DECLARATION OF ORIGINALITY

I declare that the work presented in this dissertation is my own contribution to be the best of my knowledge. The same work has never been submitted to any other university or institution. I therefore declare that this work is my own for the partial fulfillment of the award advanced diploma in Construction Technology at **ULK POLYTECHNIC INSTITUTE**

The candidate name: RUGWIZANGOGA SUGIRA Pacifique

Candidate Signature: ……………………………

Date of submission: ………/…………/……….

CERTIFICATION

This is to certify that this dissertation work entitled **"Structural design of G+4 commercial and residential building"** is an original study conducted by **RUGWIZANGOGA SUGIRA Pacifique** under my supervision and guidance of **Eng.Dr Fabrice MWIZERWA .**

The supervisor's name: Eng.Dr Fabrice MWIZERWA

Supervisor signature..

Head of department's name: Eng Bonaventure NKIRANUYE

Head of department signature...................................

Date of submission: …….……/……............/......……

DEDICATION

This dissertation is dedicated to my parents for

Their love and supports which helped me throughout my studies.

To my lovely Dady jean Damascent RUGWIZANGOGA

To my sponsor jean De dieu NTIGANDA

To my supervisor Eng.Dr Fabrice MWIZERWA

To God Almighty father in Heaven

To my brothers and sisters

To my relatives, friends and classmates

ACKNOWLEDGEMENTS

First and foremost, I would like to thank the Almighty God for the love and protection he has given to me throughout my studies.

I would like to express my deep and sincere gratitude to my supervisor **Eng.Dr Fabrice MWIZERWA** for his valuable guidance, suggestions and constructive criticism at every stage of this thesis.

I would like to express my deep gratitude to my parents and friends for their valuable guidance and encouragement which helped me to complete this thesis. Finally, I would like to thank relatives and classmates for their moral and physical support which helped me to accomplish this work.

ABSTRACT

The main objective of this research was to conduct a technical detailed study on the implementation of G+4 building in KICUKIRO DISTRICT With size of (51*41m). due to the capacity of existing carrie`re old market based on the number of the customer received on this market. It is the reason why this research has been conducted to solve that problem.

Different methods have been used for well conducting this study such as analytical method for designing different structural members like slab, beam, column, foundation, stairs and ramp, shear wall different software's has been used like Arch cad 20,for providing architectural drawing of the market building such including all plan views, sections, elevation and perspectives, protastructure have been used and manual for the structural design of beam, slab, column, footing, stair and ramp by computing beam detailing and reinforcement.

Arc GIS and Google earth have been used for well locating the study area and preparing all maps. Bill of quantity has been calculated within this study the results showed: in archictecural drawing, has size of 51m in length and 41m in width, on ground floor has 14 shop with size (6m*4m),2 restaurant with size (8m*4m),

1 pharmancy with size(8m*4m),15 toilet with size (1m*1.5m),space of vegetable shoping,stairs,ramp,on the fist floor has 12 room with size (6m*4m),room1 ,room2 with same size of 8m*4m athers floors are same as first floor each floor has height of 3.5m.

In the design of steel reinforcements to be arranged in slab were 10bars12mm of diameter at the top and bottom 4Φ10@300mm/m while for T beam designed steel reinforcements were T5@25mm at the top and 4@25mm at the bottom. And for column the designed steel reinforcement were 8Φ20mm for ground floor part the column and T8@20mm for first floor, second, third, fourth and fifth floor designed steel reinforcement were T8@20mm while foundation steel designed by Protastructure software that shows reinforcement were 6Φ20mm for the stair designed steel reinforcement were T10@150mm/m For main and T2@12mm a ramp design steel reinforcement were T12@150mm.

The estimated amounts of building 1,116,519,944 Rwf the building was well located therefore the expected results have been achieved. (in word one milliard, one hundred sixteen millions five hundred nineteen thousands and nine hundred forty-four Rwf).

LIST OF ABBREVIATIONS, FIGURES,TABLES AND SYMBOLS

KN: kilo Newton

Q: Shear force acting on the cross section

Qf: punching shear force

qsw: Total shear force carried by the all legs of stirrup

Um: average perimeter

Dl: Difference between long span and short span of the beam

Δq: Balancing shear force

S: Distance between stirrups

BM: Bending moment

SF: Shear force

As: Cross sectional area of tensile reinforcement

As': Cross sectional area of compression reinforcement

Asmin: The minimum required area of the reinforcement

B: Width of the member

BW: web width of a flanged beam

bf: breadth of section

Gk: Dead load

h: The overall depth of the member

hf: The overall depth of the flange

ho: Effective depth of the cross section

Lx: Short span length

Ly: Long Span length

M: Bending moment

$M^{+}x$: Design moment from the bottom at the shorter side

$M^{+}y$: Design moment at the bottom of the longer side

αm, ɳ: The ratio of the lever arm to the effective depth of the cross section.

P:Total design load per unit area

N: design axial load

Qk: characteristic imposed Load

Gk: characteristic dead load

Fcu: characteristic strenght of concrete

Fy: characteristic strenght of reinforcment

Fyv: characteristic strenght of links (not to be taken as more than 460N/mm2)

R_b:Design concrete compressive strength

R_s: Design steel tensile strength

R_{bt}: Concrete design tensile strength

R_{sw}: Design strength of stirrups

X: Depth of the neutral axis

Φ: The diameter of the reinforcement

$\xi = x/h_o$: The ratio between the depth of concrete compressive zone and the effective depth of the cross section.

α_m: Coefficient taking into account the bending moment action

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background of the study

Building design: refers to the broadly based architectural, engineering and technical applications to the design of buildings (Bielak, 2019). In many places, building codes of professions allow persons to design single family residential buildings and, in some cases, light commercial buildings without an architectural license (Slaton, 2001).

Many factors enter into the design of buildings, including cost, purpose, occupancy, and location (Yardim, 2013).

A high-risk building should incorporate more mitigation features than a low-risk building (Yardim, 2013).

Bollards and strong gates are less expensive than making major structural changes to a building (Solomon, 2014).

In 2020 the population of Rwanda was 12,952,218 people while the current population of Rwanda is 13,556,214. The increase of people related to urban growth where Rwanda is ranked number 76 in the list of countries which is overpopulated by having total land of 24,670 Km2 (9,525 sq. miles) apart from water surfaces and its population density is` 525 per Km2 (1,360 people per mi2);

these shows how the population growth increases day today as it was predicted to reach to 14,576,985 in 2025, and 23,048,005 by 2050 as it is linked to urban growth, it can be 2,659,944 and 6,483,462 since 2025 and 2050 respectively (Kaberuka, 2000).

KICUKIRO District is one of the three districts which compose the Kigali city. It has ten (9) Sectors which Kagarama, Niboye, Gatenga, Gikondo, Gahanga, Kanombe, Nyarugunga, Kigarama, Masaka. It covers 2900 km2 kilometres. Its relief, alternate seasons, vegetations give a smooth climate for its population.

According to the data from NISR the population of KICUKIRO District is currently estimated to 491,731. Urbanization is occurring fastest in developing countries.

The development of Rwanda in domain of construction is moving or pointing at the highest rising in building apartments (Ching, 2018). For planning this project, it means that if the development increases, then the standard of people living in KICUKIRO District increases and that’s the reason of doing the wide modern resident and camercial apartment in this city. Modern apartment includes living room, bed room, toilet, kitchen, guest room,and also comercial building, etc. (Sommers, 2012).

Rwanda is a landlocked nation situated in East Africa with area of 26,338 km^2, refer to official records of 4^{th} and 5^{th} Rwanda Population and Housing Census (PHC) shows that Rwandan population in 2012 was 10,515,973 with 415 inhabitants per km^2 and in 2022 was 13,246,394 with 524 inhabitants per km^2. This proved that Rwanda is among the most densely populated in Africa with growth rate of 2.3% and recognized as "the land of a thousand hills" due to its hilly topography, Rwanda faces challenges in utilizing its land, as a significant portion is either too steep or too wet for construction (MININFRA 2013).

1.2 Problem statement

KIGALI, Rwanda - Following a recent conference in Kigali on the country's land policy, attendees came to the conclusion that Rwanda's small size and rapid population growth are contributing to the country's rising problem of land shortage. They also came to the conclusion that the difficulties in Rwanda are exacerbated by the elites' persistent seizing of land in urban areas and by the country's mountainous terrain.

The warmest annual average temperatures in Rwanda are found in the eastern (20 - 21°C) and Bugarama valley (23-24°C) according to a report of Meteo Rwanda. However, the Eastern province especially Bugesera district's temperature is likely to rise due to an increase in urbanization in this district as the city near the Capital city of Rwanda (Kigali). Furthermore, there is global concern regarding the excessive use of energy and water, as well as the emission of greenhouse gases. Rwanda's ecological and sociological footprints have extended across extensive regions, forming an urban-rural continuum of communities with shared characteristics in individual lifestyles. The implementation of green apartment buildings aims to enhance the efficiency of energy, water, and material usage within buildings and their surroundings, thereby diminishing the adverse impacts on human health and the environment.

Given Rwanda's status as a relatively small yet densely populated country in Africa, the expanding urban areas necessitate the adoption of compact development strategies. This approach is essential to efficiently accommodate the growing population within limited space, emphasizing the need to maximize the utilization of available land resources

Therefore, it is problematic to continue to relate population growth and land shortage in a single direction. Rwanda nonetheless faces the same difficulty with urban population growth as other nations. They anticipated that by 2050, they would have doubled.

1.3 Objectives

1.3.1 General objective

The main objective of this project is to prepare structural design of a G+4 commercial and residential building.

1.4 Specific objectives The specific objectives of this study were:

a) To provide architectural drawings of proposed building;

b) To design structural elements of the proposed building;

c) To determine the bill of quantity for the proposed building;

1.4. Research questions

a) How architectural and detailed drawings can be produced?

b) How design of structural elements of the proposed project can be produced?

c) How the bill of quantity for the proposed project can be estimated?

1.5. Significance of the study

This study helps to shift from theory to practice;

Above all, it contributed to the successful completion of Bachelor's degree in Civil Engineering. There after improving the knowledge and skills of research about structural design, it is also help to master some engineering soft wares like AutoCAD, Archi CAD 21 and protostructure.

It covers the most important course of engineering like RCD I and II, and structural analysis I and II. This project study academically this must be used as a reference for students and other individuals who want to conduct any study about design of multistorey building. Thus, the region where the infrastructure is built the surrounding population would enjoy the healthy and safe life due to house of high standard.

1.6 Scope of the project

This final project covered structural elements design such as slab, beam, column, and foundation. The calculations were demonstrated in details and focus on area reinforcements in this project. It also covered the preparation of B.Q.

1.7 Methodology

This project gave different structural design elements such as Slab, beam, column and foundations. To achieve the intended goals, the standard used in design BS 8110 and EC2 were used with doing research about the different of two codes by reads books from library. Vision like (Euro code: Design of concrete structures (EC2/1992) and the design based on BS8110, with its application. In this research some software were used to achieve intended goal, that software include protostructure was used for designing structural frame (beam, column and slab), Microsoft office were used: MS word for writing and MS Excel for tables and figures.

1.8. Organization of the study

This study is broken up into five chapters. The broad introduction, found in Chapter 1, provides a comprehensive overview of multi-story buildings. It outlines the study's goals and the questions be used to measure them. Chapter 2 discusses earlier research on the design of multi-story buildings.

The materials and techniques used to accomplish the goals of the research are presented in chapter three. Finding solutions and designing suitable parts for a G+4 residential building are the topics of Chapter 4. Chapter 5 concluded with conclusions and suggestions related to the prior research in the studied area.

CHAPTER TWO: LITTERATURE REVIEW

This chapter presents only a brief explanation of structural design and the technology of constructing building elements.

2.1 Historical background

The first high-rises were built in America in the late 19th and early 20th century, notably in New York and Chicago. The Home Insurance Company Building, designed by William Le Baron Jenney and completed in 1885, is commonly regarded as the first skyscraper.

Highrise buildings arose as a result of rising real estate costs and the necessity for business proximity to city centres. The development of cast iron and steel, as well as advancements such as the safe elevator and massproduced building elements, enabled these skyscrapers to be built (Keković & Petrović, 2001).

2.2. Reinforced concrete

Reinforced concrete: is combination of concrete and steel where the steel reinforcement provides the tensile strength in the concrete. For it is capable to resist both compressive and tensile stresses, it is used in beams, columns as well also in the situation of slabs.

In this case the structures of green apartment they must have strong frames, where a frame is composed of columns, beams, and slabs. So, all those components of frame have to be made in reinforced concrete; that is why the composition of reinforced concrete must be discussed on it (Menetrey, 1994).

2.2.1. Composition of reinforced concrete

In civil engineering works, the best technique to make easy supply is using local available material. Loads acting on a structure must be ultimately transferred to the ground. In doing so, various components of the structure are subjected to internal stresses. For example, in a building, load acting on a slab is transferred by slab to ground through beams, columns and footings.

Assessing the internal stresses in the components 6 of a structure is known as structural analysis and finding the suitable size of the structural components is known as design of structure (Suhir, 2012).

Beams support floor slabs so that their vertical loads are transmitted to the column they are made of reinforced concrete or composite slabs using profiled steel sheets. Since there are lots of possibilities of bracings and connections, choosing the appropriate one and minimizing the structure cost is the major concern in the design of steel buildings.

The main reason for choosing the wind forces as the main source of lateral force is that the most severe damages in multi-story steel structures are caused by winds (Zhou, 2017).

2.2.1.1. Concrete

Concrete: is a composite a man- made material, which is the most building material in the construction industry. It consists of rationally chosen mixture of binding material such as lime or cement as binder, well graded fine and coarse aggregates, water and admixtures where they are necessarily needed as shown in figure 2.1 (Maier, 2022).

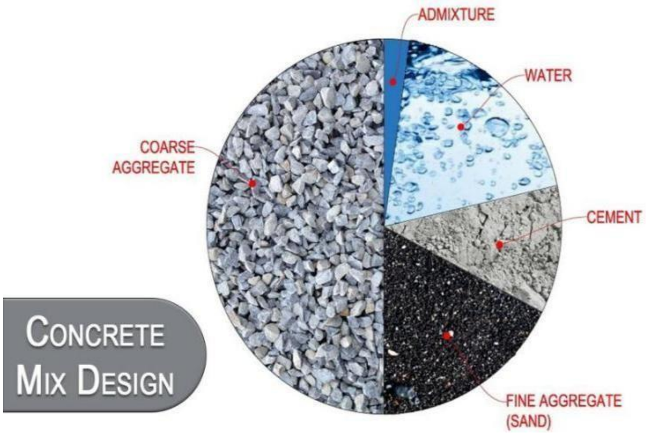


Figure 2.1: Element of concrete (Argyris, et al., 1974).

For the essential beam, at the top and bottom along the short and long span, 4T16 at the top, 3T12 at the bottom. Decrement: In a broad sense, cement is an adhesive and cohesive compound that may bind together 7 small pieces of solid material to form a strong, enduring mass.

In order to bind the fine (sand) and coarse (grits) aggregate particles together, calcareous cements with compounds of lime as their main element are the only ones permitted for use in civil engineering projects. Portland cement, the most widely used type of cement, falls into the hydraulic category of cements utilized in the construction sector. (Bauccio, 1993).

Aggregate: are the basic materials used as filler with binding material in the production of mortar and concrete? To increase the bulk density of concrete aggregates are used in two different sizes the bigger ones known to be coarse aggregate (grit) and the small ones known as fine aggregate (sand).

The coarse aggregate from the main matrix of concrete and the fine aggregate form the filled matrix between the coarse aggregate, they should be clean, hard, strong, and durable and graded in size to achieve utmost economy from the paste (Martínez, 2013). Admixture: Admixtures are substances introduced into a batch of concrete, during or immediately before it is mixed, to improve its properties.

There are many types of admixtures which are: accelerating agents, retarder's agents, water reducers or plasticizers, and super plasticizers. All those admixtures are used based on the how you want to improve the concrete (Raheem, 2010).

Water: Normally water is considered to be the source of life, but in civil engineering it is used for the purpose of hydration of the cement, to produce a workable and economical concrete, curing the concrete structures, but amount of water must be limited to produce concrete of the quality required for a job; water is also used for washing aggregates and curing.

The water quality used is not difficult to identify because the water you can use to drink can also be used for construction (Boyd, 2019).

Reinforcement: Concrete is strong in compression but weak in tension. Because of this it is normal practice to provide steel reinforcement in those areas where tensile stresses in the concrete are most likely to 8 develop. Consequently, it is the tensile strength of the reinforcement which most concerns the designer.

When steel is exposed to the atmosphere; atmospheric agencies like humid air, it causes the rusting of steel, and also the atmospheric condition with rain produces corrosion. Which means that enough cover in needed to avoid the contact of steel with the atmosphere (Kaelbling et al., 1996).

Properties of reinforced concrete

It can be seen from this list that the materials are more or less complementary. thus, when they are Combined the steel is able to provide the tensile strength and probably some of the shear strength While the concrete strong in compression, protects the steel to give it durability and fire resistance Invalid source specified (Shah, 2011). Table 2.1 describe the Properties comparison of steel and concrete (Zhang et al., 2019).

Table 2.1: Properties comparison of steel and concrete (Zhang et al., 2019).

Property	**Concrete**	**Steel**
Strength in Tension	Poor	Good
Strength in compression	Good	Good but not slender bars
strength in shear	Fair	Good
Durability	Good	Good but corrodes if unprotected

Composite action: Composite action is developed when two loadcarrying structural elements, such as a concrete floor slab and its supporting steel beams, are integrally connected and deflect as a single unit, substantially increasing its strength and stiffness.

A reduction in 9 steel weight is often possible by taking full advantage of a composite system. Since the concrete slab exists anyway and the shear connectors are inexpensive and easy to install, it is structurally advisable to use composite construction whenever possible.

The tensile strength of concrete is only about 10 % of its compressive strength. Because of this, nearly all reinforced concrete structures are designed on the assumption that the concrete does not resist any tensile forces (Tsavdaridis, 2013).

Modulus of elasticity: The short-term stress-strain curve for concrete in compression shown in Fig2.2. The Slope of the initial straight portion is the initial tangent modulus. At any point P the slope of curve is the tangent modulus and the slope of line joining P to the origin is the secant modulus depends on the stress and rate of application of the load (Popovics, 1973).

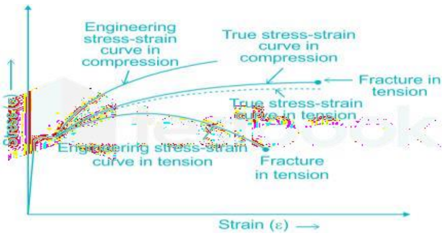


Figure 2.2: Stress-strain curve for brittle material (Riera et al., 2011).

The changes in compressive strains being transferred to the reinforcing steel results in redistribution of load. Thus, the compressive stresses in the steel are in creed so that the reinforcing steel is increased for steel to take a larger proportion of the load.

The effects of creep are particularly important in beams as the increased defection may cause the opening of cracks, damage to finishes, and the non-alignment of mechanical equipment redistribution of stress between concrete and occurs primarily in the in cracked compressive (Mohammed et al., 2019).

Modulus of elasticity, E=f/s (MPa,

N/mm2, or KN/m2)   Where, f= applied

stress on a body s= strain to correspond to the applied stress

Durability: Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. Concrete structures properly designed and constructed are long lasting and should require little maintenance.

The durability of the concrete is influenced by exposure to weather conditions, cement type, concrete quality, cover to the reinforcement and width of any cracks (Otieno et al., 2020)

Creep in a concrete is the: gradual increase in strain with time in subject to prolonged stress. The creep strain is much larger than the elastic strain on loading. If specimen is unloaded there is an immediate elastic recovery and a slower recovery in the strain due to creep.

Both amounts of recovery are much less than the original stain under loading. The main factors affecting creep in concrete are concrete mix and strength, the type of aggregate, curing, ambient relative humidity and the magnitude and duration of sustained loading (Alrshoudi et al., 2020).

2.2.1.2. Bricks materials

Bricks: are a widely used construction and building material around the world. Conventional bricks are produced from clay with high temperature kiln firing or from ordinary Portland cement (OPC) concrete, and thus contain high embodied energy and have large carbon footprint. In many areas of the world, there is already a shortage of natural source material for production of the conventional bricks (Murmu, 2018).

Bricks: are among the oldest construction materials and continues to be a most popular and leading construction material because of being cheap, durable and easy to handle and work with. Brick may be made of burnt clay or mixture of sand and lime or of Portland cement concrete. Clay bricks are used for building-up exterior and interior walls, partitions, piers, footings and other load bearing structures (Hameed et al., 2018) 11

2.2.1.3. Stone materials

Stone: has been used in the construction of most of the important structures since prehistoric age such as pyramids of Egypt, Great Wall of China and etc. It has been defined as the natural, hard substance formed from minerals and earth material which are present in rocks. Stone can serve: to construct the foundation and wall items; to manufacture elements of stair, landings, parapets and guard rails; and it can also be used as flooring material (Playfair, 2011).

2.2.1.4. Mortar materials

Masonry mortar: can be defined as a mixture of Portland cement, hydrated lime and mineral aggregates (sand) with water, which presents hardening capacity and adherence. Masonry mortar functions are: (i) bond units of masonry; (ii) distribute loads; (iii) absorb deformations; (iv) seal joints.

Masonry mortars can be employed for joining bricks/blocks, rendering and grouting (Deepak, 2003). Mortar is a mixture of sand and lime or a mixture of sand and cement with or without lime. The mortar used in brickwork transfers the tensile, compressive and shear stresses uniformly between adjacent bricks. The mortar can also be used to join stone block and etc. (Stefanidou et al., 2014).

2.2.3. Structural design elements of a building

A multi-story building structure can be divided into different elements, where each element has its own function on the building. Those elements are the following:

2.2.3.1. Foundation

A foundation: is a part of the structure which is usually below the surface of the ground and which transmits the load to the underlying soil or rock. The size and depth of a foundation is determined by the structure and the size of the building it supports and the nature and bearing capacity of the 12 ground supporting it.

To select a foundation or to design a foundation it is necessary to calculate the loads on the foundation and determine the nature of subsoil, its bearing capacity, it's likely behaviour under seasonal and groundwater level changes and the possibility of the ground movement (Day R., 2010).

2.2.3.2. Plinth beam

Plinth beam: is a beam structure constructed either at or above the ground level to take up the load of the wall coming over it is a reinforced concrete beam constructed between the wall and its foundation. It is provided to prevent the extension or propagation of cracks from the foundation into the wall above when the foundation suffers settlement. The minimum depth of plinth beam is 20cm whereas its width should match the width of final course of the foundation (Ravi Kumar Reddy, 2014).

2.4.3.3. Beam

Beam: is a horizontal member carrying lateral load transmitting to the column. they are singly reinforced concrete beam; these are rectangular beams which should be reinforced in the tension zone, doubly reinforced concrete beams, if the concrete alone cannot resist the applied moment in compression, can be provided in the compression zone and the flanged beams occurs where beams are cast integral with and support a continuous floor slab and they are divided into two types: T-beam and Lbeam (Kaliluthin, 2014).

2.2.3.4. Columns

Columns: are structural members of buildings carrying loads from roof and floors transmit to the foundations. A column stacks in a multi-story building its purpose is to carry axial loads, but. Columns are separated into two categories; short columns and slender columns. Short columns are controlled by the strength of the material and the geometry of the cross section. Reinforcing rebar is placed axially in the column to provide additional axial stiffness.

Columns qualify as being slender when their cross-sectional area is very small in proportion to their length. Unlike 13 Short Columns, Slender Columns are limited by their geometry and buckle before the concrete or steel reinforcement yields (Ramaji, 2013). Failure of column Crushing: the mode of failure for the short column and this increase cracks as shown on figure 2.3 (Zhang et al., 2019).

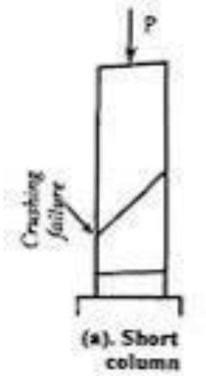


Figure 2. 3: Crushing failure

Buckling: the mode of failure of long column (bending). The buckling capacity is the capacity of the element to withstand the propensity to buckle. Its capacity depends upon its geometry, material, and the effective length of the column, which depends upon the restraint conditions at the top and bottom of the column. The capacity of a column to carry axial load depends on the degree of bending it is subjected to, and vice versa as shown on Fig.2.4 (Mou, 2020).

Figure 2.4: Buckling

2.2.3.5. Floor

A floor: is a horizontal element usually flat constructed to provide a level surface to support occupants of a building, furniture, equipment and sometimes partition, the floor also is the surface of room on which one 14 stands, is a story or a level of a building. A floor on the ground is called ground floor and others above are called upper floors. The problems of strength and stability are usually minor ones at ground and basement levels, since full support from the ground is available at all points (Luo, 2014).

2.2.3.5. Slabs

A concrete slab: is a common structural element of modern buildings, consisting of a flat, horizontal surface made of cast concrete. Concrete slab which is typically between 100 and 500 mm thick, are most often used to construct floors and ceilings, while thinner mud slabs may be used for exterior paving.

In many domestic and industrial buildings, a thick concrete slab supported on foundations or directly on the subsoil, is used to construct the ground floor. These slabs are generally classified as ground bearing or suspended. A slab is ground-bearing if it rests directly on the foundation, otherwise the slab is suspended (Adalier, 1998).

Classification of slab according to their methods of support

One-way slabs: when a rectangular slab is supported by parallel walls or beams on all the four edges and the length-to-breath ratio is equal or greater than two, and it bends in only one direction (spanning direction) while it is transferring the loads to the two supporting walls or beams, because of its geometry. Simply stating it spans and bends in only one direction. On fig2.5 the slab is considered to be a one-way slab (Gomes et al., 2020).

Figure 2.5: One-way slab

(Liu et al., 2021).

Two-way slab: Two-way slab is a slab supported by beams on all the four sides and the loads are carried by the supports along with both directions, it is known as two-way slab. In two-way slab, the ratio of longer span to shorter span is less than 2. In two-way slabs, the load be carried in both the directions. So, the main reinforcement is provided in both directions for two-way slabs. These types of slabs are used in constructing floors of a multi-storeyed building (Gupta et al., 2012).

Figure 2.6: Two-way slab

(Lee, 2010).

Flat slabs: Flat slab is a reinforced concrete slab supported directly by concrete columns without the use of beams. Flat slab is defined as one sided or two-sided support system with shear load of the slab being concentrated on the supporting columns and a square slab called ‘drop panels.

Drop panels play a significant role here as they augment the overall capacity and sturdiness of the flooring system beneath the vertical loads thereby boosting cost effectiveness of the construction. Usually, the height of drop panels is about two times the height of slab (Zineddin, 2007).

2.2.3.5. Stairs

Stairs: can be defined as set of steps leading from one floor of a building to another, typically inside the building; stairs should be designed so that they are convenient for the majority of people to use it, and because of the very young and old people may find difficult to use them, that why you have to put handrails which should be supported by balustrades on 16

the Fig 2.7 show open sides of staircases to prevent accidents (Jacobs, 2016).

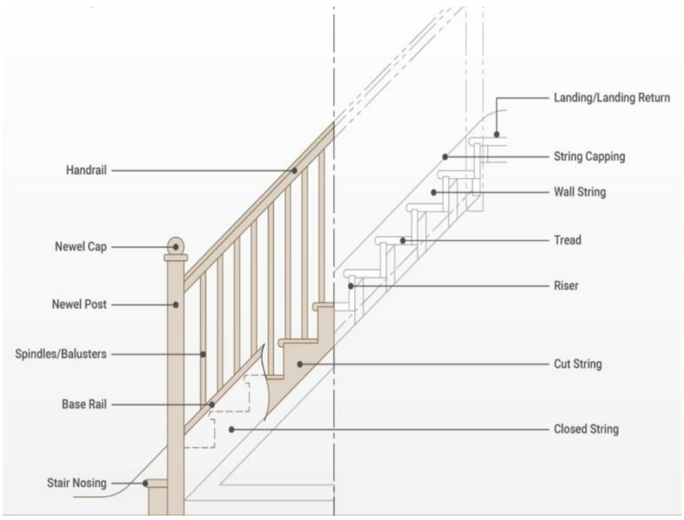


Figure 2.7: Stair case

2.2.3.6. Ramp

The Americans with disabilities (2002), defines ramp as an accessible route for walking or wheeling in the form of an inclined plane with a slope greater than or equal to 1:12 from the horizontal. The Canada Mortgage and Housing Corporation (2011), asserts that a ramp is ideal for people who are having difficulty negotiating stairs for various reasons, be it the need to carry heavy objects between levels, move a child in a stroller, or because of a disabling condition (Jenson et al., 2015).

2.2.3.7. Wall

A wall: is a continuous, usually vertical structure thin in the proportion to its length and height build to provide shelter as an external wall or divide building into rooms or compartments as an internal wall, wall separate the spaces inside and outside a building. 17 The function of an external wall is to provide shelter against wind, rain and the daily and seasonal variation of outside temperature normal to its location, for reasonable indoor comfort.

The primary function of the wall is to enclose or divide spaces of the building to make it more functional or useful. Wall separates the spaces inside and outside building wall provide privacy afford security and give protection against heats, cold, sun and rain (Green, 2004).

Functional requirement of wall structure

The function of wall is to enclose and protect a building or to divide space within the building to provide a check that a particular wall construction satisfies a range of functional requirement. The commonly accepted requirements of a wall are:

Strength and stability

Resistance to weather and ground moisture

Durability and freedom from maintenance

Fire safety e. Resistance to the passage of sand

2.2.3.8. Roof

A roof is the structure forming the upper covering of building. It includes construction materials that support it on the walls of the building or on uprights; it provides protection against rain, snow, sunlight, extreme of temperature, and wind. So, roof is a part of the building envelope.

The characteristics of a roof are dependent upon the purpose of the building that it covers the available roofing materials and the local traditions of construction and wider concepts of architectural design and practice and may also be governed by local or national legislation. Roof can either be flat or sloped based on the location and weather conditions or the purpose of the building (Verso et al., 2015). 18

2.2.4. Structural design and limit states design

2.2.4.1. Structural design

Structure design is a branch of structural engineering, structural design deals with the selection of proper material, proper sizes, protection and shape of each member and its connecting details. The selections are such that it is economical and safe, and satisfy all the stress requirements imposed by the severe combination of loads to which the structure is required to transmit or resist its self-weight (Trahair et al., 2017).

The design of a structure has two aspects: functional and strength aspect. In the first aspect, called functional design, a structure is proportioned and constructed such that it serves the needs similar for which is constructed for. For the second aspect, called structural design, the structure should be strong enough to resist external forces to which it is subjected during its entire period of service.

There by depending on the suitability; the plan layout of beams and the position of columns have to be fixed, thereafter, the loads are calculated such as the dead loads; which depend on the unit weight of the material used (concrete, brick) and the live loads; which depend on the reference standards provisions (Darwin et al., 2016).

2.2.4.2. Limits state design

The design of an engineering structure must ensure that under the worst loadings, the structure is safe, and during normal working conditions the deformation of the members does not detract from the appearance, durability or performance of the structure. The limit state method involves applying partial factors of safety, both to the loads and to the material strengths.

The magnitude of the factors may be varied so that they may be used either with the plastic conditions in the ultimate state or with the more elastic stress range in the working loads. The two principal types of limit state are the ultimate limit state and the serviceability limit state (Atutis et al., 2015)

19 Serviceability limits state

This requires that the structural elements do not exhibit any preliminary signs of failure. Generally, the most important serviceability limit states are: deflection (appearance or 19 efficiencies of any part of the structure must not be adversely affected by deflections), cracking (local damage due to cracking and spelling must not affect the appearance, efficiency or durability of the structure) and durability (in terms of the proposed life of the structure and its conditions of exposure (Alexande & Beushausenr, 2019).

Ultimate limits state

This requires that the structure must be able to withstand, with an adequate factor of safety against collapse, the loads for which it is designed. The possibility of buckling or overturning must also be taken into account, as must the possibility of accidental damage as caused, for example, by an internal explosion on Fig 8 (Olivar et al., 2020)

Figure 8: Limit states (Weichert, D. 2009).

The main serviceability limit states are as follow:

Deflection

The deformation of the structure should not adversely affect its efficiency or appearance. Deflection of beams may be calculated, but may tend to be complicated because of cracking, creep and shrinkage effects. In normal cases span-to-effective depth ratio can be used to check compliance with requirements (Arowojolu et al., 2021).

Cracking

Cracking: should be kept within reasonable limits by correct detailing. Crack width may be calculated, but may tend to be complicated and in many cases cracking can be controlled by adhering to detailing rules with regard to bar spacing in zones where the concrete is in tension (Acker & Ulm 2001).

Vibration

The structure should be under the action of wind loads or movement of the people vibrate so much as to make people uncomfortable or in worst cases even to alarm people. In analysis a section for serviceability limit states, the behaviors are assessed assuming a linear elastic relationship for steel and concrete stresses. Allowance is made for the stiffening effect of concrete in the tension zone and for creep and shrinkage (Higgins et al., 2013).

2.2.5. Characteristics and design load

2.2.5.1 Partial factors of safety

Possible variation such as constructional tolerances are allowed for by partial factors of safety applied to the strength of the materials and to the loads.

Design strength=characteristics of strength(fk)

patial factor of safety(ym)

The two factors are considered when selecting a suitable value for γm:

This strength differs from that measured in carefully prepared test specimen and it is particularly true for the concrete where placing, compaction and curing are so important to the strength. Steel on the other hand, is relatively s consistent material requiring a small partial factor of safety (Becker, 1997).

The severity of limit state being considered; thus, higher values are taken for ultimate limit state than for the serviceability limit state. Recommended values for γm are given in the table below although it should be noted that for precast factory conditions it may be possible to reduce the value for concrete at the ultimate limit state (Cuenca, 2013).

The table 2 the value of partial safety factor for loads should account for the following parameters.

Table 2.2: Values of partial factors of safety applied to materials

Limit state	**Materials**	
Ultimate	concrete	Steel
Flexure	1.5	1.115
Shear	1.25	1.115
Bond	1.4	1.115
Serviceability	1.0	1.0

2.2.5.2. Partial factors of safety for loads

Errors and accuracies may be due to a
number of causes: o Design assumptions
and an accuracy of calculation. o Possible
unusual increases in magnitude of the 22 actions.
o Unforeseen stress and redistributions.
o Construction inaccuracies.

These cannot be ignored, and are taken into account by applying a partial factor of safety

(γm) on the characteristic loads, so that,

Design value of load= characteristic load x partial factor of safety (γm) Within the value of this factor the importance of the limit state is taken into account and reflects to some extent accuracy with which different types of loading can be predicted, and the probability of particular load combinations occurring (Ellingwood, 1980).

2.6 Analysis of the structure

The analysis must begin with an evaluation of all the loads carried by the structure, including its own weight. Many of the loads are variable in magnitude and position, and all possible critical arrangements of loads must be considered. First the structure itself is rationalized into simplified forms that represent the load-carrying action of the prototype. The forces in each member can then be determined (Attary et al., 1943).

2.6.1. Loads

The loads on a structure are divided into two types those types are stated below

Dead loads, and live loads. Dead loads are those loads which are normally permanent and constant during the structure's life, they include the weight of the structure itself, and all architectural components: partitions and ceilings, equipment and static machinery, and permanent fixtures are also considered as part of the dead load.

On the other hand, live loads are variable in magnitude. Examples of imposed loads on buildings are: the weights of its occupants, furniture, or machinery, the pressure of wind, the weight of snow, and so on (Taranath, 2016).

A large building is unlikely to be carrying its full variable load simultaneously on all its floors. For this reason, the British standard code of practice allows a reduction in the total floor loads when the columns, walls, or foundations are designed, for a building more than two stores high. Similarly, the variable load may be reduced when designing a beam span which supports a floor area greater than 40m2 (Horne, 2014).

2.6.2 Application of structural load on the building

The loads are the forces that act on a structure. They belong to one of the two broad categories dead loads and live loads.

Dead load

Dead load is those that are permanent, including the weight of structure itself, dead loads in a building include the weight of non-structural components such as floor coverings, partitions and suspended ceilings. All the loads mentioned thus far are forced resulting from gravity and are referred to as gravity (Kusche, 2005).

Live loads

Live loads may not be acting on the structure at any given time, and the location may not be fixed. Example of live loads include furniture, equipment, and occupants of buildings, wind exert a pressure or suction on the exterior surfaces of building because of its transient nature, it properly belongs in the category of live loads because of the relative complexity of determining winds loads, however wind is usually considered separate category of loading.

Earthquake loads are another special category and need to be considered only in those geographic locations where a reasonable probability of occurrence (Barbat et al., 2010).

Load combination

Load combination for the ultimate state and various combinations of the characteristic values of dead load Gk, imposed load Qk, wind load Wk 24 and their partial factors of safety must be considered for the loading of the structure (Broth & Hoult, 2020). 25

Table2.3 shows Values of safety factor according to loading combination

Load combination	**Load type**					
	Dead load		**Imposed load**		**Earth and water**	**Wind**
	Advise	Beneficial	Advise	Beneficial		
Dead and Imposed (earth and water pressure)	1.4	1.0	1.6	0	1.4	-
Dead and Wind (earth and water pressure)	1.4	1.0	-	-	1.4	1.4
Dead, Wind and Imposed (earth and water pressure)	1.2	1.2	1.2	1.2	1.2	1

combinations of the characteristic values of dead load (Gk), imposed load (Qk), wind load (Wk) and their partial factors of safety must be considered for the loading of the structure. There as follow:

Dead and Imposed load l.4Gk + 1.6 Qk

Dead and wind load 1.0Gk + l.4Wk 26

Dead, Imposed and wind load 1.2Gk + 1.2Qk + 1.2Wk

2.7. Construction Terminology

Concrete cover: is term used in engineering to describe distance from steel to the formwork its purpose is to protect steel from corrosion. The concrete cover must have a minimum thickness for reasons such as to protect the steel reinforcement bars (rebars) from environmental effects to prevent their corrosion, to provide thermal insulation, which protects the reinforcement bars from fire, and to give reinforcing bars sufficient embedding to enable them to be stressed without slipping.

The premature failure of corroded steel reinforcements and the expansion of the iron corrosion products around the rebars are amongst the main causes of the concrete degradation. The carbon steel of rebars is protected from oxidation by atmospheric oxygen by the high pH of concrete interstitial water (Betona, 2014).

Formwork: are temporary or permanent shuttering molds in which concrete or similar materials are poured. Formwork comes in several types such as traditional timber formwork, engineered Formwork System, re-usable plastic formwork, permanent Insulated Formwork, stay-In-Place structural formwork systems and Flexible formwork (Prajapati, 2014).

Curing: is a chemical process employed in process engineering that produces the toughening or hardening of a material like concrete? Even if it is strongly associated with the production of thermosetting polymers, the term curing can be used for all the processes were starting from a liquid solution, a solid product is obtained (Liew et al., 2011).

Shrinkage: Shrinkage or drying shrinkage is the contraction occurs in the concrete when it dries and hardens. Drying shrinkage is irreversible but alternate wetting and drying causes expansion and contraction of concrete. The aggregate type and content are the most important factors influencing shrinkage.

The larger the size of the aggregate is, the lower is the shrinkage, the higher is the aggregate content; the lower the 27 workability and the higher the water cement ratio is, the lower is the shrinkage. Aggregates change volume on wetting and drying, such as sandstone or basalt, give concrete with a large shrinkage strain, while nonshrinkage aggregates such as granite or gravel give lower shrinkages (Elzokra et al., 2020).

Creep: Creep in concrete is the slow and gradual deformation with respect to time in a member subjected to prolonged stress. The creep strain is much larger than the elastic strain on loading. If the specimen is unloaded there is an immediate elastic recovery and a slower recovery in the strain due to creep. Both amounts of recovery are much less than the original strains under load.

The main factors affecting creep are the concrete mix and strength, the type of aggregate, curing, ambient relative humidity and the magnitude and duration of sustained loading (Jiao et al., 2020).

Brickwork: is masonry produced by a bricklayer, using bricks and mortar. Typically, rows of bricks called courses are laid on top of one another to build up a structure such as a brick wall (Hamon et al., 2016). Brick size may be slightly different due to shrinkage or distortion due to firing. Bricks of dimensions 215 mm × 102.5 mm × 65 mm; mortar beds and perpends of a uniform 10 mm (Sarhosis et al., 2019).

Foundation: is a part of the structure which is usually below the surface of the ground and which transmits the load to the underlying soil or rock. The size and depth of a foundation is determined by the structure and the size of the building it support and the nature and bearing capacity of the ground supporting it (Day C., 2012).

Cracks: a building component develops cracks whenever stress in the component exceeds its strength. Cracks are classified into structural and non-structural categories. The structural ones are due to faulty design, faulty construction or overloading which may endanger safety of buildings. The non-structural cracks are due to internally induced stresses.

There are numerous causes of cracking in concrete, but most 28 instances are related more to concrete specification and construction practices than by stresses due to induced forces (Doshi et al., 2018).

Segregation: is a case of separation of particle during applications and transportation in concrete, where particulate solids tend to segregate by virtue of differences in the size, density, shape and other properties of particles of which they are composed. Segregation also occurs due to over-vibration or compaction of concrete, in which cement paste comes to the top and aggregates settles at the bottom (Howes et al., 2019).

Admixtures: are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. Admixtures are defined as additions "made as the concrete mix is being prepared". The most common admixtures are retarders and accelerators (Li et al., 2019).

2.8. Bill of quantity

Estimating: is the technique of calculating or computing the various quantities and expected expenditure to be incurred on a particular work or project. A cost estimate is a compilation of many elements, an approximation of the probable quantity and unit cost of each of the elements (Davydov et al., 2010).

CHAPTER THREE: MATERIALS AND METHODOLOGY

This chapter presents an overview of the study area, the climate characteristics geographic location, and describes the materials and methods used to conduct the valid results.

3.1. Description of case study and study area

KICUKIRO district is located in the south-east city of Kigali, the capital of Rwanda. It is made up to ten (10) administrative sectors (Imirenge), Kagarama, Niboye, Gatenga, Gikondo, Gahanga, Kanombe, Nyarugunga, Kigarama, Masaka, 41cells (Utugali) and 333 Administrative villages (imidugudu).

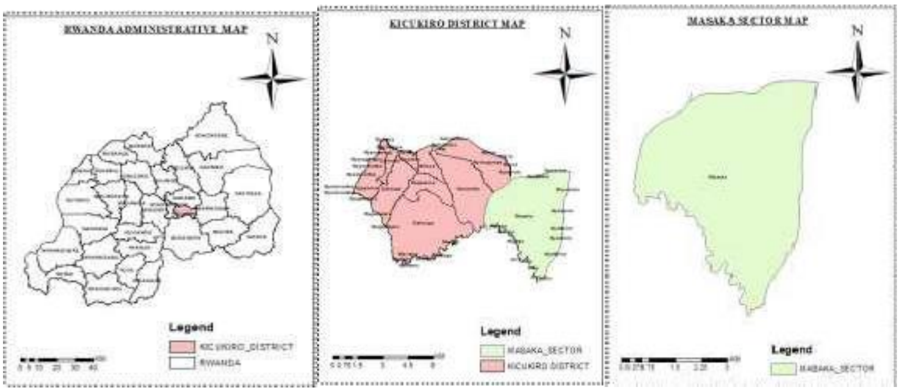


Figure 9: Location of my project.

3.2. Formula used for design

Table 3.1: Information related to the structural design of the proposed building

Building Regulations and Design Code	BS 8110: The structural use of concrete. Part 1-1997 IS 875: Code for practice Design Loads for building and Structures. Part 2 1987 BS 8666_2000: Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. BS 8004:1986 Code of Practice for Foundations. Rwanda Building Control Regulations 2012
General loading conditions	Floor slab live load 4 kN/m2 Stair slabs live Load 4 kN/m2 Slabs and Stair Finishes 1.5 kN/m2
Exposure conditions	Moderate Conditions (Internals and Externals)
Material Characteristics	Concrete: Grade M30 (fcu = 30Mpa). Reinforcement: Characteristic strength fy = 500 N/mm
Other relevant information	Self-weight of Reinforced concrete =24kN/m3 Self-weight of masonry = 19 kN/m^2

	Self-weight of plaster =20 kN/m^2
Partial safety factor	Dead load :1.4 Live load :1.6 Structure under bending and axial loading: 1.56
Design method	Design for ultimate limit states and checked for serviceability limit states (cracking and deflection).

3.3 Design of one-way slabs

According to BS 8110, the following procedures were used for the design of slabs:

Determining a suitable depth of slab.

Calculating the main and secondary reinforcement areas.

Checking critical shear stresses. Check detailing requirements. Determining a suitable depth of the slab The deflection requirements for slabs often control the depth of slab needed. The minimum effective depth of slab, d, can be calculated using Eq. 1. Table 3.2. Shows the basic span to effective depth ratio.

$$d = \frac{\text{longest span}}{\text{modification factor} \times \text{span/effective depth ratio}} \quad \textbf{(1)}$$

In order to make a first estimate of the effective depth of the slab, a value of 1.4 was assumed for the modification factor. The main steel areas were then calculated and used to determine the actual value of the modification factor. When the assumed value is slightly greater than the actual value, the depth of the slab satisfies the deflection requirements in BS 8110. Meanwhile, the calculation was repeated using the revised modification factor.

Calculating the main and secondary steel reinforcements

The self-weight of the slab together with the dead and live loads were used to calculate the design moment, M. The ultimate moment of resistance of the slab, Mu was calculated using equation 2 and the area of steel required was calculated using Eq. 3 provided that

Mu ≥M. Mu = 0.156 × bd² × fcu **(2)**

Where b = width which is taken

as 1m for slabs d= effective

depth of main steel fcu = compressive strength of concrete

$$A_s = \frac{M}{0.95 \times f_y \times Z}$$

Where M = Maximum applied moment

on the slab fy = Tensile strength of steel

Z = d[0.5 + √(0.25 − K/0.9)] **(4)**

$$K = \frac{M}{f_{cu} \times b \times d^2}$$ **(5)**

3.4. Design of two-way slabs

The design of two-way spanning restrained slabs supporting uniformly distributed loads is generally similar to that for one way spanning slabs. The extra complication arises from the fact that it is rather difficult to determine the design bending moments and shear forces in this type of slabs. BS 8110 contains tables of coefficients that may assist in this task. Thus, the maximum design moments per unit width of rectangular slabs of shorter side lx and longer side ly were given by Eq. 6 and Eq. 7respectively.

msx=Bsx X n X L2x (6)

msy=Bsy X n X L2y **(7)**

Where Msx = maximum design ultimate moments either over supports or at mid-span or on strips of unit width and span lx

02Msy = maximum design ultimate moments either over supports or at midspan or on strips of unit width and span ly n = total design ultimate load per unit area

Similarly, the design shear forces at supports in the long span direction, Vsy, and short span direction, Vsx, may be obtained from the from Eq. 8 and Eq. 9 respectively

$$Vsy = \beta_{sy} \times n \times l_y^2$$ (8)

$$Vsx = \beta_{sx} \times n \times l_x^2$$ **(9)**

3.4.1. Design of beams

Beams can be designed as singly or doubly reinforced beams. According to BS 8110, the following procedure was followed for the design of singly reinforced beams:

From the minimum requirements of span to control deflection estimate a

suitable effective depth d.
Assuming the bar diameter for the main steel and links and the required cover as determined by exposure conditions, estimate an overall depth h. where h is given by d plus bar diameter plus link diameter plus cover
Assume breadth as about half the overall depth
Calculate the self-weight
Calculate the design live load and dead load moment using appropriate load factors.
The load factors are normally 1.4 for dead loads and 1.6 for live loads.
Calculate K using Eq. 5 and z using Eq. 4. $z/d \leq 0.95$ if $k \geq 0.0428$
Calculate the required steel As using Eq. 3.
Determine the design concrete shear stress υc
Calculate the design shear stress in the beam υ by diving the ultimate shear force in the beam by the cross-sectional area of the beam
Determine the form and area of links to be used in the beam where Asv is the required area of links and Sv is the spacing of links.
The design of doubly reinforced beams is done when the design moment M is greater than the ultimate moment capacity Mu. Then areas of compression and tension reinforcements must be required and can be calculated using Eq. 10 and Eq. 11 respectively.

$$A_s' = \frac{M - M_u}{0.95 f_y (d - d')}$$

(10)

$$A_s = \frac{M_u}{0.95 f_y} + A_s'$$

(11)

Where As’ = Area of compression
reinforcement As = Area of
tension reinforcements d=
effective depth of main steel bars
d' = effective depth of secondary
steel bars

$Z = d(0.5 + (0.25 - K'/0.9)$

$K' = 0.156$

3.4.2. Design of columns

Both concrete and longitudinal reinforcements contribute to the load carrying capacity of a column. According to BS 8110, the design load carrying capacity Nu of an axially loaded short column is with a crosssectional area Ac and steel area Asc is calculated using Eq. 10.

$$Nu = 0.4 fcuAc + 0.75\ Asc\ fy \quad \textbf{12}$$

After determining the design axial load in the column, the area of reinforcements can be calculated using Eq. 10. For short braced columns supporting an approximately symmetrical arrangement of beams.

These

beams must be designed for uniformly distributed imposed loads and the spans must not differ by more than 15% of the longer span. The ultimate load is given by Eq. 13

$$N = 0.35\ fcu\ Ac + 0.67 Asc\ fy \quad \textbf{13}$$

3.4.3. Design of foundations

Pad foundations were designed in this project. According to BS 8110, the following procedure was used for the design of foundations:

Assume weight of the footing as 10% of the serviceability load (Dead load + Live load from the column). Calculate the total serviceability load by adding the weight of the footing to the total serviceability load from the column.

Calculate the base area A of the footing by dividing the allowable bearing pressure of the soil by the total serviceability load.

Assume the overall depth h of the footing and calculate the self-weight of the footing using Eq. 14.

Self-weight of the footing= A × h × density of concrete **(14)**

Calculate the total ultimate load = 1.4 dead load + 1.6 live load

Calculate the earth pressure caused by ultimate loads by dividing the total ultimate load by the plan area of the base

Calculate the maximum design moment M in the footing which occurs at the face of the column using Eq. 15

$$M = \frac{P_s \times l^2}{2} \quad \textbf{(15)}$$

Where l is the distance from the outer face of the footing to the face of the column

Ps= earth pressure

After assuming the diameter of reinforcements, calculate the effective depth of the footing d which is equal to total depth minus diameter of the bar minus the cover.

Calculate the area of reinforcements required using Eq. 3. The minimum reinforcements in the footing is 0.13% bh according to BS 8110.

Checking for punching shear

The punching shear in the footing is reduced as the depth of the footing increases. According to BS 8110, the following procedure was used to check for punching shear in the footing:

Calculate the critical perimeter Pcr using Eq. 16

Pcr = column perimeter + 8 × 1.5d

(16)

Calculate the area within the critical perimeter Acr using Eq. 17

Acr = Column width 3d2

(17)

Using Eq. 18, calculate the ultimate shear force V in the foundation.

V = Ps × (A − Acr)

(18)

Calculate the design punching shear stress using Eq. 19.

$$\upsilon = \frac{V}{Pcr \times d} \quad \textbf{(19)}$$

From Table 5, determine the design shear stress in concrete υc. For the foundation to be safe, υc ≥ υ otherwise the footing depth must be increased.

3.5.1.5. Stairs

Computation of equivalent thickness (h)

dl, rise (H), going (G)

$$\theta = \tan^{-1}\left(\frac{rise}{going}\right)$$

$$h = \frac{H}{2} + \frac{dl}{\cos\alpha},$$

Effective height (ho) =equivalent thickness (h) - concrete cover

Loads on the stairs

Total load =dead load +finishes + live load

Required steel reinforcement in the stair

$$A_s = \frac{M}{0.95 \times f_y \times Z} \quad \textbf{(20)}$$

3.5.1.6. Ramp

Dl=height of one floor $(\frac{1}{20}, \frac{1}{30})$

For the ramp h is zero because it hasn't risen but only going.

α=arctan

$\frac{half-height\ of\ floor}{lenght\ of\ ramp}$

hl =_*dl* , ho =hl-concrete cover

$\cos_a$

Total load =dead load +load from finishes + live load

$$M^{max} = \frac{q * l^2}{8} \quad \textbf{(20)}$$

$$A_s = \frac{M}{0.95 \times f_y \times Z} \quad \textbf{(21)}$$

3.5.1.7 Cost estimation

Estimating is the technique of calculating or computing the various quantities and expected expenditure to be incurred on a particular work or project.

The quantity like earth work, foundation concrete, brickwork, can be workout by Long wall-short wall method: in this method,

the wall along the length of room is considered to be long wall while the wall perpendicular to long wall is said to be short wall. To get the length of long wall or short wall, calculate first the center line lengths of individual walls. Then the length of long wall, (out to out) may be Calculated after adding half breadth at each end to its canter line length.

Thus the length of short wall measured into in and may be found by deducting half breadth from its center line length at each end. These lengths are multiplied by breadth and depth to get quantities.

Table 3.2: Methods used in bill of quantity

Item No	Description of item	Quantity	Unit	Rate	Amount

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0. Introduction

This chapter presents the results of the designed project where it shows and analyse the results obtained by using different software as discussed in chapter 3, G+4 apartment which was supposed to be constructed in Kicukiro district.

4.1. Architecture design

Architecture conceptualization comes with regarding different factors affecting the layout of bus terminus and basic amenities to be established in terminal, where researcher use Vadodara central bus station as reference to introduce architectural plans with necessary facilities, terminal is composed of ground floor and other 4 stories (G+4)

The arrangement of rooms and other room size standard should be taken into consideration, the building was designed to accommodate 4 families at each floor and the apartment designed to accommodate 24 families because the designed apartment has five floor and the Fig.8 shows the floor plan and Fig.3.1 shows the perspective of designed apartment,Figure 9: 3D view of building structure element

Architecture conceptualization comes with regarding different factors affecting the layout of bus terminus and basic amenities to be established in terminal, where researcher use Vadodara central bus station as reference to introduce architectural plans with necessary facilities, terminal is composed of ground floor and other 4 stories (G+4)

Figure 4.1: the perspective view of designed building

4.2 Structure design

The structural design was to find the internal forces and moments from the whole structure that were in equilibrium with the design loads for the required loading combination. The distributed loads from the building (dead loads and live loads) were carried over the spans.

The worst combination of load (critical loading) on the structure was used to design the building. Stability against overturning, sliding and buckling of the structure were taken into account during this project. The structure models of the building is shown in Figure 4 which describes how the beams, columns, Ramp, slabs and shear wall are arranged in 2D and 3

GROUND FLOOR LAYOUT PLAN, SCALE:1/100

Figure 4.2: floor plan view

In archictecural drawing, has size of 51m in length and 41m in width, on ground floor has 14 shop with size (6m*4m),2 restaurant with size (8m*4m),1 pharmancy with size(8m*4m),15 toilet with size (1m*1.5m),space of vegetable shoping,stairs,ramp,on the fist floor has 20 shop with size (6m*4m),resitauurant ,bank,betting ,bar with same size of 8m*4m athers floors are from second floor to fourth floor has 4rooms, look like residential floor instid of first floor looks like camercial floor and same as ground floor, each floor has height of 3.5m.

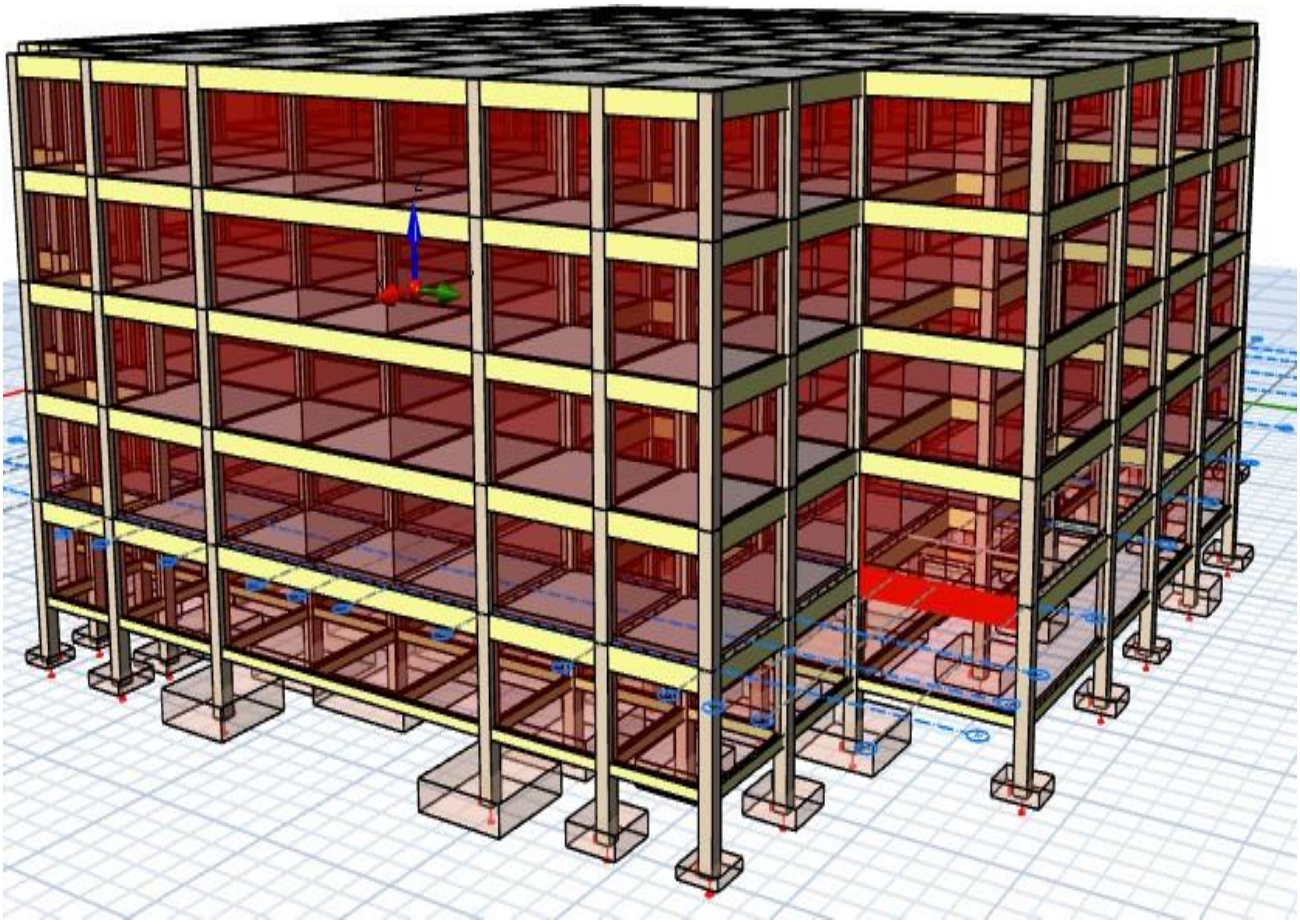


Figure 4.3: 3D view of building structure element

4.3 Structure element design

4.3.1 Design of slab

During this part a bigger middle span was chosen for design

Given data:

Fy= 460 MPa

Fcu= 30MPa

Slab thickness= 150mm

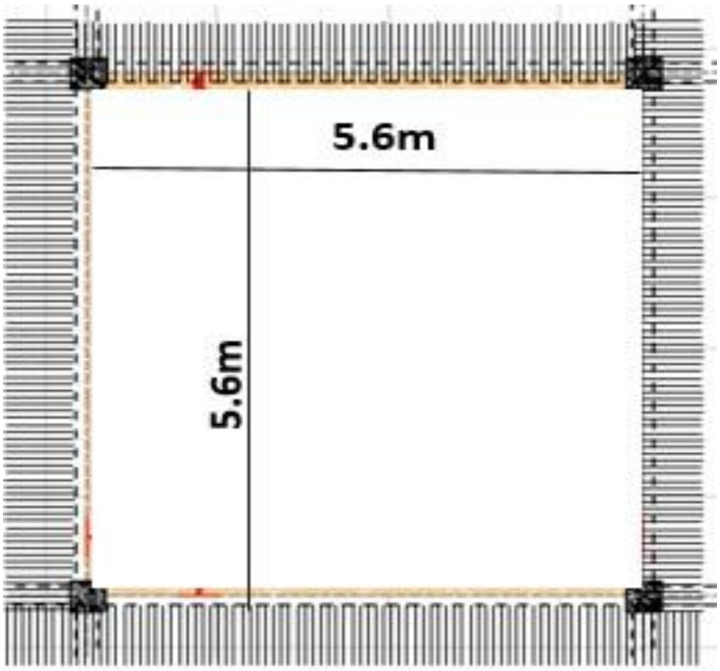
Live load on roof slab= 1,5KN/m2

Live load on critical slab= 4KN/m2

Unit weight of concrete γc= 24KN/m3

Assume dimension of main steel φ= 10mm

Cover= 25mm



Type of slab Ly÷Lx= 5.6÷5.6= 1<2

We have two way slab

I. Design of roof slab

A. Load calculation

Self-weight= γc *h = 24*0.15= 3.6 KN/m2

Live load on roof 1.5KN/m2

Design load = 1.4DL+ 1.6LL= 1.4*3.6+ 1.6*1.5 = [5.04+ 2.4]KN/m2=7.44KN/m2

B. Bending moment calculations

Generally M=αnLx

Mx- = 0.046*7.44kN/m2*5.62m= 10.73KNm/m

Mx+= 0.035*7.44kN/m2*5.62m= 8.2KNm/m

My-= 0.032*7.44kN/m2*5.62m= 7.46KNm/m

My+= 0.024*7.44kN/m2*5.62m= 5.6KNm/m

M-max= 10.73KNm/m

M+max= 8.2KNm/m

C. Area and spacing at the middle of span (10.73KNm/m)

Effective depth, d= h-cover- φ/2= 150-25-10/2=120mm

$$K = \frac{M}{FCubd} = \frac{10.73 * 10^6}{25 * 1000 * 120^2} = 0.029 < K = 0.156$$

No compression steel required

$$Z = d * +[0.5 + \sqrt{0.25}] \frac{k}{0.9} = 120 * [0.5 + \sqrt{0.25} -] \frac{0.029}{0.9} = 116mm > 0.99d = 114mm$$

Keep Z= 114mm>

$$\text{As required} = \frac{M}{0.87FYZ} = \frac{10.73 * 10^6}{0.87 * 460 * 114} = 235.18mm^2$$

As min=0.13%bh=0.13/100*1000*150=195mm^2

since As required<As min,As=235.18mm^2

$$\text{Spacing} = \frac{\text{Area ofsteel bar} * 1000}{AS} = \frac{\pi * \frac{10^2}{4} * 1000}{235.18} = 333.78mm \sim 250mm$$

$$\text{As provided} = \frac{\pi * \frac{10^2}{4} * 1000}{250} = 314mm^2$$

Provide T10 @ 250c/c

D. Area and spacing at the edge of span (8.2KNm/m)

Effective depth, d= h-cover- φ/2= 150-25-10/2=120mm

$$K = \frac{M}{FCUbd^2} = \frac{8.2 * 10^6}{25 * 1000 * 120^2} = 0.03 < k' = 0.156$$

No compression steel required

$$Z = d * (0.5 + \sqrt{0.25} - \frac{k}{0.9}) = 120 * (0.5 + \sqrt{(0.25 - \frac{0.013}{0.9}}) = 118.7mm > 0.95d = 114mm$$

Keep Z=114mm

$$\text{As required} = \frac{M}{0.87FYZ} = \frac{4.86 * 10^6}{0.87 * 460 * 114} = 179.73mm^2$$

As min = 0.13%bh= 0.13/100*1000*150=195mm2

Since As required <As min, As= 195mm2

$$\text{spacing} = \frac{\text{Area of steel bar} * 1000}{AS} = \frac{\pi \frac{10^2}{4} * 1000}{195} = 402.56mm \sim 300mm$$

$$As\ provided = \frac{\pi * \frac{10^2}{4} * 1000}{300} = 262mm^2$$

Provide T10 @ 300c/c

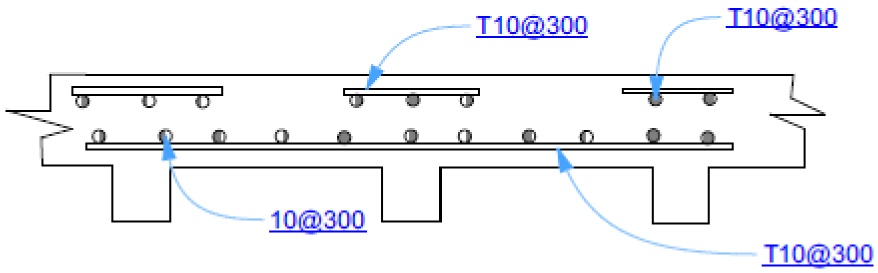


Figure 4.4: slab detail

On this slab. Consider to use critical slab which has dimensions (5.6*5.6m) to choose critical slab consided to large span than shows its over loaded I provide T@ 300C/C

4.3.2. Design of beam

Given data:

- 1) Design load on slab= 5.04+6.4
- 2) Unit weight of concrete γc= 24KN/m3
- 2) Unit weight of wall γwall= 19KN/m3
- 3) Beam size=[600*300]mm
- 4) Cover= 25mm
- 5) Fy= 460 MPa
- 6) Fcu= 25MPa
- 7) Thickness of wall and partition: 200mm
- 8) Floor to floor length=3.5m

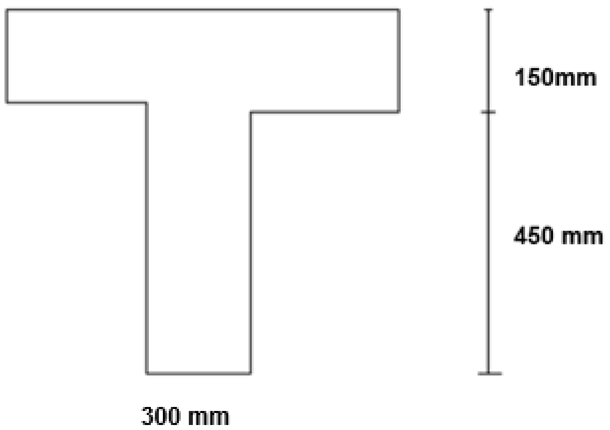


Figure 4.5:Beam dimension

Beam on typical slab

Loads

Distribution load from slab to beam

$Load = 2 * [\frac{nLx}{2}(1 - \frac{1}{3k^2})]$

$Load = 2 *= [\frac{(13.54)*5.6}{2}(1 - \frac{1}{3(\frac{5.6}{5.6})2})]$=37.952+12.89=50.85KN/m

Self-weight of beam = 24*(0.6-0.15) *0.3*1.4=4.536KN/m

Self-weight of wall= 18*0.2*(3.5-0.5) *1.4=14.616KN/m

Design load on beam = 50.85+4.5+14.616=69.97KN/m

Bending moment

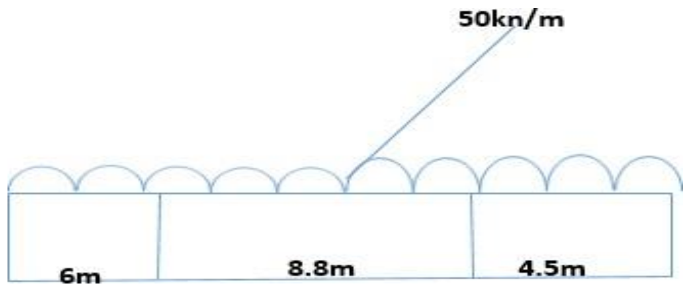
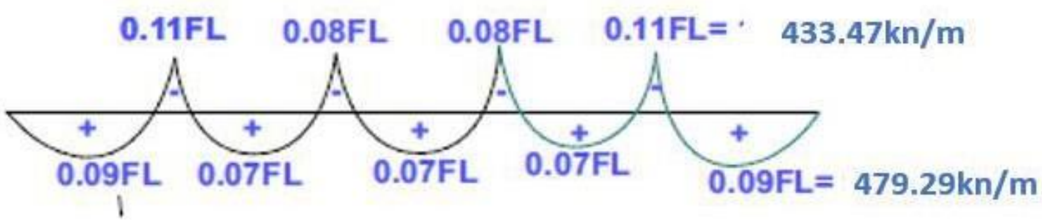


Figure 12: Bending moment diagram



M-max= 433.47KNm

M+max= 379.29KNm

Area and number of bars of the middle of span (M=433.47KNm)

T- beam

Effective flange width bf= bw+ 0.7/5L= 300+0.7 = 250+0.7/5*8800= 1532mm

Mf = 0.45*Fcu*bf*hf*(d-hf/2)

D=457mm assuming that φmain: 20mm, φstirrup: 8mm and cover = 25mm

Mf= 0.45*25*1532*150*(557-150/2) = 1246.09 KNm

M < Mf design as rectangular beam

$$K = \frac{M}{fcubd^2} = \frac{433.47 * 10^6}{25 * 153 * 557^2} = 0.03 < k'$$

No compression reinforcement required

$$Z=df\left(0.5+\sqrt{0.25-\frac{k}{0.9}}\right)=557\left(0.5+\sqrt{0.25-\frac{0.03}{0.9}}\right)=457.45mm \leq 0.95d$$

=529.15mm

Keep z=529.15mm

$$As = \frac{M}{0.87fyz} = \frac{433.47 * 10^6}{0.87 * 460 * 529} = 2046.13mm^2$$

N^0 of bars=$\frac{2046.13}{\frac{\pi*25^2}{4}}$=4.4→5 bars

As provided=5*$\frac{25^2}{4}$=2453.125mm^2

Area and numbers of bars in the middle of the span (Mmax+=379.29m)

Effective flanged width,b=b_w+$\frac{0.71}{5}$=300mm+$\frac{0.7*8800mm}{5}$=1532mm

d_f=600mm-25mm-8-$\frac{20mm}{2}$=557mm

K=$\frac{M}{fcubd^2}$=$\frac{379.29*10^6}{25*300*557^2}$=0.16<k'

Compression reinforcement required

Mu=0.156fcub□2=0.156∗ 25∗ 300∗ 557=362,99kN

$$AS'req = \frac{M - MU}{0.95fy(d-d')} = \frac{379.29 * 10^6}{0.95 * 460 * 516} 72.7mm^2$$

Keep z=428.18mm

As =$\frac{M}{0.95fyz}$=$\frac{379.29*10^2}{0.95*460*482.18}$=1800.03$mm^2$

As' + =Asprovided 1800.03+72.7=1872.73mm2

Keep z=428.18mm

$N^o$of steel bars = $\frac{1872.73mm^2}{\frac{\pi*25}{4}}$ = 3.8→4bars

$AS_{provided}$ = 4* $\frac{\pi*25^2}{4}$ =1962.5mm^2

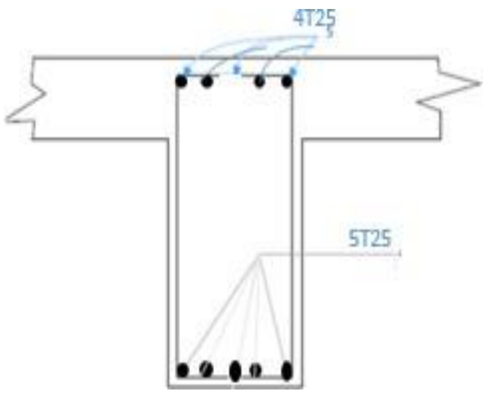


Figure 13: beam detailing

On design of this T beam with dimension (300*600) I choose this dimension and this beam because long span of 8.8m .provide 5T25mm for up and 4T25mm fo lower.

4.3.3. Column Reinforcement Design

1C38 (E-7) (500/500)

Materials: C25/30 / Grade 460 (Type 2) (Links: Grade 460 (Type 2))

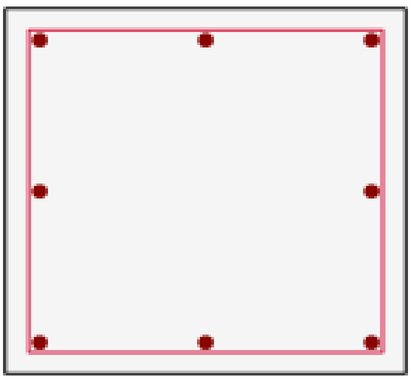


Figure 4.6: section of column shows arrangement of steel

Table 4.1:load combination

No	NTop (kN)	M1 Top (kN.m)	M2 Top (kN.m)	NBot (kN)	M1 Bot (kN.m)	M2 Bot (kN.m)
1	4283.2	-29.6	141.2	4308.4	7.2	-66.9
2	3268.7	1.4	156.2	3293.9	-6.6	-73.5
3	3295.5	-45.8	61.1	3320.7	16.8	-29.5
4	3615.9	-30.4	141.2	3641.1	8.5	-67.1
5	3259.9	2.5	76.5	3285.1	-6.8	-35.7
6	3563.7	-24.7	93.7	3585.3	5.9	-15.5
7	3536.7	-24.2	140.9	3558.3	6.0	-95.7
8	3536.7	-51.3	117.0	3558.3	47.6	-55.2
9	3563.7	2.4	117.6	3585.3	-35.8	-56.1

Critical Loading: 1 - (G+Q)

		Min	Design	
N	4308.4	-	4308.4	Kn
M11	-29.6	-86.2	0.0	kN.m
M22	141.2	86.2	169.7	kN.m

NMax 3554.9

Concrete Cover = 25.0 mm

(BS8110 - Cl. 3.8.4.5)

N/bhFcu =0.000

Beta =0.00

Table 4.2: shear force and rebars result

Shear		**Rebars**
$V_{d(1/2)}$ =0.0 / 0.0kN	Slender Column...	As(Req):%0.40(min)1000.00 mm^2
$v_{c'(1/2)}$=0.55/0.55N/mm^2	$L_{e1}/b1$ = 4.7 ≥ 0.0	As 1.01% 2513.27 mm^2 (Sup):
$v_{(1/2)}$ = 0.00 / 0.00 N/mm^2	$L_{e2}/b2$ = 4.5 ≥ 0.0	
	$M_{Add(1)/2)}$ = 0.0 / 0.0 kN.m	**8T20**
Links = T8-225		

1C87 (N-6) (500/500)

Materials: C25/30 / Grade 460 (Type 2) (Links: Grade 460 (Type 2))

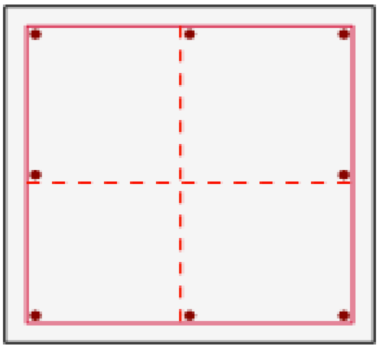


Figure 4.7:section of column and arrangement of steel

Table 4.3:load combination

N o	**NTop**	**M1 Top**	**M2 Top**	**NBot**	**M1 Bot**	**M2 Bot**

	(kN)	(kN.m)	(kN.m)	(kN)	(kN.m)	(kN.m)
1	832.6	4.7	-5.8	857.8	8.8	5.4
2	650.6	1.9	1.6	675.8	3.3	1.9
3	741.2	4.8	-11.6	766.4	9.1	6.9
4	735.3	5.2	-10.9	760.5	9.7	7.6
5	774.2	1.2	-6.1	799.4	2.2	5.7
6	699.2	3.8	-29.3	720.8	7.1	45.5
7	708.8	3.9	19.3	730.4	7.3	-36.4
8	703.8	9.7	-3.9	725.4	38.0	2.7
9	704.2	-1.9	-6.1	725.8	-23.7	6.3

Critical Loading: 1 - (G+Q)

		Min	Design	
N	857.8	-	857.8	kN
M11	8.8	17.2	32.0	kN.m
M22	-5.8	-17.2	0.0	kN.m
NMax	3554.9			

Concrete Cover = 25.0 mm

(BS8110 - Cl. 3.8.4.5)

N/bhFcu =0.114

Beta =0.86

Table 4.4:shear force and rebars result

Shear		**Rebars**
$V_{d(1/2)}$ = 0.1 / 0.5kN	Short Column...	As (Req):%0.40 (min) 1000.00 mm^2
$v_{c'(1/2)}$ = 0.51 / 0.58 N/mm^2	$L_{e1}/b1$ = 4.6 < 15.0 √	As(Sup):%0.64 1608.50 mm^2
$v_{(1/2)}$ = 0.00 / 0.00 N/mm^2	$L_{e2}/b2$ = 5.4 < 15.0 √ $M_{Add(1)/2)}$ = 0.0 / 0.0 kN.m	8T16
Links = T8-175		

On design of column I design 2 column. The inner one which is critical with dimension (500*500 mm) and outside on with dimension (400*400 mm) provide 8T20 mm for inner and 8T16 for outside column.

4.3.4. Pad Footing Report

F-1C38 Design Summary

Footing Materials

Concrete Material C25/30

Rebar Material

Grade 460 (Type 2)

Size of footing

BX 4400.00 mm

BY 4400.00 mm

Height 1000.00 mm

Taper Height 0.00 mm

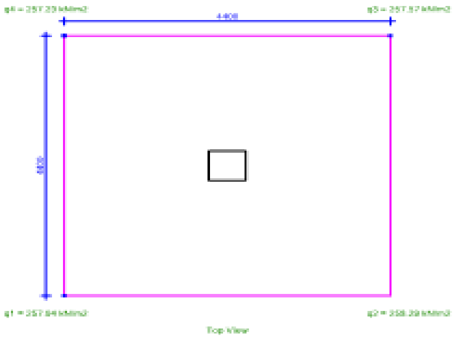
Corner Stresses

Lower-Left Corner 257.94 kN/m^2

Lower-Right Corner 258.29 kN/m^2

Upper-Right Corner 257.57 kN/m^2

Upper-Left Corner 257.23 kN/m²



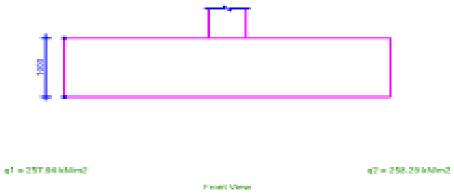


Table 4.5:Total footing, soil and pedestal weight

Member	Volume (m3)	Unit Weight (kN/m3)	Weight (kN)
Pad Footing	19.36	24	464.64
Soil	11.616	18	209.088
Total			673.728

Punching Check

Punching capacity will be calculated according to EN 1992-1-1:2004 (6.4.4)

(6.47) vRd,c1 = CRd,c k (100 ρl fck)^(1/3) + k1 σcp

k = 1 + (200/d)^(1/2)

k = 1.46,

ρ_l = (ρlx ρly)^(1/2) * ρf , ρlmin = 0.02

ρ_{lx} = 0.002, ρly = 0.002, ρf = 1,

ρ_l = 0.002,

σ_{cp} = ΣN / LxLy = 0.22 N/mm²

$C_{Rd,c}$ = 0.12, k1 = 0.10

$v_{Rd,c1}$ = 0.34 N/mm²

v_{min} = 0.035 k^(3/2) fck^(1/2) + k1 σcp

v_{min} = 0.36 N/mm²

$v_{Rd,c}$ = Max(vRd,c1, vmin) = 0.36 N/mm²

v_{Rdmax} = 0.5 (0.6 (1 - (fck / 250))) fcd

$V_{pc\text{-}cf}$ = vRdmax up d,

$V_{pc\text{-}ep}$ = vRd,c up d,

u_p = 2(BEPx + BEPy) = 16800

B_{EPx} = Bx + 2dsect = 4200

B_{EPy} = By + 2dsect = 4200

d_{sect} = 2deff = 1850

$V_{pc\text{-}cf}$ = 9768 kN

$V_{pc\text{-}ep}$ = 6081 kN

Punching check is performed for each column on footing. The column having minimum capacity/demand ratio is considered for each combination.

Table 4.6:comparison between demand and capacity

Comparison at	**Demand / Capacity**	**Status**
Effective Perimeter	443.3 kN / 6143.7 kN	√
Column Face	4925.8 kN / 9768.0 kN	√

Shear Check

Table 4.7:comparison between design moment and selected bar

Comparison of	Design Moment	Selected Rebar	Required / Provided	Status
Reinforcement Area in X-Direction	2160.3 kN.m	19ϕ25 / 250.0 mm	6316.61 mm2/8639.38 mm2	√
Reinforcement Area in Y-Direction	2159.8 kN.m	19ϕ25 / 250.0 mm	6315.28 mm2/8639.38 mm2	√

Pad Footing Report

F-1C87 Design Summary

Footing Materials

Concrete Material C25/30

Rebar Material Grade 460 (Type 2)

Size of footing

BX 1500.00 mm

BY 1500.00 mm

Height 300.00 mm

Taper Height 0.00 mm

Corner Stresses

Lower-Left Corner 389.42 kN/m^2

Lower-Right Corner 404.47 kN/m^2

Upper-Right Corner 434.25 kN/m^2

Upper-Left Corner 419.20 kN/m^2

Table 4.8:Total footing, soil and pedestal weight

Member	Volume (m3)	Unit Weight (kN/m3)	Weight (kN)
Pad Footing	0.675	24	16.2
Soil	2.925	18	52.65
Total			68.85

Punching Check

Punching capacity will be calculated according to EN 1992-1-1:2004 (6.4.4)

(6.47) $v_{Rd,c1} = C_{Rd,c\ k}$ (100 ρ_l f_{ck})^(1/3) + k_1 σ_{cp}

k = 1 + (200/d)^(1/2)

k = 1.92,

ρ_l = (ρlx ρly)^(1/2) * ρf , ρlmin = 0.02

ρ_{lx} = 0.0025, ρly = 0.0025, ρf = 1,

ρ_l = 0.0025,

σ_{cp} = ΣN / LxLy = 0.35 N/mm^2

$C_{Rd,c}$ = 0.12, k1 = 0.10

$v_{Rd,c1}$ = 0.49 N/mm^2

v_{min} = 0.035 k^(3/2) fck^(1/2) + k1 σcp

v_{min} = 0.55 N/mm²

$v_{Rd,c}$ = Max(vRd,c1, vmin) = 0.55 N/mm²

v_{Rdmax} = 0.5 (0.6 (1 - (fck / 250))) fcd

$V_{pc\text{-}cf}$ = vRdmax up d,

$V_{pc\text{-}ep}$ = vRd,c up d,

u_p = 2(BEPx + BEPy) = 5744

B_{EPx} = Bx + 2dsect = 1436

B_{EPy} = By + 2dsect = 1436

d_{sect} = 2deff = 468

$V_{pc\text{-}cf}$ = 2471 kN

$V_{pc\text{-}ep}$ = 943 kN

Punching check is performed for each column on footing. The column having minimum capacity

Table 4.9: comparison between demand and capaciy

Comparison at	Demand / Capacity	Status
Effective Perimeter	77.4 kN / 952.9 kN	√
Column Face	823.7 kN / 2471.0 kN	√

Shear Check

Table 4.10:comparison between design moment and selected bar

Comparison of	Design Moment	Selected Rebar	Required / Provided	Status
Reinforcement Area in X-Direction	81.1 kN.m	7ϕ16 250.0 mm	1070.45mm^2/1206.37 mm^2	√
Reinforcement Area in Y-Direction	80.8kN.m	7ϕ16 250.0 mm	1066.16mm^2/1206.37 mm^2	√

For this footings. designed footings are under to the column I design because is those that are over loaded.Provision dimension for first height of 1m and length of 2m and width 2.5.m. for second height of 1m and length 1.5m and width 1.5m.

4.3.5. Stair design

A stair is a set of steps leading from one floor to another, typically inside the building. The room or enclosure of the building in which the stair is located is known as staircase. The opening or space occupied by the stair is known as a stairway.

Assume R= 150mm and T=300 mm height of the building=3.5m

Number of riser = $\frac{3.5m}{1.5m}$ = 23.33 = **24**

Number per flight = $\frac{24}{2}$ = 12

Number of going=12-1=11

Check conformability 550<2

2r + t = 2 × 150mm + 30mm = 600 it ok

Effective length of stairs=3.3m+1m=4.3m

$\frac{L}{d} = \frac{4300mm}{30}$ =143.33 = 150mm

Assume: Q=12mm, concrete cover=25mm, fcu=30MPa, fy=500MPa

Waist thickness(d) = 150mm + 25mm + $\frac{12}{2}$ =181□□=200□□

Effective depth = h -$\frac{q}{2}$ = −□□□□□□□□ □□□□□=200□□− $\frac{12}{2}$ −20□□=174□□

Load calculation

Landing load calculation

Floor finishes=1kn

Live load=2.5kn/□2×1□=2.5□□/□

Self-weight of landing=24kn/□3×0.15□×1□=3.6□□/□

Design load=1.4DL+1.6LL=1.4(4.6) +1.6(2.5) =10.44KN/m

Load on stairs

live loads= 2.5kn/□2×1□ =$\frac{2.5kn}{m^2}$ ×1□=2.5□□/□

floor finishes=1kn/□2×1□=1□□/□

self-weight of waist slab per tread=□□□□ □□□□h□×□×$\sqrt{T^2}$ +R^2 × $\frac{1}{T}$

= $\frac{2.4kn}{m^2}$ x 0.2 x $\sqrt{0.3^2}$ + 0.15² x $\frac{1}{0.3}$ = 5.345kn/m

Self-weight of steps per tread=unit weight×($\frac{1}{2}$ x R x T) x $\frac{1}{T}$

= $\frac{24kn}{m^2}$ X ($\frac{1}{2}$ ×0.15□×0.30□) × 3.33□=1.798□□/□=1.8kn/m

Design load=1.4DL+1.6LL=1.4(8.3) +1.6(2.5) =15.62KNn/m

bending moment

$V_{max} = \frac{wl}{2} = \frac{15.62kn/mX3.3m+10.44kn/mX1m}{2}$ =30.993□□/m

M_{max}=30.993□□×2.65□−10.44□□×2.15□−25.773□□×0.825□=38.423□□/□

check depth against bending moment

Mu=0.156fcub□^{2}

D = $\sqrt{\frac{Mu}{0.156fcub}} = \sqrt{\frac{38.423X10^6}{0.156\ X\ 30\ X\ 1000}}$ =90.60mm<174mm it ok

Calculation of steel rebars required

□= $\frac{M}{fcubd^2} = \frac{38.423\ X\ 10^6}{30\ X\ 1000\ X\ 1710^6}$ = 0.0442 < 0.156 it ok

Z=d(0.5+$\sqrt{0.25 - \frac{k}{0.9}}$ = 174(0.5+$\sqrt{0.25 + \frac{0.05}{0.9}}$ = 127.8 < 0.95D it ok

$As_{req} = \frac{M}{0.87fyz} = \frac{38.423\ X\ 10^6}{0.87\ X\ 500\ X\ 127.8}$ = 691.14mm^2

$As_{min} = \frac{0.13bh}{100} = \frac{0.13\ X\ 1000\ X\ 150}{100}$ = 195mm^2

Asprov=754□□^{2}

PR0VIDE T10@150mm

Checking for shear force

$$Tmax = \frac{Vmax}{bd} = \frac{30.993Kn\ X10^6}{1000\ X\ 174} = 0.178MPa$$

$\frac{100ASprov}{bd} = \frac{100\ X\ 754mm^2}{1000\ X\ 174}$ = 0.433

d = 174mm Vc = 0.62

Vc = 0.62MPa > 0.178MPa no shear rainforcement required

checking fordefrection

Actual span to effective depth ratio $= \frac{1}{d} = \frac{4300}{174} = 24.71$

Allowable span to effective depth ratio=29.2×□□

$MF = 0.55 + (\frac{477-fs}{120(0.9\ \frac{M}{bd^2})}) \leq 2$

$Fs = \frac{5}{8}X\ \frac{fy\ Asreq}{ASprov}$ X $\frac{1}{bl} = \frac{5}{8}$X $(1+x)^n = 1 + \frac{500\ X\ 691.14mm^2}{754mm^2}$ = 286.44MPa

$\frac{M}{bd^2} = \frac{38.423X10^6}{1000\ X\ 174^2}$ =1.269

MF= 0.55 + $\frac{(477-286.44)}{120(0.9+1.269)}$ = 1.279

Allowable span = 29.2 X MF = 29.2 X 1.279 = 37.375

ALLOWABE SPAN > ACTUAL SPAN there is no defflection

Checking development length

L = 43 X 12 = 516mm

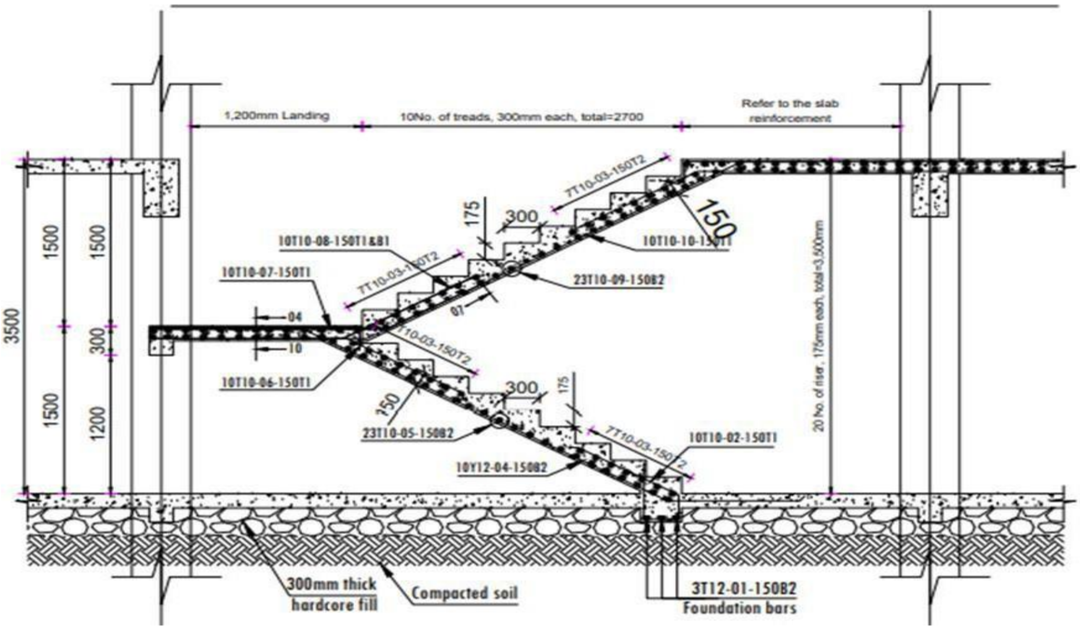


Figure 4.8: Stair section and details

4.6. Ramp design

Dl=350(1/20, 1/30)

Dl= 350/20=17.5cm and 350/30= 11.66cm the average between these two distances gives us the value of dl= 15cm.

For the ramp h is zero because it hasn't risers but only going.

α = arctan (1.5/10.39) = 7.96o The ramp that will be designed is supported by two inclined parallel beams supported by two parallel columns and between these columns there is another small beam that connects them.

We have to design one part of ramp because all two parts are similar

HI = $\frac{DL}{Cosa} = \frac{dl}{Cosa} = \frac{15}{cos7.96}$ = 15.15cm

Load on ramp

ho= hl-concrete clear cover =15.15-2.5=12.65cm

Dead loads= 1.4*0.15*1*24=5.04KN/m

Load from finishes=1.4*1=1.4KN/m

Live load=1.6*2.5=4KN/m

Total loads=6.44+4=10.44KN/m

The total distributed load that is applied on the slab of the ramp including permanent load calculated based on the ramp thickness, finishes and live load in total it is 10.44KN/m

Moment calculation

The slope length of stairs

(L)= √ (Span2 +R2)

(L)= $\sqrt{10.39^2}+1.5^2$ = 10.49

M = FL^2/8

M = 10.44*10.49^2/8 = 143.6KNm

Required steel reinforcement in the ramp

Ho=h-2.5=27.7-2.5=25.2cm

ASreq = $\frac{143.6*1000}{0.990*25.2*40}$ = 143.89mm^2

Asprov=377 mm^2

Provide T12@150mm

This ramp has length of 20m and in width of 5m in designing of it. Provide

T12@150

4.7 Design of shear wall

Loads on the shear wall

Column cross-section = 2.75m*3.6 m

Elevator live load = 1.6*4*2.75*4 = 70.4KN

Self-weight of elevator = 1.4*1.5*0.1*3.6*2.75=2.079 KN

Load from finishes = 1.4*0.02*2.75*4*20*2= 35KN

Self-weight of shear wall = 1.4*0.25*3.6*2.75*24 = 85KN

Loads form slab roof = (1.4*0.15*24*2.75*4)/2 = 27.72 KN

Total loads acting on shear wall = 70.4 + 2.079 + 32=5 + 85 + 27.72= 211KN

Ground floor part of the shear wall

N = (70.4 + 2.079 + 35 + 85) + 27.72 = 990 KN

Shear wall height = 400cm

Effective height = lf = 0.75*400 = 280

Column slenderness = $\lambda = \frac{lf}{a} = \frac{3600}{2750}$ = 2 <14.3 column's short

Required steel reinforcement

Nu = 0.4fcuAc+0.75 Asc fy

990*103 = 0.4*30(2.75*0.25 – Asc) + 0.75*500 Asc

Asc = 3166 mm2

Provide: 28T12

To design shear wall I consider to where elevater is located that shear wall is like column and beam that curry out the weight of elevater I provide 28T12mm

4.8. Bill of quantity

Table 4.11: Summary of bills of quantities

No	Names	Sub/total cost estimation (Rwandan francs (RWF)
1	Ground floor	325,639,246
2	First floor	201,721,300
3	Second floor	201,721,300
4	Third floor	201,721,300
5	Fourth floor	308,396,300
Total cost		1,116,519,944 Rwf

1. Discrepancy in Ground and Fourth Floor Costs:

•The Ground floor cost is significantly higher (325,639,246 RWF) than the other floors, which might be due to foundational work, utilities, or site preparation. However, this variance should be well-justified and documented in the detailed BOQ.

•The Fourth floor also shows a notable increase (308,396,300 RWF) compared to the first, second, and third floors. If this floor includes additional features or specialized construction work, it should be clearly detailed to explain the cost difference.

2. Similar Costs for Intermediate Floors:

•The First, Second, and Third floors have identical costs (201,721,300 RWF each), which suggests uniformity in construction work and materials for these floors. This consistency is expected unless there are floor-specific variations that were not captured. Ensure that these estimates accurately reflect the actual scope of work, such as mechanical or electrical services unique to each floor.

3. Clear Justification of Cost Breakdown:

•Ensure that the detailed BOQ includes a breakdown of how the costs are derived for each floor (e.g., materials, labor, equipment). For example, the increase in the Ground and Fourth floors could be due to elevators, specialized finishes, or mechanical systems, which should be clear in the individual cost line items.

4. Clarification on Overall Cost:

•The total cost is 1,116,519,944 RWF. It would be helpful to ensure that this summary matches with the individual cost breakdowns and that the BOQ reflects any contingencies or allowances (if applicable) for unexpected variations.

5. Check for Omissions:

•The table format and the summary suggest a well-structured approach; however, ensure that all potential costs (e.g., external works, site clearance, additional features) are included. The focus on floors suggests the building's structure, but ensure that landscaping, parking, or other external infrastructure is also budgeted if relevant to the project.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Since the main question was to know how architectural and structural design of KICUKIRO District Camercial and Residential building by contributing in the vision of Rwanda 2050, researcher conclude the dissertation in following ways:

New designed both of camercial and residential building of G+4 with 51m*41m was made to facilitate all the people who wish to do their activities an in Kicukiro district to invest in trading and living. All investors in different sectors can invest their business like wholesales, commercial institution.

By designing, the provided slab has 15cm depth, beam of 60 cm as depth and 30 cm as the breath. Column having height of 3600cm and cross section of 50cm *50cm as the most loaded column, while outside column which is less loaded has 3600cm as height and cross section of cm*40cm for each story. Foundation carrying most loaded column has depth of 1cm and the cross section of 440 cm *440cm while the foundation carrying less loaded column has depth of 30cm and cross section area of 150*150cm2.

Though, the main purpose of this project is a final year dissertation but it can be benefitable for KICUKIRO District in case it is implemented because it can contribute to the development of this district as well as surrounding district.**5.2.**

Recommendations

Due to findings that researcher found on the site, following recommendations were made:

I. Researcher recommend KICUKIRO district to implement this project for the sustainable development of KICUKIRO's people.

II. Other students can use this dissertation to make their own dissertations while conducting any project regarding structure, architectural, and cost of construction project.

III. RWANDA can encourage students to conduct such project, because is one way of helping them to shift their knowledge from paper to practical field.

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APPENDICES

Appendix A: sectional areas of groups of bars (mm^2)

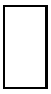
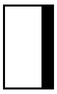
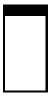
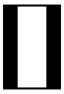
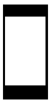
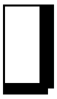
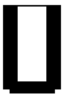
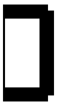
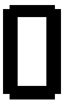
Bar size (mm)	Number of bars													Weight (Kg/m)
	1	2	3	4	5	6	7	8	9	10	11	12	14	
6	28.3	56.5	85	113	141	170	198	226	254	283	311	339	396	0.222
8	50.3	101	151	201	251	302	352	402	452	503	553	603	704	0.395
10	79	157	236	314	393	471	550	628	707	785	864	942	1100	0.617
12	113	226	339	452	565	679	792	905	1018	1131	1244	1357	1583	0.888
14	154	308	462	616	770	924	1078	1232	1385	1539	1693	1847	2155	1.208
16	201	402	603	804	1005	1206	1407	1608	1810	2011	2212	2413	2815	1.578
18	254	509	763	1018	1272	1527	1781	2036	2290	2545	2799	3054	3563	1.998
20	314	628	942	1257	1571	1885	2199	2513	2827	3142	3456	3770	4398	2.466
22	380	760	1140	1521	1901	2281	2661	3041	3421	3801	4181	4562	5322	2.984
24	452	905	1357	1810	2262	2714	3167	3619	4072	4524	4976	5429	6333	3.551
25	491	982	1473	1963	2454	2945	3436	3927	4418	4909	5400	5890	6872	3.853
26	531	1062	1593	2124	2655	3186	3717	4247	4778	5309	5840	6371	7433	4.168
28	616	1232	1847	2463	3079	3695	4310	4926	5542	6158	6773	7389	8621	4.834
30	707	1414	2121	2827	3534	4241	4948	5655	6362	7069	7775	8482	9896	5.549
32	804	1608	2413	3217	4021	4825	5630	6434	7238	8042	8847	9651	11259	6.313
34	908	1816	2724	3632	4540	5448	6355	7263	8171	9079	9987	10895	12711	7.127
36	1018	2036	3054	4072	5089	6107	7125	8143	9161	10179	11197	12215	14250	7.990
38	1134	2268	3402	4536	5671	6805	7939	9073	10207	11341	12475	13609	15878	8.903
40	1257	2513	3770	5027	6283	7540	8796	10053	11310	12566	13823	15080	17593	9.865

Appendix B: coefficients related to the design of members subjected to bending moment

Ξ	*a* m = M Rb*.b*h2	ɳ	Ξ	*a* m = M Rb*.b*h2	ɳ
0.01	0.010	0.995	0.37	0.302	0.815
0.02	0.020	0.990	0.38	0.308	0.810
0.03	0.030	0.985	0.39	0.314	0.805
0.04	0.039	0.980	0.40	0.320	0.800
0.05	0.049	0.975	0.41	0.326	0.795
0.06	0.058	0.970	0.42	0.332	0.790
0.07	0.068	0.965	0.43	0.338	0.785
0.08	0.077	0.960	0.44	0.343	0.780
0.09	0.086	0.955	0.45	0.349	0.775
0.10	0.095	0.950	0.46	0.354	0.770
0.11	0.104	0.945	0.47	0.360	0.765
0.12	0.113	0.940	0.48	0.365	0.760
0.13	0.122	0.935	0.49	0.370	0.755
0.14	0.130	0.930	0.50	0.375	0.750
0.15	0.139	0.925	0.51	0.380	0.745
0.16	0.147	0.920	0.52	0.385	0.740
0.17	0.156	0.915	0.53	0.390	0.735
0.18	0.164	0.910	0.54	0.394	0.730
0.19	0.172	0.905	0.55	0.399	0.725
0.20	0.180	0.900	0.56	0.403	0.720
0.21	0.188	0.895	0.57	0.408	0.715
0.22	0.196	0.890	0.58	0.412	0.710
0.23	0.204	0.885	0.59	0.416	0.705
0.24	0.211	0.880	0.60	0.420	0.700
0.25	0.219	0.875	0.61	0.424	0.695
0.26	0.226	0.870	0.62	0.428	0.690
0.27	0.234	0.865	0.63	0.432	0.685
0.28	0.241	0.860	0.64	0.435	0.680

0.29	0.248	0.855	0.65	0.439	0.675
0.30	0.255	0.850	0.66	0.442	0.670
0.31	0.262	0.845	0.67	0.446	0.665
0.32	0.269	0.840	0.68	0.449	0.660
0.33	0.276	0.835	0.69	0.452	0.655
0.34	0.282	0.830	0.70	0.455	0.650
0.35	0.289	0.825			
0.36	0.295	0.820			

Appendix C: Coefficients related to the design of slabs

Panel	coefficients		$\lambda = \frac{L_y}{L_x}$							
			1.0	1.1	1.2	1.3	1.4	1.5	1.7	2.0
	Short side α_{sx}	M^-	-	-	-	-	-	-	-	-
		M^+	0.037	0.044	0.051	0.059	0.066	0.072	0.083	0.095
	Long side α_{sy}	M^-	-	-	-	-	-	-	-	-
		M^+	0.037	0.036	0.036	0.035	0.034	0.032	0.029	0.024
	Short side α_{sx}	M^-	0.089	0.098	0.105	0.110	0.113	0.116	0.119	0.122
		M^+	0.033	0.038	0.043	0.047	0.050	0.053	0.057	0.061
	Long side α_{sy}	M^-	-	-	-	-	-	-	-	-
		M^+	0.027	0.025	0.024	0.022	0.020	0.018	0.015	0.011
	Short side α_{sx}	M^-	-	-	-	-	-	-	-	-
		M^+	0.027	0.034	0.042	0.049	0.055	0.062	0.074	0.089
	Long side α_{sy}	M^-	0.089	0.096	0.098	0.099	0.098	0.094	0.084	0.068
		M^+	0.033	0.035	0.035	0.035	0.035	0.034	0.032	0.028
	Short side α_{sx}	M^-	0.069	0.073	0.076	0.078	0.079	0.080	0.081	0.082
		M^+	0.027	0.027	0.031	0.033	0.034	0.035	0.036	0.038
	Long side α_{sy}	M^-	-	-	-	-	-	-	-	-
		M^+	0.018	0.016	0.014	0.013	0.011	0.010	0.009	0.006
	Short side α_{sx}	M^-	-	-	-	-	-	-	-	-
		M^+	0.018	0.024	0.031	0.037	0.043	0.051	0.064	0.080
	Long side α_{sy}	M^-	0.069	0.076	0.084	0.090	0.093	0.094	0.091	0.079
		M^+	0.027	0.029	0.030	0.031	0.032	0.032	0.032	0.029
	Short side α_{sx}	M^-	0.063	0.074	0.084	0.093	0.099	0.104	0.112	0.118
		M^+	0.027	0.032	0.037	0.041	0.045	0.049	0.054	0.059
	Long side α_{sy}	M^-	0.063	0.061	0.059	0.055	0.051	0.046	0.039	0.029
		M^+	0.027	0.027	0.026	0.025	0.023	0.022	0.019	0.015
	Short side α_{sx}	M^-	0.056	0.062	0.067	0.071	0.074	0.076	0.079	0.081
		M^+	0.023	0.026	0.028	0.031	0.032	0.034	0.036	0.038
	Long side α_{sy}	M^-	0.042	0.039	0.035	0.032	0.028	0.025	0.020	0.015
		M^+	0.020	0.019	0.017	0.016	0.014	0.013	0.011	0.008
	Short side α_{sx}	M^-	0.042	0.053	0.064	0.073	0.081	0.089	0.101	0.111
		M^+	0.020	0.025	0.030	0.035	0.038	0.043	0.049	0.056
	Long side α_{sy}	M^-	0.056	0.058	0.059	0.058	0.057	0.054	0.047	0.037
		M^+	0.023	0.023	0.023	0.023	0.023	0.022	0.019	0.016
	Short side α_{sx}	M^-	0.042	0.050	0.056	0.062	0.066	0.070	0.074	0.078
		M^+	0.018	0.021	0.024	0.027	0.029	0.031	0.034	0.037
	Long side α_{sy}	M^-	0.042	0.041	0.039	0.037	0.034	0.031	0.026	0.020
		M^+	0.018	0.018	0.017	0.016	0.015	0.013	0.012	0.009

Msx=*a* sx*ɳ*lx2

May= *a* sy* ɳ*lx2

Appendix D: Values of Asv/Sv

Table 3.13 Values of A_{sv}/s_v

Diameter (mm)	Spacing of links (mm)										
	85	90	100	125	150	175	200	225	250	275	300
8	1.183	1.118	1.006	0.805	0.671	0.575	0.503	0.447	0.402	0.366	0.335
10	1.847	1.744	1.57	1.256	1.047	0.897	0.785	0.698	0.628	0.571	0.523
12	2.659	2.511	2.26	1.808	1.507	1.291	1.13	1.004	0.904	0.822	0.753
16	4.729	4.467	4.02	3.216	2.68	2.297	2.01	1.787	1.608	1.462	1.34

GROUND FLOOR					
CODE	**DESCRIPTION OF WORKS / ACTIVITIES**	**UNIT**	**QUANTITY**	**U.P.**	**T.P.**
I	**PRELIMINARY WORK**				
1	Demolition and evacuation of existing building				3,000,000
2	Site installation				3,000,000
	S/TOTAL				**6,000,000**
II	**FOUNDATION EXCAVATION**				
1	Trench excavation	m^3	148.29	2,700	400,383
2	excavation for footing	m^3	101.09	2,700	272,943
3	bases concrete	m2	`472.5	8,000	3,780,000
4	foundation in masonry stone joined	m^3	89	55,000	4,895,000

	by cement mortar				
5	Cap on foundation	m2	198	7000	1,386,000
6	damp proof	m2	198	5000	990,000
7	Back filling	m^3	1300	2,500	3,250,000
8	Compacting	m2	620	1,300	806,000
9	Paving	m2	620	8,000	4,960,000
	S/TOTAL				**20,740,326**
III	**CONCRETE**				
1	for blinding concrete	m3	67.46	7,000	472,220
2	for footings	m^3	248.6	380,000	94,468,000
3	for sub column	m^3	42	380,000	15,960,000
4	for beam	m^3	154.5	380,000	58,710,000
5	for column	m^3	52.5	380,000	19,950,000
6	for slabs	m^3	180	380,000	68,400,000
7	for stairs	m^3	7	380,000	2,660,000
	S/TOTAL				**246,256,220**
IV	**Masonry**				
1	Elevation of the walls with burnt bricks	m^3	311.5	60,000	18,690,000
	S/TOTAL				**18,690,000**
V	**FURNITURE**				
1	Simple door (90x210)	pcs	17	70,000	1,190,000
2	Double door (180x240)	pcs	5	180,000	900,000
3	Window (150x170)	pcs	17	80,000	1,360,000
4	Window (100x120)	pcs	2	60,000	120,000
5	window (60x70)	pcs	7	35,000	245,000

	S/total				**3,815,000**
VI	**PLASTERING**				
1	Sand and cement mortar rendering to slab soffit. (ceiling)	m^2	472.5	4,000	1,890,000
2	Plastering internal & external wall and beams	m^2	585	4,000	2,340,000
3	Tiles in the toilet	m^2	47.88	15,000	718,200
4	Tiles on the slab	m^2	472.5	20,000	9,450,000
	S/TOTAL				**14,398,200**
VII	**PAINTING**				
1	painting of, column, and beam (double side)	m^2	402	3,500	1,407,000
2	Painting wall (2 sides)	m^2	2047.5	2,000	4,095,000
3	Painting of door and window	m^2	200	2,250	450,000
	S/TOTAL				**5,952,000**
VIII	**SANITARY DETAILS**				
1	Wash hand basin	pcs	14	75,000	1,050,000
2	Toilet	pcs	14	140,000	1,960,000
3	Shower	pcs	14	85,000	1,190,000
	S/total				**4,200,000**
IX	**ELECTRICAL INSTALLATION**				
1	Electrical cables and conduits	1	5,500,000	5,500,000	
2	Socket	pcs	35	1,500	52,500

3	Lamps	pcs	35	1,000	35,000
	S/total VII				**5,587,500**
	GROUND FLOOR TOTAL				**325,639,246 Rwf**
1st,2nd, 3rd and 4th floor					
1	for beam	m^3	23.4	380,000	8,892,000
2	for column	m^3	12.6	380,000	4,788,000
3	for slabs	m^3	75.87	380,000	28,830,600
4	for stairs	m^3	7	380,000	2,660,000
	S/TOTAL				**45,170,600**
II	**Masonry**				
1	Elevation of the walls with burnt brick.	m^3	311.5	60,000	18,690,000
	S/TOTAL				**18,690,000**
III	**FURNITURE**				
1	Simple door (90x210)	pcs	17	70,000	1,190,000
2	Double door (180x240)	pcs	5	180,000	900,000
3	Window (150x170)	pcs	18	80,000	1,440,000
4	Window (100x120)	pcs	2	60,000	120,000
5	window (60x70)	pcs	7	35,000	245,000
	S/total				**3,895,000**
IV	**PLASTERING**				
1	Sand and cement mortar rendering to slab soffit. (ceiling)	m^2	472.5	4,000	1,890,000
2	Plastering internal & external wall and beams	m^2	585	4,000	2,340,000

3	Tiles in the toilet	m²	47.28	15,000	718,200
4	Tiles on the slab	m²	472.5	20,000	9,450,000
	S/TOTAL				**14,398,200**
V	**PAINTING**				
1	painting of, column, and beam (double side)	m²	402	3,500	1,407,000
2	Painting wall (2 sides)	m²	2047.5	2,000	4,095,000
3	Painting of door and window	m²	200	2,250	450,000
	S/TOTAL				**5,952,000**
VI	**SANITARY DETAILS**				
1	Wash hand basin	pcs	14	75,000	1,050,000
2	Toilet	pcs	14	140,000	1,960,000
3	Shower	pcs	14	85,000	1,190,000
	S/total				**S/total**
VII	**ELECTRICAL INSTALLATION**				
1	Electrical cables and conduits		1	5,500,000	5,500,000
2	Socket	pcs	40	1,500	60,000
3	Lamps	pcs	40	1,000	40,000
	S/total VII				**5,600,000**
VIII	**RAILS**				
1	Rail grassed frame	m	58.6	65,000	3,815,500
	1st,2nd, and 3rd floor TOTAL (Each)				**101,721,300 Rwf**
IX	**PARAPET WALL**				
	Bricks parapet wall	m³	89	75000	6,675,000
	4th floor TOTAL				**308,396,300Rwf**

VARIOUS SUPPLIES & FACILITIES		
1	Purchase &installation of electrical	260,500,000
2	Purchase &installation of fire protection	80,000,000
3	Networking & generator purchase & installation	85,500,000
S/Total		**426,000,000**
TOTAL		**1,165,199,446 Rwf**
UNEXPECTED 10%		**116,519,944Rwf**

Appendix F: perspective of drawing