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Structural design of public swimming pool at University of Global Health Equity Butaro campus, Rwanda.

Author: DUKUZUMUREMYI Edison
Email: dukuzumuremyie34@gmail.com

Abstract

Swimming pools have become an essential attachment to most habitable coastal construction such as hotels, condominiums and single family residences. A large swimming pool type structure may obstruct the free flow of flood water and increase the turbulence. This in turn may increase the scour potential and the wave/debris action on the building and foundation. A conceptual breakaway concrete swimming pool design is described herein. It is demonstrated that this pool will withstand everyday factored water/soil loading, but will collapse and break away under extreme wave action, thereby minimizing the detrimental effects of a solid pool. This study was done based on the serious issues of stress remarkable from various institution in Rwanda, especially those who are increasing their life standards in spending their money in hardworking. The main aim is to design public swimming pool appropriate to such organization and uniquely beneficial to the improvement of their health through leisure. It is designed to serve an institution of 200 members approximately within their special guests. The site was visited, and some data were collected. Soil parameters consist of internal friction angle, internal friction angle coefficient and the unit weight of the subsoil. The site visit permits really to select a shaped rectangular pool of public swimming pool. This study did not include bills of quantities which would be another way considered before when deciding the implementation. The results observed in this study is that a selected rectangular swimming pool can be stable for concrete of fcu=30N/m, on stem and key elements T20@300C/C bottom and T10@200C/C top can be used, at T20@280C/C and T10@220C/C bottom and top reinforcement respectively was found at heel, toe can use T12@300C/C and T10@220C/C and slab T10@200C/C and T10@300C/C bottom and top reinforcement respectively. At the end of the study different conclusion and recommendation was highlighted.

Keywords: Structure; Loads; Swimming Pool; Design

1. INTRODUCTION

A pool is a constructed or prefabricated artificial basin; chamber or tank intended to be used primarily by bathers, and not for cleaning of the body or for individual therapeutic use. Includes in-ground and above-ground pools and includes, but need not be limited to hot tubs, portable and non-portable spas, and wading pools (Department of Building and safety, 2019).

According to Wilson (2015), in the 19th and early 20th centuries Britain's Queen Victoria ordered the construction of public baths and encouraged the whole population, for their own safety, to learn to swim. The public baths were built in towns all up and down the country and, in addition to a large swimming pool, included numerous small personal bath tubs which, with a continuous supply of hot water, allowed the general population to get a good wash on a regular basis (Wilson, 2015). At a time when most people did not have access to a bath or hot water the public baths became very popular. The swimming pools became a model for all modern swimming pools in terms of size, the use of chlorine for water conditioning and for the circulation and filtration of water. Since then many different types of pools have been developed (Wilson, 2015).

In many countries have an extensive tidal shorelines (Bochy, 2003). In recent years, these shorelines have been subjected to rapid development and construction due to a massive population influx (Bochy, 2003). Swimming pools have become essential accessories attached to habitable coastal construction in terms of property value and the tourism industry in Florida. Virtually all of these pools are situated seaward of the habitable structures (Nur Yazdani et al., 1997). According to the researchgate.net (2017) the Federal Emergency Management Agency (FEMA) oversees the construction of all structures (including pools) in the Coastal High Area Hazard Areas (V-zones) in order for these structures to be insured under the National Flood Insurance Program (Nur Yazdani, 2017). These requirements are contained in 44CFR Section 60.3 which states that all new construction and substantial improvements in Zones VI-V30, VE, and V shall have the area below the lowest floor level either free of obstruction, or constructed with non-supporting breakaway walls or similar structures (Nur Yazdani, 1997).

If a swimming pool is placed below the level of a building, but above natural grade, it may behave as an obstruction to the free flow of floodwater (Australia, 2001). A large object, such as a swimming pool, placed above the natural grade may increase the turbulence of the floodwater, resulting in an increase in the scour potential under and around pools, and around the pile supports (Barss, 2008). The extra turbulence created by the presence of the pool structure may also cause increased wave and debris action on the elevated portion of the building or other adjacent structures and foundations (Barss et al., 2008).

Swimming pools should withstand everyday water and soil loads with an adequate factor of safety, but should collapse and break away in case of a L-year flood event without acting as an obstruction to the flow of floodwater (Wiklund, 1989). Swimming pools designed to be frangible will help preserve the integrity of the beach/dune system and other structures in extreme flooding conditions. The effect of a swimming pool type massive structure on coastal topography during a storm has been apparent over the years; however, documentation of this effect has started only recently. Nur Yazdani, Soronnadi Nnaji and Michelle Rambo-Rodenberry (1997) state that no basic research has been performed on understanding this effect, or on ways to minimize such costly damage.

2. MATERIALS AND METHODS

2.1. Study area

My site is located in Mulindi Village, Mubuga Cell, Butaro Sector, and Burera District in Northern Province of Rwanda. This site is approximately flat as the best parameter to consider which makes execution ease and simple during setting out within excavation and construction works. The area of study is UGHE Butaro Campus visited.

The aim was to look for the total number of the users (Campus residents) for expectation which is helpful in estimating the quantity of water (Capacity of swimming pool container) These data have been used to calculate the really capacity of water needed in the swimming pool container within the water tank as reserve of water in motion and the flow rate of water in and out of swimming.

2.2. Study design and process

A case study method was selected for this study as the most appropriate technique because the situation being studied was for supporting decision about technology adoption. The definition of a case study that was adopted is one defined by Anderson (1998) that was developed from Merriam (1988) and Yin (1994). A case study is a holistic research method that uses multiple sources of evidence to analyse or evaluate a specific project. Most case study research is interpretive and seeks to bring to life a case. It often, but not exclusively, occurs in a natural setting and it may employ qualitative and/or quantitative methods and measures Anderson (1998).

The research started from a series of British and Indian standards, which presented contemporary public swimming pool design and their benefits. The research was structured to include, from the beginning, from the preliminary papers of the thesis, three important aspects of the underground living: the motivations for underground living, specific problems in developing underground and semi-buried houses and case studies on completely underground cities.

Multiple sources of data and data collection methods were employed and triangulation was used to interpret and develop generalizations from the study. The three compositions (Planning, Design, construction) were the foundation for the problematic exposed in the thesis, the information helped shape a general image on the occurrence, development and cyclic proliferation of underground. Besides the literature, divided in sub-domains of research, and the case studies, the thesis permanently used varied digital sources: digital libraries and databases, sites specialized in constructions, virtual groups of enthusiastic amateurs and underground home owners, who shared their personal experiences in building such houses, forums with opinions of specialists, search engines, etc., all with the scope to create a credible speech and a coherent structure to the theoretical demarche.

2.3. Data collection

The following table summarizes the data collection techniques and the method used for analysis

No	objectives	Data required	Data source	Data acquisition tools	Method of analysis
1	To analyze and determine the loads applied on swimming pool .	Soil bearing pressure, number of users, material used for construction, pool shape and volume.	Site visit, laboratory test	Contract document, Literature review tools	Comparison analysis between earth pressure and total imposed loads
2	To calculate the required reinforcement needed to support all the loads applied	Pa(pressure),moment, h, b, k, z, As.	Author selection and calculation	Principal of equilibrium	$K=\frac{M}{fcubd^2}$ $K< 0.156$, There will be no compression reinforcement
3	Learning and applying the calculus methods employed for verifying the stability conditions of potentially sliding slopes by positioning swimming pool	Shear forces	Calculation From designed moment	BS8102:2009 Code of practice, EN1992-3:2006 Design of Concrete Structures	$As=\frac{Mu}{0.95fy*Z}$ Through As the number of steel bar and its diameter was analyzed. Shear force analysis to check the stability of structures

Summary of data collection techniques

2.4. Data analysis

This visit helped in gathering basic information of the site such as site location, existing infrastructures, soil information, size of the site, water use and cost, and so many others, Other areas such as Mateo Rwanda, hardware's and others gave me information relating to the prices, rainfall intensity of the area, and many others. Data have been recorded both internal and external of the computer and papers. After getting information, processing them has been of great importance in the aim of having tangible thing to reach the findings. The design process was for the aim of giving real shapes of public swimming pool itself and different outcomes and so on. All information has been typed in the computer for the production of the thesis. Drawings were scanned from AutoCAD to the word processing software. Tables have been scanned from MS Excel spread sheets to Word.

3. RESULTS AND DISCUSSION

EVERYDAY LOADING DESIGN

A swimming pool must be able to withstand everyday maximum loading. For pools situated above ground, these loads include the water load inside the pool when it is full, the total load is:

$WA = 0.5 \gamma_w H^2$ per unit width of wall (1)

In which γ_w = unit weight of water, and H = height of pool.

The bending moment at the pool base is given by:

MA = $0.083\gamma_w H^3$ per unit width (2)

For a below ground pool, the maximum everyday forces are caused by soil outside the pool when it is empty. This force and the corresponding moment are expressed as the following for a 20° coefficient of internal friction for soil:

WB = $0.235\ \gamma_s H^2$ per unit width (3)

MB = $0.078\ \gamma_s H^3$ per unit width of wall (4)

In which γ_s = unit weight of soil. The groundwater table was assumed to be low, which would cause negligible force on a below ground pool. For higher water levels to pool should remain filled with water to prevent it from floating up. A floating pool is likely to crack and will rarely settle back in the original position after flooding subsides.

Design of kidney underground swimming pool

Design data	**Design Elements**
μ=0.7 $\gamma_{s=}$17KN/m^3 ϕ= 20^0 H1=2.2m H2= 2.0m γ_c= 24 KN/m3 f_{cu}=30N/mm, f_y= 460 N/mm^2	The elements of the swimming pool are generally constructed by reinforced structural members: The walls and the bottoms.

The everyday maximum forces and moments expected on the pool wall are presented in Tables 3. The water load on an aboveground pool is slightly higher than the soil load on a belowground pool; the two forces just act in opposite directions, Therefore, only the design of an above ground pool with water load is presented herein.

Design shear forces and moments with ACI load factors on a 2 foot width of pool wall are shown in Table 3(c). Corresponding vertical steel design at the splice (0.9m from top) and at the bottom (1.8m from top) are also presented.

Table 2. Everyday maximum forces and moments on pool wall.

Wall Height(m)	Above Ground Pool(KN/m width)	Below Ground Pool(KN/m width)
	(a)Everyday forces	
1.2	7.3	6.6
1.5	11.4	10.28
1.8	16.38	14.8
2.1	22.3	20.16
	(b) Everyday Moments at the Base	
1.2	9.71	8.78
1.5	18.96	17.14
1.8	32.76	29.61
2.1	52.04	47.03

Depth from Pool Top (mm)	**Ultimate Shear (KN)**	**Ultimate Moment (KN.m)**	**Reinforcement Design**
(c) Ultimate Shears and Moments in Wall			
0.9	11.46	11.46	
1.8	45.88	91.77	

The stability of structure as whole against overturning shall be ensured so that the resisting moment shall not be less than the sum of 1.2 times the maximum overturning moment due to characteristic dead loads and 1.4 times the maximum overturning due to characteristic imposed loads.

In cases where dead load provides the resisting moment, only 0.9 times the characteristic dead load shall be considered. Resisting moment due to imposed load shall be ignored. It should be noted that the dead loads are reduced by 10% to take into account the saturation where they might had been over estimated. Thus 0.9∗resisting moment$\nless$1.4 overturning moment, safety factor F= $\frac{1.4}{0.9}$ =1.55

Types of loads	Horizontal loads KN	Distance from A point m	Moment about A point KNm
Active earth pressure (Pa)	$Pa=\frac{1}{2}Ka * \gamma * h2$ $Pa=0.5 * 0.48 * 17 * 3.2^2$	$\frac{H}{3}=\frac{3.2}{3}=1.07$	41.7*1.07=-44.6
Total	**41.7**		**-44.6**
Vertical loads			
Wall	$2.94 * 24 * 0.2 * 1 = 14.1$	$0.7+0.05+\frac{0.2}{2}=0.85$	$14.1 * 0.85 = 12$
	$\frac{1}{2} * 0.05 * 2.94 * 24 * 1 = 1.764$	$0.7+0.05 * \frac{2}{3} = 0.73$	$1.764 * 0.73 = 1.3$
Base	$2.1 * 0.26 * 24 * 1 = 13.1$	$\frac{2.1}{2}=1.05$	$13.1 * 1.05 = 13.75$
Key	$0.6 * 0.25 * 24 * 1 = 3.6$	$0.7+\frac{0.25}{2}=0.825$	$3.6 * 0.825 = 2.97$
Backfill	$1.15 * 2.94 * 17 * 1 = 57.4$	$0.7+0.25+\frac{1.15}{2}=1.525$	$57.4 * 1.525 = 87.53$
Total	**89.96**		**117.55**

POOL WALL STABILITY

The pool wall is designed as retaining wall fixed on bottom pool (base slab). For pool wall design it is necessary to consider the active earth pressure (Pa) acting horizontal and perpendicularly to the wall surface.

It is also necessary to consider the unit weight of the soil γ_s, unit weight of water γ_w and the angle of response of the backfill for finding the earth pressure coefficients Ka, whereas the backfill is the retained materials.

$Ka=\frac{1-\sin\theta}{1+\sin\theta}$ and $Kp=\frac{1+\sin\theta}{1-\sin\theta}$

These coefficients conduct to analyse the bending moment, shear force and steel reinforcements.

The main bars reinforcements are calculated from maximum bending moment

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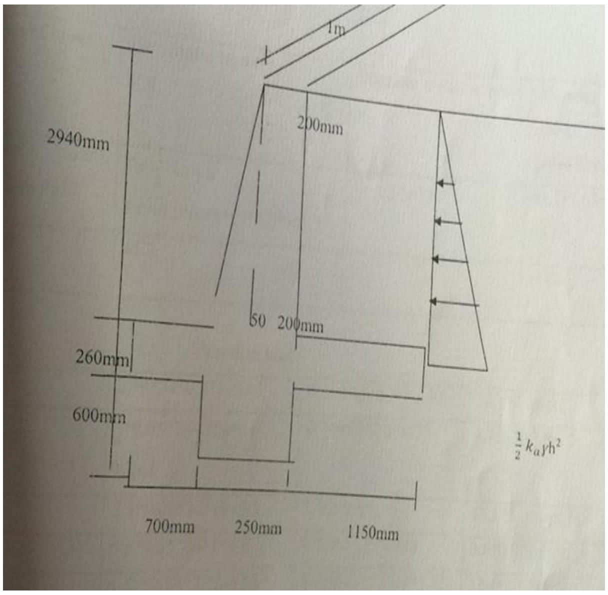
in the wall caused by forces and horizontal earth pressure acting on wall structures.

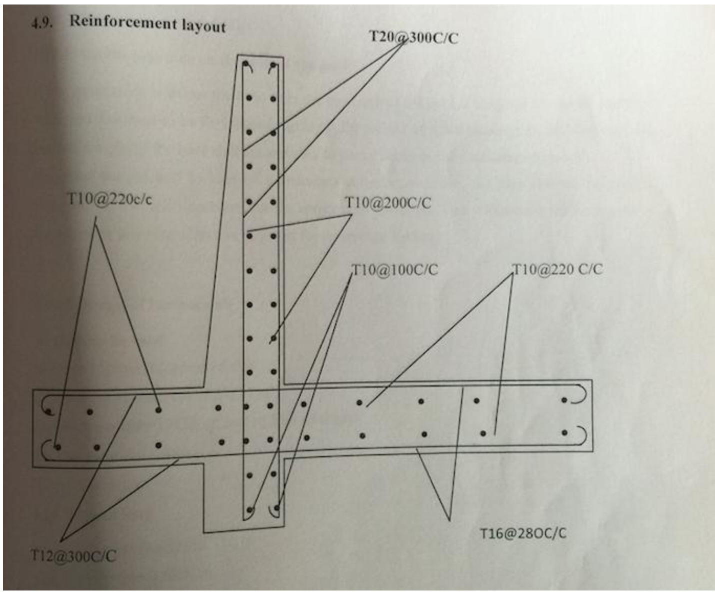
The distribution bars of reinforcements are calculated; note that 0.13 per cent of minimum section area for high yield stress of steel f_y=460N/mm^2.

Coefficient of earth pressure

$Ka = \frac{1-\sin\theta}{1+\sin\theta}$ therefore $\frac{1-\sin 20}{1+\sin 20} = 0.48$ and

$Kp = \frac{1+\sin\theta}{1-\sin\theta}$ therefore $\frac{1+\sin 20}{1-\sin 20} = 2$





RESULTS PRESENTATION

Nº	ELEMENTS	MATERIALS		
		CONCRETE	**STEEL**	
1	Stem	Fcu=30N/m	T20@300C/C	T10@200C/C
2	Heel	Fcu=30N/m	T16@280C/C	T10@220C/C
3	Toe	Fcu=30N/m	T12@300C/C	T10@220C/C
4	Key	Fcu=30N/m	T20@300C/C	T10@100C/C
5	Slab	Fcu=30N/m	T10@200C/C	T10@300C/C

IMPACT OF DEBRIS ON FOUNDATION

If a pool is designed to be frangible, it is likely to breakaway in several pieces during an extreme flooding. It is possible that the broken debris may be carried away by wave action and impact on the adjacent house or foundation. The foundation should be designed with proper consideration for this impact force from a frangible pool. There are many variables which are likely to influence the magnitude of the debris impact force, such as the size of the pieces that will break away, the velocity of the broken pieces, the wave height and wave depth, the amount of time the broken pieces will remain in contact with the foundation, and the manner in which the pieces come in contact with the foundation. The position of the pieces in the wave is also a factor for transitional or deep water. Simplifying assumptions were made in order to develop an expression for the debris impact force on adjoining foundations. It was assumed that the pool wall will break into 2 foot by 3 foot by 6 inch thick pieces (according to the breakaway design for concrete pools developed in this study) and will impact at a velocity equal to the velocity of the water (a conservative assumption). From Impulse-Momentum relationships (Beer and Johnston, 1988):

$$\int F dt = mv \quad (5)$$

In which F = impact force, dt = increment of time, m = mass of broken piece, and v = velocity of piece when it comes in contact with the foundation. The velocity of the piece, assuming shallow water conditions, is as follows (Herbich et al., 1984):

$$V = H/2\, (g/d)^{1/2} \cos(\theta) \quad (6)$$

In which H = wave height, d = depth to SWL, θ phase angle of wave, and g = acceleration due to gravity = 9.81m/sec^2.

For maximum velocity, assuming θ = 0 degrees:

$$\int F dt = 13.98\, (0.5H)\, (g/d)^{1/2} \quad (7)$$

4. CONCLUSION

The objective of this study was to design a public swimming pool for University healthcare purposes. Architectural and structural designs of swimming pool depended on the number of users; and the consideration of aesthetic that bearded a kidney shaped structure. The limitation of the provided time for such a project made me to consider some parameters of the soil based on the international standards for a clayey soil without considering the results from laboratory. Indeed, there was not look on bill of quantities, and this would be done before implementation of this project. The struggle for achieving had improved not only my theoretical skills but also put emphasize on our practical performance which shall lead our whole professional career of engineering, especially in the matter of special structures including different varieties of swimming pool. The following conclusions may be made based on the findings of the study:

1. There have been no previous or continuing studies which address frangibility criteria for this swimming pool.
2. It is feasible to theoretically and practically design and construct a good and safe swimming pool made of concrete. A good breakaway concrete pool design includes vertical joints and splices in the reinforcing steel.
3. Scour that causes undermining of the pool wall may cause failure. For example, for the concrete swimming pool design, a 6 foot wall undermined approximately 3 feet will fail due to the weight of the water inside the pool.
4. Recreational swimmers with limited diving skills are at risk of sustaining diving injury in the typical home swimming pool. Hence, it is useful to consider the engineering and enforcement processes presented in this study, along with incorporation of participant education (skills) recommendations of previous research. These provide a comprehensive and multifaceted approach to prevention of diving injuries and enhance safe, enjoyable home pool use.

5. LIST OF ABBREVIATIONS

These figures were used in this paper:

dt = increment of time;

F=impact force;

g =acceleration due to gravity;

H =wave height;

MA =bending moment at pool base

MB=bending moment (below ground);

m = mass of broken piece;

WA= water load inside (above ground);

WB = water load inside pool when full (below ground pool);

$\gamma_{s=}$ unit weight of soil;

γ_w= nit weight of water;

θ = phase angle of wave;

V=Velocity of piece on impact.

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Authors' contributions

AMR conceptualize the idea and implementation

Authors' affiliation AMR, Distance production house University/IST Burkina Faso

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