same for both

Table 4: The quantities used for the cost estimate.

The following rates have been used for the cost comparison. The rates include the labour component.

Excavation	-	Rs. 300/= per m^3
Rubble work	-	Rs. 2000/= per m^3
Grade 35 concrete	-	Rs. 8000/= per m^3
Steel	-	Rs. 70,000/= per ton
Shuttering	-	Rs. 700/= per m^2
Screed	-	Rs. 300/= per m^2

It is shown that the use of gravity wall type swimming pools could be a viable solution in Sri Lanka. The structural design concepts that comply with the recommendation given in BS 8007: 1987 were presented for gravity wall type swimming pools. The precautions that should be taken to ensure structural integrity were highlighted. A cost estimate carried out to compare the conventional solution with the proposed solution indicated a cost saving of about 35 % with respect to the structural costs.

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