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DEPARTMENT OF CIVIL ENGINEERING

OPITION: CONSTRUCTION TECHNOLOGY

DESIGN OF ABOVE-GROUND EQUALIZATION WATER TANK FOR MWOGO SECTOR-KAGASA CELL

CASE STUDY: MWOGO SECTOR BUGESERA DISTRICT

Submitted in partial fulfilment of the requirements for the Award of advanced diploma in construction technology.

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Kigali, October 2024

DECLARATION

I declare that this project entitled “Design of above-ground equalization water tank for Mwogo sector-Kagasa cell” is original work that I have done through my own research. This project has never been submitted to any university or other institution of higher learning.

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Signature …………………………..

Date of submission ………………...

APPROVAL

This is to certify that this dissertation work, entitled "**DESIGN OF ABOVE-GROUND EQUALIZATION WATER TANK FOR MWOGO SECTOR- KAGASA CELL**. CASE STUDY: **MWOGO SECTOR IN BUGESERA DISTRICT**" is an original study conducted by Emmanuel GAKWAYA under my supervision and guidance.

The supervisor's names: Eng. MUNYANEZA Cloude

Signature of the supervisor: ………….........

Submission date: ……………………………...

DEDICATION

To God

To our parents

To our supervisor

To our friends and family

To also any other person who gave us supportive ideas

ACKNOWLEDGEMENT

I' am very grateful above all to God and our parents, friends and other family members deserving thanks for the sacrifices endured during my education.
My gratitude also goes to those who supported me during my childhood until today in my education.

I would like to thank my supervisor **Eng. MUNYANEZA Claude** and all my Lecturers for helping me during my studies with advice and guidance. I thank my class mates for always being supportive till this final year project submission.

I wish to express my sincere gratitude to KIGALI INDEPENDENT UNIVERSITY in particular the Civil Engineering department staffs for facilitating me to carry out this research project and their guidance to complete my studies with skills and knowledge.

May God bless you all!!!

ABSTRACT

Water is important for human beings; it is used for personal hygiene, drinking, food cooking, toilet-flushing and other domestic activities. In Mwogo sector-Kagasa cell there is a problem of lack of water which causes inhabitants to suffer from all problem caused by insufficient water for daily use.

This project was selected to contribute in solving the serious problem concerning insufficient water in Eastern Province. The equalization water tank was designed to increase the available quantity of water to satisfy the population of Mwogo Sector for at least four days.

During this research I used internet, books and other source of information to base my design standard requirements.

The calculation begins by considering the volume required, which is 2084.3 m3 with height of 6.2m, freeboard height= 0.2m,The section area of tank is 347.38m2 for the design of the whole tank to be accurate determined

Keywords: Ground Equalization Water Tank

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LIST OF SYMBOLS AND ABBREVIATIONS

1. ULK: Kigali Independent University

2. Roll N: Roll Number

3. R.C: Reinforced Concrete

4. H: height of the tank in m.

5. PVC: Polyvinyl Chloride

6. R = radius [m]

7. T: Maximum hoop tension

8. Th: hoop tension

9. IS: Indian standard

10. BS: British standard

11. t: thickness of tank wall

12. Mm ax= Maximum moment

13. Vmax = Maximum shear force

14. @: spacing between reinforcement

15. As: area of reinforcement

16. BM: bending moment

17. c/c: center to center

18. D: depth 20.

19. D’: effective depth

20. M: modular ratio of concrete

21. V: volume

22. W: width

23. $\boldsymbol{Ast^{hoop}}$: Area of hoop tension reinforcement

24. $\boldsymbol{Astmin}$: Minimum area of steel

25. C: constant average increase of population per year

26. N: number of year

27. P: population at present

28. PN: number of population in N year

CHAPTER 1: INTRODUCTION

1.1. Background of the study

A water tank is a container for storing water. It began in New Zealand when settlement began during the first part of the 19th century; the first priority was the digging of wells to provide a continuous supply of fresh water. In the late 1800's settlers discovered that by rolling corrugated roofing iron into a circle and then riveting and soldering the joins, a large watertight container could be made. These corrugated iron tanks were generally about 500 gallons (10,000L) capacity. Also in use about this time and well into the next century were heavy square iron containers, riveted at the joints. These containers were used to export farm machinery parts from England. The Machinery was generally packed in grease, which then had to be cleaned out before the tank could be used.
(DHINESH KUMAR M, 2011)

As the main purpose of water tank is to provide storage of water to be used in many applications such as: water for drinking, fire suppression, agricultural farming both for plants and livestock, chemical manufacturing, food preparation as well as many other uses. Water tank parameters include: general design of the tank and choice of construction materials and linings.

The various materials which are used for making a water tank are: plastics, (polyethylene and polypropylene) fiberglass and concrete, steel (welded or bolted, carbon or stainless).
Earthen pots also function as water storages for rural areas. Water tanks are an efficient way to help developing countries to store clean water.

1.2. Problems statement

Fluctuation in water demand causes people spending long time fetching water and this negatively affect the country’s economy. Children often abandon school helping their parents to look for water. In region experiencing water shortage, affected people are constrained to use untreated water from rainfall, river and pond.

This causes people to suffer from water borne diseases like Trachoma (Eye Infection), Typhoid fever, Cholera, Dysentery, Amoebiasis and Malaria.

In addition, depending upon size and capacity of water treatment plant which is not matching with the needs of the population (Water demand), rationalization can be done to share the available amount of water to different regions.

The solution to fight all those challenges mentioned above, is to design a water storage tank with the purpose of storing water produced by the treatment plant in time when the demand is low or when the population is using the water (e.g. during night period).

This study is conducted in Eastern province, BUGESERA district, MWOGO sector where water obtained from a treatment plant is used but the quantity is not adequate for the population. The water shortage is likely to increase in this region which population is increasing fast. The main purpose of my project is to design a durable above-ground water tank which will provide enough water to satisfy the needs of the population of MWOGO sector-Kagasa cell.

Figure 1:

(a) People fetching dirty water

(b) People wait to fetch water on the tap

The above pictures were taken in BUGESERA District, MWOGO Sector, and KAGASA Cell in Cyarurimbi swamp.

1.3. Research objectives

1.3.1. The main objective

The main objective of this project is to design an above - ground equalization water storage tank that is suitable and sustainable for storing water that cover per capital water demand of Mwogo sector-Kagasa cell.

1.3.2. Specific objectives

The specific objectives of this project are the following:

i. Determine the per capital and total water demand of Mwogo sector-Kagasa cell;
ii. Determine the needed volume of the equalization water tank
iii. Determine the best location of the equalization water tank
iv. Conduct architectural and structural design of the equalization water
v. Provide a cost estimated of the water tank.

1.4. Research question

Research question of proposed project is:

"What are the characteristics (volume, sizing, location and cost) of an equalization water tank that can satisfy the water demand of Mwogo sector- Kagasa cell?"

1.5. Scope of study

This project is about the design of an equalization water storage tank for MWOGO Sector-Kagasa cell. In the course of this project we will determine the water demand of this region, design the adequate volume of water storage tank, indicate the best location of the tank, conduct architectural and structural design of the tank and estimate its cost.

1.6. Significance of the study

This project study is very significant on administrative, academic and personal levels

i. Administrative significance

This project shall highlight the need of development of the basic infrastructure that could benefit the population of Mwogo sector and different institution of the region (schools, markets, hospitals, etc)

ii. Academic significance

This project will be considered as reference document not only for students but also for future researchers regarding the construction of water storage tanks.

iii. Personal significance

This project increased the knowledge and skills of the authors in assessing the population water needs and designing of water storage structures for gravity water supply.

1.7. Subdivision of the study

1. Chapter 1,

Indicates an introduction to the study of which includes a comprehensible background study of the proposal, The statement of the problem, objective of the study along with the scope of the project and its contribution to different domains.

2. Chapter 2,

This section summarizes records of related to the particular topic of research and give review of what has been researched and published by others.

3. Chapter 3,

This contains the presentation and description of methods and materials to be used in execution of this project. The procedures and data analysis are well described in this chapter.

4. Chapter 4,

This chapter will represent the result of the project after doing the test using the methodology said in chapter three in accordance of specific objectives.

5. Chapter5,

This chapter will be considered as conclusion after analysis of the results obtained in this study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A water tank is used to store water to tide over the daily requirement. In the construction of concrete structure for the storage of water and other liquids the imperviousness of concrete is most essential.

The permeability of any uniform and thoroughly compacted concrete of given mix proportions is mainly dependent on water cement ratio. The increase in water cement ratio results in increase in the permeability. The decrease in water cement ratio will therefore be desirable to decrease the permeability, but very much reduced water cement ratio may cause compaction difficulties and prove to be harmful also. Design of liquid retaining structure has to be based on the avoidance of cracking in the concrete having regard to its tensile strength. Cracks can be prevented by avoiding the use of thick timber shuttering which prevent the easy escape of heat of hydration from the concrete mass.

The risk of cracking can also be minimized by reducing the restraints on free expansion or contraction of the structure. (STAHEL, 1893)

2.2 Classification of water tanks:

- Tanks based on materials are discussed below.

Plastic, galvanized steel, Ferro-cement, stainless steel and reinforced concrete.

1. What is RCC or masonry tank?

Constructed tanks on the ground or roof, generally with capacities exceeding 50,000 l, are mostly made of reinforced cement concrete (RCC). The RCC tank is less expensive for tanks sized smaller than 1,000,000 litre capacity. For tanks greater than 1,000,000 litre capacity, a pre-stressed concrete tank is supposed to be less expensive by approximately 20 per cent compared with the cost of an RCC tank of that size [10]. Walls of the underground water reservoirs of comparatively smaller depth can be made of bricks. Generally, tanks of capacities ranging from 15,000 to 50,000 litres can be made of bricks [11]. Tanks can be built in any shape and size with these materials. Masonry tanks are economical; however, making them watertight is difficult.

2. What is a Ferro-cement tank?

Ferro-cement is a cement-based composite construction material; it is modified from normal reinforced cement concrete by using mesh reinforcement instead of reinforcing bars. This type of construction is effective and durable construction material for water tanks. Ferro-cement water tanks can be used for water storage in buildings.

3. What is Stainless steel tank?

These tanks are made of stainless steel sheets with thickness varying from 0.6 to 3 mm depending on the size and ranging from 200 litres to as big as 1 million [13] litres. These tanks are durable, highly resistant to corrosion and almost maintenance-free; however, they are costlier.

4. What is a Plastic tank?

These tanks are made of fibreglass-reinforced plastics, high-density polyethene or other plastic materials.

❖ Water tank classification based on shape:

1. Cylindrical tank
2. Rectangular tank

❖ Water tanks based on location:

1. On ground tanks
2. Underground tanks
3. Elevated(overhead) tanks

❖ Water tank components

1. Side walls (rectangular or cylindrical)
2. Base slab
3. Cover slab or Dome
4. Columns, Beams , Bracings for elevated tanks

2.2.1 Benefits of concrete water tanks:

- **Cost-effective and durable**

Concrete is a very durable material and is also very cheap. Because they are built to last, you also will not need to spend on repairs very often, making it an excellent cost-effective and durable option. A good quality concrete water tank can last for up to 50 years

- **Available in different sizes**

Versatile Tanks' rectangular water tanks are available in 3 different size options: 6700 litters, 11700 litters and 22500 litters. Depending upon the type of property you are installing the tank at, your water requirements will change, and so will the size of the tank you choose.

- **Low maintenance**

Concrete is a very low maintenance material. They are extremely durable and can withstand almost all kinds of weather conditions. If installed underground where they are not exposed to harsh weather conditions, they may require even less maintenance. And when maintenance is required, it is usually quite cheap and easy. After some years, a concrete tank may develop cracks and leaks, which can be easily repaired using simple concrete waterproofing solutions. Check the backflow prevention valve every year and the tank for leaks and cracks every 2 years and you're good to go!

- **Easy Installation**

Because our concrete water tanks are made in a precast mould, they do not have any complex parts and bits and pieces to assemble. Once the hole has been excavated in the ground, the tank can be placed right in and be ready for use in a matter of hours.

- **Improved water quality**

Concrete is a naturally algae-resistant material. Stored water can often develop smells, especially if stored in plastic tanks or have a metallic taste when stored in metal tanks. However, water stored in concrete tanks tastes fresher and is algae and disease-free.

2.2.2 Tips for installation:

- Get in touch with your local council and check permissions. Also talk to local authorities to check the plans for gas, electricity, sewage systems, storm water drainage and other essential services to ensure your property has the space for a concrete tank.
- Talk to one of Versatile Tanks' friendly representatives and get advice on the best type and size of tank to choose.

- Prepare yourself for the day of installation by booking a crane and ordering a pump system with working pressure above 300kPa, mark the area you want the tank to be installed in. If the tank will be placed underground, you will also need to hire an excavation service.
- Order a low slump ballast mix with low density and low slump concrete. This mix will act as a cushion between the ground and your tank.
- Check the weather forecast for the day of the installation and conduct a thorough risk assessment. The area where you will place the tank needs to be flat, preferably laser leveled.
- On the day of the installation, make sure the hole is big enough to easily fit your concrete tank and that there are no people in the vicinity.
- Using the crane, your installation team will lift the concrete rectangular water tank and slowly lower it into the hole that has been created for this purpose.
- Once the tank is in position, the unit will be backfilled using the concrete ballast mix and the original soil will be put back in.
- Finally, the pump systems will be connected to the tank and your tank is ready for use!

2.2 Water demand

Total quantity of water required for various purposes by a town or a city. As a matter of fact, the first duty of the engineer is to determine the water demand of the town and then to find suitable water sources from where the demand can be met.

❖ **Sources of water supply**

The various sources of water can be classified into two categories such as: surface source and subsurface source.

▪ **Surface sources:**

✓ Ponds and lakes
✓ Streams and rivers
✓ Storage reservoirs
✓ Oceans, generally not used for water supplies, at present.

▪ **Sub-surface sources or underground sources:**

✓ Springs
✓ Infiltration wells
✓ Wells and Tube-wells. (G.hemeletha , 2012)

2.3.1 Water quantity estimation

The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data:

Water consumption rate (Per Capital Demand in liters per day per head) Population to be served.

Quantity of water needed = Per capital demand x Population

Average Daily per Capital Demand = Quantity Required in 12 Months/ (365 x Population) (Yorke, 1996)

Table 1: Guidelines values for water demand

Water quantity standards	**Vital minimum**	**Sanitation standards**
Domestic needs	7-20L/PER/day	30-60L/pers/day
Health center	10L/pers/day	
Hospital	50l/bed/day	50-220L/bed/day
School	10L/student/d	15-30L/student/day
Market	Used By ACF: 10L/pers/day	
Temple/Mosque/church	Used By ACF: 5L/vistor/day	
Small size cattle(goat, pigs)	5L/Animal/day	10-20L/animal/d
Large size cattle(cows)	30-60l/animal/d	
Accessibility/Availability		
Maximum distance between user and water point	125 to 250 m	
Maximum number of users per water Point	600	150

Source: (Yorke, 1996)

2.3.2 Factors affecting per capital demand

The factor affecting per capital demand:

- Size of the city
- Presence of industries
- Climatic conditions
- Habits of economic status
- Quality of water
- Pressure in the distribution system
- Cost of water (G. hemeletha, 2012)

2.3.3 Fluctuations in rate of demand

There different types of fluctuations in rate of demand:

- **Seasonal variation:** The demand peaks during summer.
- **Daily variation** depends on the activity that make people draw out more water on Sundays and Festival days, thus increasing demand on these days.
- **Hourly variations** are very important as they have a wide range. During active household working hours i.e. from six to ten in the morning and four to eight in the evening, the bulk of the daily requirement is taken.

So, an adequate quantity of water must be available to meet the peak demand. To meet all the fluctuations, the supply pipes, service reservoirs and distribution pipes must be properly proportioned. (Thevendran, 1986)

2.3 Design periods

Generally, water projects are designed for a design period of 20 to 40 years, after their completion. The time lay between the design and the completion should not be more than 2 years. In some specific components of the project, the design period may be modified. Different segments of water treatment and distribution systems may be approximately designed for differing periods of time using different capacity criteria, so that expenditure far ahead of utility is avoided. Following can help to view the design periods of various components of a water supply project.

Table 2: Design period for water supply project

SN	COMPONENT	DESIGN PERIOD (YEARS)
1	Storage by dams	50
2	Infiltration works	30
3	**PUMP SET**	
	i. All prime movers except electric motors	30
	ii. Electric motors and pumps	15
4	Water Treatment unit	15
5	Pipe connection to the several treatment unit and other small appurtenance	30
6	Raw water and clear water conveying main	30
7	Clear water reservoir at the head works, balancing tanks and service reservoir (over head or ground level)	15
8	Distribution system	30

Source: (Timoshenko, 1957)

2.4.1. Factors affecting the design period

The factors affecting the design period are:

- Useful life of the pipes, structures and component used in water works. If the useful life is more, the design period is also more.
- The anticipated rate of growth of population. If the rate is more, design period is less.
- The rate of inflation during the period of repayment of loans. When the inflation rate is high, a longer design period is adopted.
- The rate of interest of loans taken for the construction of project. If the rate is more the design period will be less. (Stahel, 1893)

2.4.2. Population forecasting methods

Two types of population estimates are needed for the operation and design of water supply and waste water treatment works. Those types of population estimates are: inter-census and post - census.

The following are the standard methods by which the forecasting population is done.

▪ Arithmetic progression method

▪ Geometric progression method

▪ Incremental increase method

▪ Decreasing rate of increase method

▪ Graphical extension method

❖ **Arithmetic progression method**

This method is based on the assumption that the population is increasing at a constant rate. The rate of change of population with time is constant. The population after N years can be determined by the following formula.

PN = P + N * C

Where:

PN: number of population in N year

P: population at present

N: number of year

C: constant average increase of population per year

❖ **Geometric progression method**

This method is based on the assumption that the percentage increase in population from year to year remains constant. In this method the average percentage of growth of last few years is determined; the population forecasting is done on the basis that percentage increase per year will be the same. The population at the end of N years is calculated by:

$$P_N = P\left[1 + \frac{I_C}{100}\right]^N$$

Where:

PN: number of population in N year

P: population at present

N: number of year

IG: average percentage of population growth per year

(Thevendran, 1986)

2.4 Water tank design

2.4.1 Introduction

In water retaining structure a dense impermeable concrete is required therefore, proportion of fine and course aggregates to cement should be such that give high quality concrete. Concrete mix weaker than M20 is not used. The minimum quantity of cement in the concrete mix shall be not less than 30 KN/m3. The design of the concrete mix shall be such that the resultant concrete is efficiently impervious. Efficient compaction preferably by vibration is essential.

The permeability of compacted concrete is dependent on water cement ratio. Increase in water cement ratio, increases permeability, while concrete with low water cement ratio is difficult to compact. Other causes of leakage in concrete are defects such as segregation and honey combing. All joints should be made water-tight as these are potential sources of leakage.

Design of liquid retaining structure is different from ordinary R.C.C structures as it requires that concrete should not crack and hence tensile stresses in concrete should be within permissible limits.

A reinforced concrete member of liquid retaining structure is designed on the usual principles ignoring tensile resistance of concrete in bending.

(W.H Mosly, 1987)

2.4.2 Specification of materials

- **Grades of concrete and characteristic strength: IS456-1978**

Indian Standard IS456-1978 specifies seven grades of concrete designated as M10, M15, M 20, M 25, M 30, M 35 and M 40. In the designation of concrete mix, letter M refers as the mix and the number to the specified characteristic compressive strength (fck) of 15cm Cube at 28 days, expressued in N/mm2. The characteristic strength is defined as the strength of the material below which not more than 5% of the test results are expected to fall

Tensile strength of concrete

The flexural and split tension strengths shall be obtained as described in IS516- 1959 and IS 5816- 1970 respectively. When the designer wishes to use an estimate of the flexural tensile strength from the compressive strength, the following formula may be used (IS456-1978): flexural tensile strength fck = $0.7\sqrt{fck}$ N/mm2

Where fck: is the characteristic compressive strength of concrete in N/mm2. (Bhavan, 1967)

2.4.3. Steel reinforcement

The most important characteristic of a reinforcing bar is its stress curve and the important property is the yield stress or 0.2% proof stress. The idealized stress strain curve for mild steel bars assumed by IS 456-1978, is shown in figure 2.1.

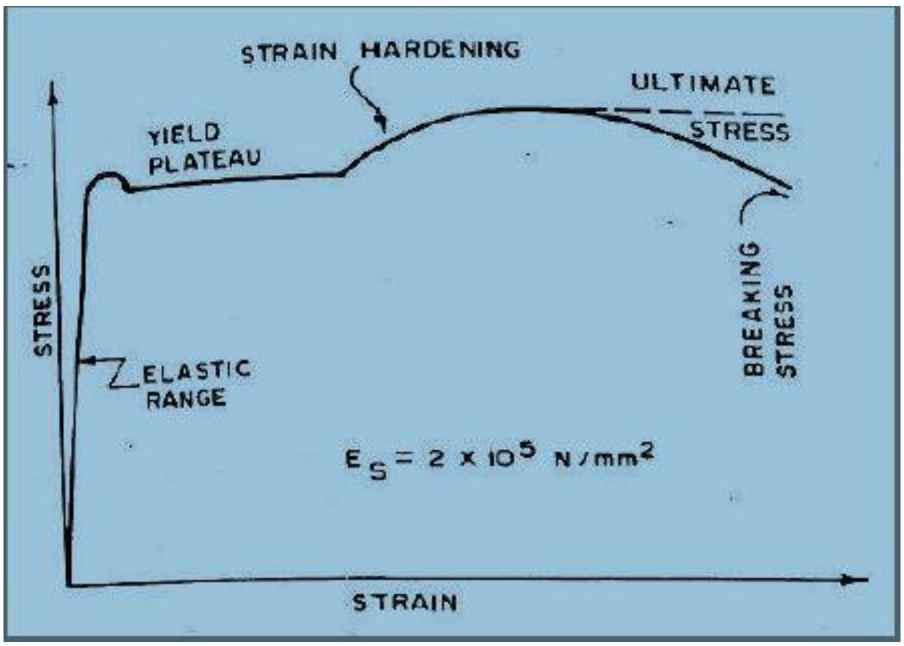

Figure 2: Stress strain curve for mild steel

- **Characteristic Strength of Steel Reinforcement**

The characteristic strength (fy) means that value of strength below which not more than 5% of the test results are expected to fall. Until the relevant Indian Standard specifications for reinforcing steel are modified to include the concept of characteristic strength, the characteristic value shall be assumed as the minimum yield/0.2 percent proof stress specified in the relevant Indian Standard Codes.

(Manak Bhavan, 1967)

2.4.3 Minimum reinforcement

In order to minimize cracking due to shrinkage and temperature, minimum reinforcement in walls, floors and roofs in each of two directions at right angles is recommended as:

▪For thickness 100 mm = 0.3 % concrete section

▪For thickness 450 mm = 0.2% concrete section

▪For thickness between 100 mm to 450 mm = varies linearly from 0.3% to 0.2%

In concrete sections of thickness 225 mm or greater, two layers of reinforcement steel shall be placed one near each face of the section to make up the minimum reinforcement. Storage tanks are designed as crack free structures to eliminate any leakage. Adequate cover to reinforcement is necessary to prevent corrosion. In order to avoid leakage and to provide higher strength concrete of grade M20 and above is recommended for liquid retaining structures. (Bertoline, 2005)

Note: The maximum spacing of reinforcement should not be greater than three times the thickness of the wall nor 450 mm

2.4.4 Minimum cover to reinforcement

For liquid faces of parts of members either in contact with the liquid (such as inner faces or roof slab) the minimum cover to all reinforcement should be 25mm or the diameter of the main bar whichever is greater. In the presence of the sea water and soils and water of corrosive characters the cover should be increased by 12mm but this additional cover shall not be taken into account for design calculations.

For faces away from liquid and for parts of the structure neither in contact with the liquid on any face, nor enclosing the space above the liquid, the cover shall be as for ordinary concrete member. (Ghoneim, 2008)

2.5 General design requirements

- **Design method**

Due to fixity at base of wall, the upper part of the wall will have hoop tension and lower part bend like cantilever. For shallow tanks with large diameter, hoop stresses are very small and the wall act more like cantilever. For deep tanks of small diameter, the cantilever action due to fixity at the base is small and the hoop action is predominant. The exact analysis of the tank to determine the portion of wall in which hoop tension is predominant and the other portion, in which cantilever action is predominant, is difficult. Simplified methods of analysis are:

- Reissner‘s method
- Carpenter ‘s simplified method
- Approximate method
- IS code method

The reference should be made to IS 3370 (Part I and Part II) 2009. And IS 3370 (Part IV) 1967 for design of RCC water tanks, the code specifies some constraint over concrete mix to make it more impermeable and free from shrinkage cracks. The major provisions for concrete in RCC, Water tank are given below:

• The maximum cement content (excluding fly ash) should be 400kg/m3.

• The minimum cement content should be 320 kg/m3.

• Maximum water to cement ratio should be less than 0.45

• It is usual to use rich mix like M30 grade in most of the water tanks and more strong than this. (RAY, 1995)

- **Design process**

The design process of structural planning and design requires not only imagination and conceptual thinking but also sound knowledge of science of structural engineering besides the knowledge of practical aspect such as recent design codes and laws, backed up by ample experience, intuition and judgment. The purpose of standards is to ensure and enhance the safety, keeping careful balance between economy and safety.

- **Design procedure**

For tank design the following steps must be followed: site investigation,tank site selection, selection of tank type, determine basic parameters, settlement checking make structural and architectural drawing.

2.6 Foundation

Foundation is the lowest part of the building that is in direct contact with the soil which transfers loads from the structure to the soil safely. The safe bearing capacity of the soil must not be exceeded otherwise excessive settlement may occur, resulting in damage of the building structure. Foundation failure can also affect the overall stability of a structure so that it is liable to slide, to lift vertically or even overturn.

It is important to have an engineering survey made of the soil under a proposed structure so that variations in the strata and the soil properties can be determined. Drill holes or trial pits should be sunk, in situ tests such as the penetration test performed and samples of the soil taken to be tested in the laboratory information gained it is possible to recommend safe earth bearing pressures and also check if settlements of the structure are within allowed range. (Beohar, 2005)

2.6.1 Floors of tanks resting on ground (base slab)

If the tank is resting directly over ground, floor may be constructed in concrete with nominal percentage of reinforcement. Ground will carry the load without appreciable subsidence in any part and that the concrete floor is cast in panels with sides not more than 4.5m with contraction or expansion joints in between. In such cases a screed or concrete layer less than 75mm thick shall first be placed on the ground and covered with a sliding layer of bitumen paper or other suitable material to destroy the bond between the screed and floor concrete. In normal circumstances the screed layer shall be of grade not weaker than M 10, where injurious soils or aggressive water are expected, the screed layer shall be of grade not weaker than M 15 and if necessary a sulphate resisting or other special cement should be used. (Zienkiewicz, 1983)

2.6.2 Walls of cylindrical water tanks.

Wall is structural element used to divide or enclose the building to form the periphery of a room or a building. While designing walls of cylindrical tanks the following points should be taken into account: Walls of cylindrical tanks are either cast monolithically with the base or are set in grooves and key ways (movement joints). In either case deformation of wall under influence of liquid pressure is restricted at and above the base. Consequently, only part of the triangular hydrostatic load will be carried by ring tension and part of the load at bottom will be supported by cantilever action.

CHAPTER III: DATA COLLECTION AND ANALYSIS PROCEDURES

3.1 Introduction

This chapter deals with data and methods used for obtaining those data also it shows some other information about the area of the study like geographical description and maps of the area.

3.2 Description and location of the study area

Our project is located in Eastern Province, Bugesera district, Mwogo sector,Kagasa cell.

This sector has 67,360 of population and is situated a distance of 12km from Nyamata center on main road linking Nyamata – Kigali From the climate point of view, the study area is having three seasons namely short rainy season(from march to May), short sunny season(from September to February) and long sunny season(from June to august).

This area 75% of population are cultivators and 20% of population are business man, then 5% of population are jobless

Table 3: Location of the project

Province	EASTERN
District	BUGESERA
Sector	MWOGO
Coordinate-X	23607
Coordinate-Y	28256
Elevation (m)	1766

Figure 3: Location plan

The above map indicates the precise placement of the tank within its surrounding environment, including nearby infrastructure and access points.

3.3 Methodology and techniques to be used

During the design of this project, the following methodologies were used:

1. Site survey to assess the topography of the region.
2. Visiting the NZOVE treatment plant for the more information about the distribution of water in the ground water tank.

3. Water demand assessment to estimate the capacity of the tank

4. Applying of ArchiCAD software to produce structural drawings.

5. Applying of British Standard IS456-1978 to analyze and design structural members of the ground tank.

6. Drawings to determine the quantities of materials and overall cost of project.

7. Use of online library to develop a relevant literature

8. Consulting supervisor in order to get feedback and useful comments and go ahead.

3.4 Research design

While dealing with research design the following points should be taken into account

- **Site visit and observation:** this is the stage where we had site visit then we got overview image of how situation there look like.
- **Assess relevance of the project in questionnaire form:** during this stage we draft questionnaire and we distributed it to the population and leader after responding we found that the project is crucial needed as summarized in table 3.1
- **Population forecasting:** during this stage we made population study after getting total population at design period we determine storage tank capacity.
- **Topographic survey:** after accessing relevance of the project and site visit we take topographic data by using global positioning system (GPS) that, will be used for producing topographic map or contour map and also to get the difference in elevation between storage tank site and treatment plant for determining the energy required to pump water to the storage tank.
- **Determine bearing capacity of foundation soil:** after site selection we perform dynamic cone penetrometer test and we deduce resistance of soil at any depth.
- **Use modern engineering software to produce architectural and structural drawing:** after getting dimension of the tank we produce drawing for easy implementation of the project.

3.5 Research instrument

To carry out the relevance of the project,questionnaire was distributed to the people and reader of this sector and make any interview. For getting desired population for design period we get data from census statistic office of Mwogo sector. About topographic data we use global positioning system (GPS), about bearing capacity we had used dynamic cone penetrometer that help us to get bearing of foundation soil at any depth after all of these we produce architectural drawing by using ArchCard.

3.6. Research population

Population refers to the total number of targeted respondents from where the research is to be carried out. The research population for this project is equal to 67,360 people.

Sample is a segment of the population selected to represent the population as a whole. The sample should be representative and allow the researcher to make accurate estimates of the thoughts and behavior of the larger population.

3.7. Determining the sample

Sample size is determined by using Solvin's formula which stipulates that population is definite.

$n = \frac{n}{1+Na^2}, or\ n\ \frac{n}{1+Ne^2}$

Where: n= Sample size

N= Population size

a or **e** = Level of significance or Confidence level that can either be 10% (**0.1**) or 5% (**0.05**) respectively.

N=$\frac{67360}{1+67360(0.1)2} = 99.92 = 100\ Sample\ size$

3.8. Data analysis and presentation

3.8.1. Data gathering procedure

For getting useful information for our project first I go at Mwogo sector headquarter in social affair office then he gave me current population live in this sector. Then after by applying formula i get sample size represent that total population, after getting that i assess if the water storage tank is needed by using questionnaire supported by an interview as the result shown in table 4 below

- **Population study**

For determining the current population for the design period i get data from census statistic department from social affair office of Mwogo sector for different year then i forecast the future population for the design period by using arithmetic mean method.

About data collection for chosen site, ii use global positioning system (GPS) for taking not only data that will be used for producing topographic map for chosen site but also it was used for taking data along the supplying line system from BUGESERA water treatment plant for getting different in elevation between the water source and storage tank.

The 80% of answer of sample want to construct a ground water storage tank there, because the more people need and use the water in difference activities and more of them meet with luck of water in certain period of time data of respondent are summarized in the table below depending on the research done.

Table 4: Data collected from the site (population)

Respondent persons		**Number**	**Answer**
Age	15-20	30	Once this project is being implemented: -it will increase revising time for study. -fresh water for drinking will be available always
	26-45	23	-it will reduce distance travelled while finding other sources -it will reduce time taken while waiting water on the tap
	Above that age	11	-it will reduce money spend in medical care in these waters born diseases
Education level	A2	15	-it will change living condition better
	A1	9	-children's abandon school can get back to continue their study
	A0	7	-it will increase economy of the country
Leaders		5	-it will increase hygiene for the people
TOTAL		100	

3.9. Determination of foundation soil strength

Foundation soil strength is that resistance of soil needed to support the load of super structure safely without excessive settlement. It is determined by conducting soil test such as dynamic cone penetrometer test (DCP) then data collected are being interpreted for getting bearing capacity of soil by applying the following formula:

Resistance to the point (qd) = M2HN)/Ae(M+P) in Kpa

Where:

M: weight of hammer=0.10269KN

H: drop height = 0.76m

N: number of blows

A: section area of the trip = 0.0010287m2

P: weight of mass struck = 0.06566KN

e: driving = 0.1m

3.10. Project cost estimation

After the project is designed, it is required to estimate how much funds need to be raised in order to have the designed project executed. To come up with that total cost, i went through the following steps

- Dividing the project of design of ground water storage tank into parts of works such as: site preparation, excavations, execution of concrete structures, finishing works, etc
- Calculating the quantities of various works which have to be executed in related units.
- Calculating the rates for the excavation of each unit of work, considering every single activity that needs to be done and resources which were spent on it. This rate including all expenses for the accomplishment of a single unit of work, like cost of material used and transport to the area of use, cost of man power, direct and indirect supervision cost, taxes, etc.
- Summing all the amount for all works falling in the same part of work
- Summing up the resulting sums from different parts of work and get the total cost of the project.

CHAPTER IV: DESIGN SPECIFICATION (RESULT AND DISCUSSION)

4. Introduction

This chapter documents all the calculations that lead to the true proportions/ dimensions of the designed ground water storage tank. It shows also the estimated cost for the proposed project as well as all the specifications for some construction materials and drawings for the project.

In order to determine the preliminary and final design parameters of ground water storage tank design, some data have been collected and basic calculations done.

Table 5: Population forecasting by using arithmetic method

Table SN	Year	Population	Increase in population
1	2002	24,621	-
2	2005	29,344	4723
3	2012	34,839	5495
4	2015	40,575	5736
5	2018	46,354	5779
Total	-	-	21724
Average growth rate	-	-	21733/16= 1357.753 in 16 years

Expected population from 2018 to 2033 = 46,354 + 1,357.753 * 15= **67,360 people**

Depending upon the design standard for clear water storage tank as 15 years that is why the design of a water storage tank which is capable for supplying 67,360 and 4200 students from 4 boarding schools and 50 beds from health center.

4.1 Determination of tank capacity

¬ Domestic water demand = 67,360* 30L = 203800 L, 2020.8 m3

¬ Schools = 4200 students *15L = 63000L= 63 m3

¬ Health center = 50 beds *10L = 500L = 0.5 m3

¬ TOTAL VOLUME = 2084.3 m3

• **Dimension and data of the tank:**

- Volume of tank = 2084.3 m3

- Total height of tank = 6.2m and free board height = 0.2m

- Tank useful height = 6.2 – 0.2 = 6 m

- Concrete grade = M20

- Permissible stress in bending compression = 7 N/mm2

- Permissible stress of steel in tension = 150N/mm2

Cross sectional area of tank = $\frac{VOLUME}{HEIGHT} = \frac{2084.3\ m3}{6\ m} = 347.38\ m2$

Diameter of tank =

$$\sqrt{4A/\pi} = \sqrt{\frac{4(347.38)}{3.14}}$$

= 21.05 m, 21m is used as tank diameter

1. Determine the hoop force and Vertical moment

- Thickness of the wall = 30H + 50, T = 30*6 + 50 = 230mm40
- Ratio H2 /DT, 62 /21*0.23 = 7.453, Hence the coefficient varies between 6 and 8.
- In table 2.10, coefficient = $\frac{0.514+575=}{2}$= 0.5435.
- Maximum hoop tension force = $Coefficient * \gamma w * H * D/2$,

  Th = 0.5435 *$\frac{21}{2} * 9.81 * 6 = 335.899\ KN$
- Vertical moment, M = $Coefficient * \gamma w * H/2$

In table 2.9, coefficient =$\frac{-0.0187-0.0146}{2}$ = −0.01665

MV = -0.01665*9.81*63 = -35.28 KNm

2. Determination of steel bars

- Hoop reinforcement: A_{st} hoop = $\frac{t\ h}{ost} = \frac{335899*1000}{150} = 2239.326$ mm^2

- Let use steel bars of Ø20mm

- Area of Ø20mm = $D^2\pi/4$, A_{st} = $(20^2 * 3.14)/4$ = 314mm^2

- Spacing =$\frac{Ast*l}{Ast} = \frac{314*1000}{2239.326}$= 140.22 =140mm

- Area of steel provided A_{st} =$\frac{Ast*l}{Spacing} = \frac{314*1000}{140}$= 2242.857mm^2

- Provide: T20@140mm c/c

- Vertical bars; $A_s \frac{M}{ost*j*d}$=, $d_{1=}\frac{M}{RB}$ and d_2= t-cover

d2 = 230mm - 25mm = 205mm; d1 =?

R= $\frac{1}{2}$ obc * j * k *; k=$\frac{mocbc}{mocbc+ost}$ where by m=280/3*7=13.33

K= $\frac{13.33*7}{(13.33*7)+150}$= 0.3835 and j= $1-\frac{k}{3}$ = 1-$\frac{0.3835}{3}$ = 0.87

Then R = $\frac{1}{2}* 0.87 * 7 * 0.3835 = 1.167\ N/m\text{m}^2$

Hence, the greatest depth was used, **d = 205mm**

AS (vertical bars) = $\frac{35280000Nmm}{0.87*150*205}$ = 1318.755 mm^2 /m

AS provided, T16@152mmC/C = 1321.64mm²

3. Cracks control

To avoid cracks $\frac{Th}{1000t+(m-1)Ast} \leq \sigma cat$ and σcat = 0.27 fck where by m = 13.3

σct = $\frac{335.899*1000}{(1000*230)+(13.3-1)326}$= 1.304 N/mm^2

- σcat = 0.27 fck = 1.2N/mm^2

-since σ_{ct} = 1.304 N/mm^2 > σ_{cat} =1.2N/mm2 not ok because there are some cracks, therefore to eliminate these cracks increase the thickness of the tank wall $\frac{Th}{1000t+(m-1)Ast}$= 1.2

- 1.2 [1000 * t + (13.3 – 1) * 2239.326] = 335899

- 1200t + 27,543.7 = 335899, $\frac{335899-2754.7}{(1200)}$=256.96mm, Assume t=260mm

Checking:

σct = $\frac{335.899*1000}{(1000*250)+(13.3-1)326}$ =1.168 N/mm^2 < 1.207 N/mm^2

✓ Therefore, there is no cracks

4. Bending reinforcement

$$Ast = \frac{M}{ost*j*d} \text{ where: j = 1 – k/3, k =} \frac{mocbc}{mocbc+ost,}$$

d = t – Ø/2 – cover; d = 260 – 20/2 – 25 = 225

- k= $\frac{13.33*7}{(13.33*7)+150}$= 0.3835 and j = 1 – 0.38/3 = 0.87

✓ Ast = $\frac{35280000Nmm}{150*0.87*225}$ = 1201.53mm^2

✓ Let use steel bars of Ø20mm**,**ast = D2π/4, ast = (202 * 3.14)/4 =314mm^2

- ✓ Sp$acing$= $\frac{ast*L}{Ast}$, $Spacing$ = $\frac{314*1000}{1201.53}$ = 261.33mm = 260 mm
- ✓ Area of steel provided Ast = $\frac{ast*L}{Spacing}$, Ast = $\frac{314*1000}{260}$ = 1207.692 mm^2

- Provide: T20@260mm c/c

5. Distribution steel

For distribution steel provide area of steel minimum:

- Since thickness = 260 which is between 100 and 450, $A_{s\ min}$= 0.3$\frac{0.1(t-100)*b*t}{(450-100)*100}$
- = 0.3 $\frac{0.1(260-100)}{(450-1)*100}$ = 0.25%
- As min= $\frac{0.25*1000*260}{100}$ = 650mm^2
- Let use steel bars of Ø12mm**,** Area of Ø12mm = D^{2}π/4, ast = $\frac{122*3.14}{4}$ =113.04mm^2
- $Spacing$ =$\frac{ast*L}{Ast}$,Spacing = $\frac{113.04*1000}{650}$ = 173.9 mm = 180 mm
- Area of steel provided Ast = $\frac{ast*L}{spacing}$, Ast = $\frac{113.04*1000}{180}$= 628 mm^2

  - Provide: T12@180mm c/c

6. Design of tank base slab

Let use the base thickness which equal to the thickness of the wall = 260mm, also the reinforcement to be provided is equal to As min = 0.3 $\frac{0.1(t-100)*b*t}{(450-100)}$

= 0.3 $\frac{0.1(260-\ \ )}{(450-1\ \ )*100}$= 0.25%

- $A_{s\ min}$= $\frac{0.25*1000*260}{100}$= 650mm^2

Area of steel to be distributed at the top and the bottom,

A_s^{top} = $\frac{Ast}{2}$= $\frac{650}{2}$ = 325 mm^2 and A_s^{bottom} = $\frac{Ast}{2}$ = $\frac{650}{2}$ = 325mm^2

- ➢ Area of Ø10mm = D^{2}π/4, a_{st} = (102 * 3.14)/4 = 78.5mm^2
- ➢ $Spacin$ =$\frac{ast*L}{Ast}$,Spacing = $\frac{78.5*1000}{325}$, = 241.53 mm = 250mm

- ✓ Area of steel provided Ast = $\frac{ast*L}{spacing}$, Ast = $\frac{78.5*1000}{250}$ = 314 mm^2

- Provide: T10@250mm c/c /

7. Design of tank cover (RC domes)

- ❖ The thickness of the dome is 100 mm = 0.1m

- Unit weight of concrete is $24kN/m^3$
- The live load on the dome: $2kN/m^3$
- Dead load = self-weight +finish (0.75 to 1.5 KN/m)
- Permissible compressive stress of concrete for strength calculation for M20 is 5MPa
- Height or rise of dome = $\frac{1}{2}D = \frac{1}{2}\,21 = 4.2m$
- Radius of curvature of the dome R = $\frac{\left(\frac{D}{2}\right)2+r2}{2r} = \frac{(\frac{21}{2})}{2*4.2}$ = 15.225m
- Diameter of 21m
- $\sin\emptyset = \frac{\frac{D}{2}}{R}$, $\emptyset = \sin^{-1}0.689 = 43.60^0$
- W: total load on dome per square meter = self-weight +live load

  W = (t$*\ \gamma$c+ finishes) + live loads = (0.1 * 24+1) + 2 = $5.4KN/m^2$
- Meridional thrust $M = \frac{WR}{1+cos}$, $M = \frac{5.4*15.225}{1+cos43.6}$ = 47.68 KN
- Meridional stress = $\frac{M}{bt}$, $M = \frac{47680}{1000*100}$= 0.4768 N/mm^2 < $5N/mm^2$

Hence it is safe.

- Circumferential force = $FH = WR$ (cos Φ-$\frac{1}{1+cos\Phi}$),

FH = 5.4 $*$ 15.225(cos 43.3 $-\frac{1}{1+cos43.6}$) = 11.854 KN

- Circumferential stress = $\frac{FH}{tb}$,= $\frac{11.854*1000}{100*1000}$, = 0.11854 N/mm^2

Therefore, the provided 100 mm thick section is sufficient or adequate

8. Determine the reinforcement in dome slab

Provide the minimum reinforcement of allowed by IS 456-1978 because stresses acting on the dome are small.

For dome thickness = 100mm

- As min = $\frac{0.3bt}{100}, = \frac{0.3*1000*100}{100}$ = 300 mm^2

Provide steel bars of Ø8 mm @ 160 mm c/c, As provided = $\frac{50.24*1000}{160}$ = $314mm^2$

AS provided: T8@160mm c/c = 314 mm2

9. Design of ring beam

The Hoop force in the ring beam due to the horizontal component of meridional thrust,

- Ft= $T\ cos\theta * \frac{D}{2}$ = 47.68 $*\ cos$43.6 $* \frac{21}{2}$ = 362.549 KN

- Area of Hoop Reinforcement Ast = Ft/δ_{st} , Ast = $\frac{362.549*1000}{150}$ = 2416.99 mm^2
- Area of Ø20mm = $D^2\pi/4$, a_{st} = $(20^2 * 3.14)/4$ = 314mm^2
- ***As* Provided: 8T20**

10. Dimensions of ring beam

Size of ring beam is obtained based on tensile stress relation, Here the ring beam is not subjected to water load and it is in full tension. So, permissible tensile stress for M20 concrete is 2.8 N/mm^2

(Table 2.8) of IS 456-1978 [σct=2.8 N/mm^2]

✓ $\delta ct = \frac{Ft}{Ac+(m-1)Ast}$, $\delta ct \frac{362.549*1000}{Ac+(13.3-1)2416.99} = 2.8$

2.8[Ac + 29729.0139] = 362549, Ac = 99752.771mm^2

Ac Provided =102400mm^2**,** (320 mm by 320 mm)

11. Determine the area of stirrup

Since the ring beam is in direct tension, provide a minimum area of stirrup, $\frac{Asv}{Sv} \geq \frac{0.4b}{0.87fyv}$

By use of diameter of 6mm, As = $\frac{\pi d2}{4} = \frac{3.14*62}{4}$ = 28.26 mm^2 = $\frac{Asv}{2}$s

This means that 28.26mm^2 = 56.52Asv

➢ $\frac{56.52}{sv} \geq \frac{0.4*100}{0.87*410}$ Sv= $\frac{0.87*415*56.52}{0.4*100}$ = 510.16 mm. Let 500mm be used as Sv

A reinforcement drawing for water typically illustrates the design and placement of reinforcing bars or steel mesh with the tank structure

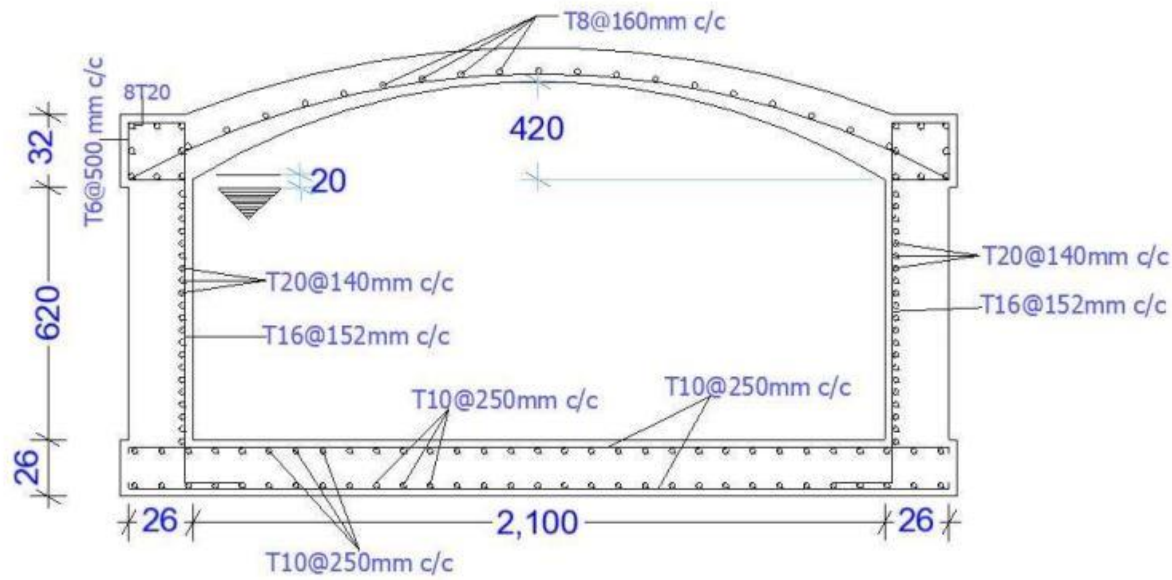

Figure 4: Reinforcement drawing

4.2 Architectural drawings

Note: all dimensions are in cm.

Scaled diagram showing the layout of the tank’s base, including ground section view as top view

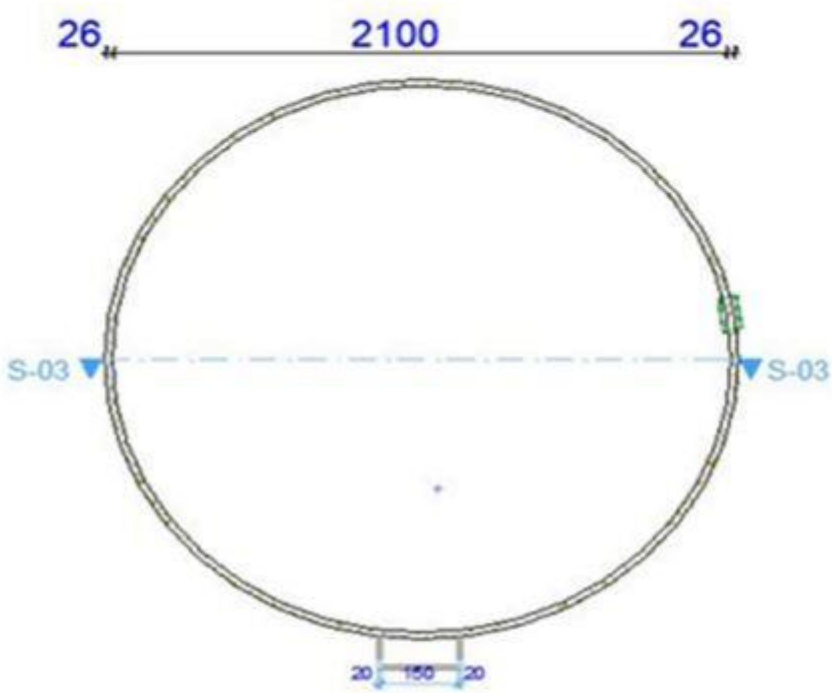

Figure 4: Floor plan of water tank

Tank section design showing dimensions, materials, and internal features for construction purposes.

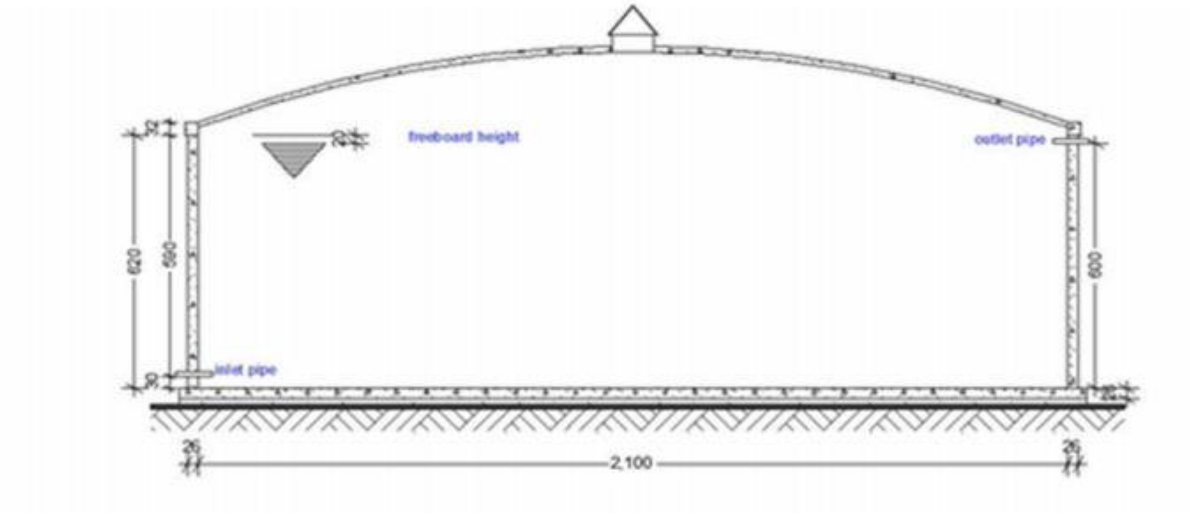

Figure 5: Section plan

47 Illustration showing 3D view of the tank section, portraying its internal structure, capacity, and access points,

Figure 6: Perspective section of water storage tank

4.2 Project cost estimation

This table shows cost of designed ground water storage tank project at Mwogo sector

Table 6: Cost estimation of the project

N°	Description of works	unit	Quantities	Rate	Amount
I	**Preliminary work**				
1	Site installation	LS	1	180,000	180,000
2	Site clearance	LS	1	100,000	100,000
3	Foundation trench	m3	62.88	2,500	157,224
4	Compaction	LS	1	90,000	90,000
	S/T1				**527,224**
II	**FOUNDATION**				
1	Blinding concrete	m3	13.97	180,000	2,514,600
2	RCC base slab	m3	90	300,000	27,000,000
	S/T2				**29,614,600**
III	**ELEVATION**				
1	RCC wall	m3	97.4791	300,000	29,243,730
2	RCC ring beam	m3	3.19536	300,000	958,590
3	RCC dome (cover slab)	m3	3.19536	300,000	958,590
	S/T3				**38,586,420**
IV	**FINISHING WORK**				
1	Internal and external plastering	m2	1,664.087	8000	13,312,672
2	Ladder	Pcs	2	25,000	50,000
3	Dome and manhole opening cover	Pcs	2	15,000	30,000
	S/T4				**13,382,672**

V	**FENCE CONSTRUCTION**				
1	Foundation trench	m3	11	2,600	28,600
2	Blinding concrete	m3	3	180,000	540,000
3	Foundation stonework construction	m3	25	48,000	1,200,000
4	Fence foundation screed	m2	50	2,000	100,000
5	Fencing material	RM	100	3000	300,000
6	Gate	LS	1	150,000	150,000
7	Hallow metal tube	Pcs	20	6000	120,000
	S/T5				**2,588,600**
	Total				84,699,516
	Contingency 4%				3,387,980
	Total				**88,087,580**
	Profit 10%				8,808,758
	GENERAL TOTAL				**96,896,338 Rwf**

The cost of the project is ninety-six million eight hundred ninety-six thousand three hundred thirty eight Rwandan francs (96,896,338 Rwf)

CHAPTER V: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The design of ground water storage tank helps the people to use water from tank in different activities like: drinking, cleaning of house, cooking and other domestic activities.

For the case of MWOGO sector, sometimes they face with the shortage of water within the area and consequently mattered people use dirty water, which causes water borne diseases thus to eliminate all of these issues, the provision of water storage tank is very crucial needed for keeping enough water all time.

Based on the result obtained in interview, once this project is being implemented, it prevents MWOGO's people to use storm water from untreated source also it reduces the time waiting for water on the tap thus the objectives become achieved.

5.2. Recommendations

Based on observation during this research and problems occurred should be solved by the following recommendations:

- Government should take into account the project of student to see if they are some of them can be supported for the interest of the government and society in general.
- Government should update all data that can be required while working the final year project to the internet, so that the information can be taken easily
- ULK should buy sufficient books for library.

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