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DEPARTMENT OF CIVIL ENGINEERING

FINAL YEAR PROJECT

STRUCTURAL DESIGN OF A G+3 STUDENT APPARTEMENT BUILDING: CASE OF STUDY GASABO, GISOZI SECTOR

Submitted in partial fulfillment of requirement for the award of **Advanced diploma in construction technology.**

Submitted by: MANA OBIGABA Jonathan: 202150144

Under the guidance of: Eng. MUNYANEZA Jean Pierre

Kigali, September 2024

DECLARATION

I, MANA OBIGABA JONATHAN, hereby declare that the work entitled Architectural and structural design of a G+3 student apartment building: case of study Gasabo, Gisozi sector, which is entirely original with no submissions for credit toward any degree or examination at any other university or college, and that all references to the sources we have used or quoted are included.

The candidate's name: MANA OBIGABA Jonathan

Signature of the candidate:

Date of submission:

CERTIFICATION

This certifies that MANA OBIGABA JONATHAN, working under the direction of Engineer MUNYANEZA Jean Pierre, conducted the study titled:

"Structural design of a G+3 student apartment building: case of study Gasabo, Gisozi sector."

Supervisor : Eng. MUNYANEZA Jean Pierre

Signature : Date :

Head of department: Eng. BONAVENTURE NKIRANUYE

Signature: Date:

Submitted to ULK Polytechnic Institute held in September 2024

DEDICATION

I would gladly dedicate this project:

- To almighty God, for his support and guidance in undertaking this undergraduate degree program
- To ULK Polytechnic Institute staff.
- To my Supervisor Eng. MUNYANEZA Jean Pierre
- To my family, parents, brothers and sisters
- To my relatives and friends for being my side, I dedicate this work.

ACKNOWLEDGMENT

Above all, we are grateful to God the Almighty for his protection and guidance throughout our studies. May these simple words communicate how grateful I am to him.

I extend my special thanks to the Rwandan government for their technical assistance. I would like to thank the ULK Polytechnic Institute and its faculty, particularly the Civil Engineering Department. By the way, the completion of this project is the product of their collaborative efforts.

My heartfelt thanks goes to my supervisor, Eng. Munyaneza Jean Pierre, for his persistent supervision and guidance during the writing of this dissertation, as well as his technical and smart comments, recommendations, and corrections that made this project a success, without forget Eng. Bonaventure who is not only the head of Department but also one of our main lecture, he though me Reinforced Concrete Design, the course which had a much impact in this dissertation.

I express my gratitude to my families for their unwavering support throughout my studies. Thank too to my classmates and friends, Rachel, Thadine, Mathieu, Frederic and all others friends, for their moral guidance.

Thank you everybody...!

ABSTRACT

With the arrival of international students, the architectural and structural design of student apartments in regions like Gisozi presents several challenges. It is essential to develop infrastructures that meet modern living standards, emphasizing sustainable practices while accommodating cultural diversity, security, and educational needs for both international and local students. Achieving this balance within budgetary and regulatory constraints represents a significant challenge for architects and engineers. To address these issues, this project, titled "Architectural and Structural Design of a G+3 Student Apartment," was undertaken as a requirement for the Advanced Diploma program at ULK Polytechnic Institute. The project comprises two main components: conceptualization and structural design, both developed with a strong emphasis on user communication to ensure practical applicability.

The building, located in Gisozi, Kigali, has dimensions of 22 meters by 19.20 meters and a total estimated cost of 1,255,483,719 Rwf. The structural design follows British Standards (BS 8110-1:1997 and BS 6399-1:1996) and includes detailed plans for beams, slabs, columns, stairs, and foundations. Key features include slab reinforcement using T10@300 mm c/c with a slab thickness of 15 cm and an area provided of 262 mm^2, and beam reinforcement of 3T16 top and bottom (603 mm^2) with 8 mm diameter stirrups spaced at 200 mm. The beams have a total height of 65 cm and a width of 40 cm. The columns are reinforced with 4T16 from the third to the second floor and 7T16 from the first floor to the ground floor, with 8 mm stirrups spaced at 200 mm. The square footing measures 2.5 m by 2.5 m, with a depth of 0.6 m to support a load of 853.224 kN, reinforced with T25@125 mm, providing an area of 3930 mm^2. The staircase, with a height of 3 meters, includes a landing at 1.5 meters, and features 19 goings and 20 risers, reinforced with T12@125 mm for the landing and T12@300 mm for the flight, providing an area of 377 mm^2.

Through this project, we aim to contribute to improving the standard of living for students in Kigali, particularly in the Gisozi sector, and thereby support Rwandan educational objectives.

Keywords:

Structural Design: Engineering analysis for building safety.

G+3 Building: Ground floor plus three stories.

Student Apartment: Housing designed for students.

Reinforced Concrete: Main construction material.

Gisozi Sector: Project location in Kigali

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LIST OF ABREVIATIONS

CAD : Computer-Aided Design

GIS : Geographical Information System

PPC : Portland Pozzolan

ACI : American Concrete Institute

Mpa : Mega-pascal

AIA: American Institute of Architects

ICC: International Code Council

ASCE: American Society of Civil Engineers

RC: Reinforced Concrete

LRFD: Load and Resistance Factor Design

LSD: Limit State Design

ULS: Ultimate Limit State

SLS: Serviceability limit state

FEM: Finite Element Method

ly: Long span of the slab

lx: short span of the slab

d : slab thickness

h_0 : slab Effective height

GK: Characteristic Dead load

QK: Characteristic live load

wc: Self-weight of the slab

γc: unit weight of concrete

b: breath of slab

q: self-weight of slab

BS: British-Standard

n: design

M: moment

Msx : moment about x-axis

Msy: moment about y-axis

βsx: moment coefficient about x-axis

βsy: moment coefficient about y-axis

F: Ultimate Force

L: Effective span

βvx: shear force coefficient about x-axis

βvy: shear force coefficient about y-axis

MRC: Moment of Resistance of Concrete

fcu: compressive strength of concrete

As: Area of steel

K: lever arm factor

Z: lever arm

Kbal: design lever arm

As req: Area of steel Required

As prov: Area of steel provided

mm: millimeter

m: meter

cm: centimeter

kn: Kilo-Newtown

N: Newtown

mm^2: millimeter square

m^2: meter square

cm^2: centimeter square

m^3: cubic meter

S max: maximum spacing

D: diameter

π: pi

min: minimum

max: maximum

As min: Area of steel minimum

As max: Area of steel maximum

V: shear stress

Uc: shesr capacity

fy: yield strength of reinforcement

bw: web width

MF: Modification Factor

fs: the design

ht: total height

%: percent

W: Uniformly distributed load

F: Design load per span

Φ: diameter

L_0: Unbraced length of column

Le: Effective length of column

β: coefficient refered to slenderness ratio

LL: live load

N: Newtown

Ac: Cross-sectional Area

V: Ultimate shear force

T: tear

R: rise

QTO: Quantity Take-Off

UCM: Unit Cost Method

G: Going

C/C: center to center

λ: slenderness ratio

a: side of column

pu: Ultimate pressure

B and L: footing dimensions

∑M: sum of moment

RCD: Reinforced Concrete Design

AS’: Area of steel in compression

CHAPTER 1: GENERAL INTRODUCTION

1.1 Background of the study

Kigali, the capital of Rwanda has undergone a very large urbanization in recent years, precisely since the 2000s, the average rate of population increase is 4%. This is due to the economic explosion and the search for new opportunities in the city (UN-Habitat, 2014). The Rwandan Ministry of Education Stimulates that the existing infrastructure is not up to meeting the demands for housing and that most of the existing ones are not one with living conditions (Ministry of Education, 2017). Architectural, structural, but also aesthetic attention is necessary when designing a student apartment. The architectural plan must be able to offer students the necessary spaces for their own development and education. It must allow students to be able to study on rest and interact with the community in complete tranquility. On the other hand, the structural plan must be able to ensure stability, durability and security, particularly for our case of the construction of a multi-stories student apartment G + 3. According to Allen and Iano (2013), A good mix of architectural and structural plan is very important for the construction of a functional infrastructure which is able to withstand man-made stresses (Iano, Edward Allen and Joseph, 2013). Gisozi Represents a special case, because it is characterized by the proximity of several educational institutions. It also reports several problems such as the viability of the construction site and topographical problems. The use of sustainable practices Reduces the impact of the infrastructure on the environment, but also significantly increases sustainability, sustainable practices, use of resources present on the ground such as material contributes to the creation of a Living environment where conditions are favorable to the health and well-being of individuals (Kibert, C. J., 2016). Our study which is the Structural design of a G+3 student apartment, will help to address the problems encountered by students when it comes to finding residential houses.

1.2 Statement of the problem

With the arrival of international students, the Structural design of student apartments in regions, such as Gisozi presents several challenges. For the development of the country, it is very important to be able to set up infrastructures that meet the standards of modern living with an emphasis on the use of sustainable condition practices. The design must be done in such a way that it can meet the need for cultural diversity, security, education of international and local students. The important thing is the budgetary and regulatory balance, while respecting all these requirements above, represents a challenge for architects and engineers, our study which is "Structural design of a G + 3 student apartments building " is made to face this great challenge, to meet these challenges, through this project, we wish to contribute to improving the standard of living of students in Kigali, precisely in Gisozi and by these facts, support Rwandan educational objectives

1.3 Purpose of the study

The purpose of our study are:

1.Finding design solutions capable of improving the living conditions of students.

2. Contribute to the development of student stays and their academic success.

3.To provide to students' affordable apartments that they can afford and meet all their needs.

1.4 Research objectives

To complete our study, we set ourselves some important objectives to achieve:

1.4.1 General objective

The General objective of this study is to provide a comprehensive architectural and structural design for a three stories apartment building located in Kigali City, precisely in the Gasabo District, Gisozi sector.

1.4.2 Specific objectives

To achieves the General objective, we have these specific objectives:

a. Is to make structural analysis and Architectural plan of the structure.

b. Estimates the value of the building when constructed.

c. Contribute to general knowledge in the structural and architectural design of a student apartment, which will allow future students and researchers to accomplish similar projects

1.5 Research questions

Some questions have been asked in order to achieve our study:

1. What are the requirements and problems we may encounter while designing a G+3 student apartment building in Gisozi sector of Kigali City?
2. What is the value of the building according to the price of the materials?
3. How can the experiences we have gained help other students to achieve their project?

1.6 Geographical scope

The geographical scope is located in the Gisozi sector, In the Gasabo district in the city of Kigali in Rwanda. This specific location was chosen near educational institutions to more easily meet the needs of students.

Here are more detailed explanations of the choice of the location of our work site:

1. Gisozi Sector: Gisozi sector is located in Gasabo district one of the most important district of Kigali city. It is known because it contains academic and commercial institutions which leads to rapid urbanization which is followed by a great demand for housing.
2. Local context: For the design, architectural and structural, the local cultural and environmental factors must not be neglected, that is to say the traditional methods of construction, the availability of materials and the environmental conditions specific to the Gisozi sector.
3. Proximity to institution: The location of the project, located near the majority of local institutions in the Gisozi sector, will allow students to get there easily. This proximity will also help them to avoid taking public transportation to reduce de rate of accidents.

1.7 Significance of the study

Our study which is The architectural and structural design of student apartments has an importance for two types of people, Future students of Kigali Independent University and researchers.

1.7.1 For researchers

It is important for researchers because it allows an improvement in terms of idea concerning the architectural and structural design of infrastructures intended for students. It will contribute a stone to the building In terms of solving certain problems encountered by students during their stay in the apartments, Its problems can be architectural As in the layout of the rooms And the lighting of the rooms. It is the will contribute to the improvement of the standard of living, students or other occupants depending on the structure, taking into account the local construction codes.

1.7.2 For Kigali Independent University students

For students of Kigali Independent University Our study will be a source of inspiration and reference that will serve as a guide for them in writing their final year project. Like students of other academic institutions, If once, the project is selected and carried out by the government of Rwanda, Then the main objective which was to be able to provide the Gisozi sector with an apartment for students will be achieved, Kigali Independent University students will be part of the beneficiaries and this will contribute to their academic success.

1.8 Organization of the study

Our research will be composed of five chapters, all contributing to the accomplishment of our study which is the Structural design of a G+3 student apartment case of study: Gasabo, Gisozi sector. Chapter one establishes the foundations in the context of the objectives and methodology. Chapter two Consists of the review of existing literature to have a Contextual idea about our study. Chapter three will focus on the methodology used from the field study to the techniques used for architectural and structural design. Chapter four Presents a more in-depth analysis of the design and information found While chapter five Will synthesize our work While giving useful recommendations to future researchers working in the context of our study. This organization of the study will give us a general perspective in the design and construction of a G+3 student apartment in the Gisozi sector: Kigali.

1.9 Methodology

In order to ensure the completion of our general objective which is to provide a comprehensive architectural and structural design for a three stories apartment building located in Kigali City. We have used a comprehensive methodology, which includes a series of techniques and processes to follow:

1. Architectural Design Using Computer-Aided Design (CAD)

The architectural plan will be carried out using an advanced CAD software, precisely Graphisoft's ArchiCAD 26. This choice, will facilitate the accomplishment of a more precise drawing and a global visualization in 3D of our project.

2. **Structural Analysis and Design**

The British Standard code will be respected for a structural analysis, more advanced and more adapted to our project, this will give us an assurance that our structural consideration is in order with the international recognized standard in order to improve the durability, safety and the integrity of our building. All structural elements will be designed manually using precise formulas with taking in consideration important factors such as load-bearing Capacity and applied Load.

3. Geographical Information Systems (GIS)

Before we can start our structural and architectural design It is important to know the exact location where our project will be implemented once chosen by the government or another institution. We have decided to be able to use this GIS software That will help us to establish a detailed map of our study area, This ensures that our project has been well understood in the geographical context that will be integrated into the design processes.

4. Cost Estimation

In order to be able to provide yo a thoughtful estimate of our project, methods such as takeoff, unit cost method, and bottom-up estimating were employed. The prices of materials, wages of workers and other resources will be taken into account to inform the project budgeting, and the implementation of a clear financial plan. The results of these calculations will be presented by an Excel sheet, which presents a clear and organized format for cost estimation data.

5. Comprehensive Reporting

All the results of our use will be compiled into a report that will include, among other things, steps from the structural and architectural plan to cost estimation and project management consideration. This report will be an information and documentation tool for our methodology, for our results found, and our recommendations while giving researchers detailed insights into the project's scope, objectives, and outcomes.

6. Presentation of the final-year project

Our final report will be presented as part of the final year project, bringing to the attention of researchers and readers the results of our research, analysis, and design efforts. To contribute to the establishment of a solution to the lack of student housing not only in the Gisozi area, but also in the capital of Rwanda, Kigali.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview of literature review

The literature review analyzes the links between the structural and architectural designs of student apartments or buildings in the Gisozi sector, Kigali. It begins by focusing on the principles of architectural design in general with an emphasis on spatial planning and the principles of sustainable design of infrastructure (Ching & Francis D.K., 2014). Taking into account the evolution of urbanization in Kigali, which is increasing, causing the increase in demand for housing in rapidly developing urban areas (UN-Habitat, 2014). Structural analysis, seismic resilience and safety standards are very important elements to consider when designing a multi-stories structure thus ensuring its safety and durability (Ching & Francis D.K., 2014). The studies on the cases of the projects of the design and construction of student buildings provide necessary information to our study, they put to our knowledge, the lessons learned and the practices shedding light on the application of international standards in the local context of Kigali (Pieterse, Susan Parnell and Edgar, 2014). In other words, this study shows the importance of applying sustainable design practices in the field of civil engineering, such as the design of green buildings and the use of sustainable materials in order to maintain a healthy environment conducive to human life (Kibert, C. J., 2016).

2.2 Structural Design Principles

Structural design principles give us the rules and practices needed to design buildings, multi-stories or single-story, capable of supporting any type of weight including live loads and dead loads, while ensuring the durability and safety of the structure (Iano, Edward Allen and Joseph, 2013). These principles also take into consideration the load-bearing capacity, the selection of materials, the stability, and the resistance to man-made stresses. Structural analysis helps engineers find the loads and stresses that each part of the structure will have to support. This gives us insurance against the failure of the structure. In addition, the design principle must consider seismic activities, dynamic forces, and wind loads that can impact the longevity and integrity of the structure (Ching & Francis D.K., 2014). By following all these principles, engineers and architects will be able to set up buildings that are safe, stable, durable, and do not exceed financial margins (Iano, Edward Allen and Joseph, 2013).

2.3 Structural Principles of Multi-Stories Buildings

Structural principles of multi-story buildings have been put in place to ensure the safety, stability, and functionality of the structure. The principle includes:

2.3.1 Load-bearing capacity

It is important to ensure that the building can support all types of loads such as live loads (occupants and furniture), dead loads (weight of the structure itself) and environmental loads including wind and seismic forces (Iano, Edward Allen and Joseph, 2013), the bearing capacity can be assume depending to local design code.

2.3.2 Structural integrity and stability

The building must be designed to resist deformations and collapses under multiple loads. For this use of systems such as shear walls, frames and core structures, to counteract lateral forces if necessary (Iano, Edward Allen and Joseph, 2013).

2.3.3 Selection of materials

The strength, durability and resistance of any structure greatly depends on the material used. It recommends to use materials such as concrete, steel and composite materials for the construction of multi-stories buildings (Ching & Francis D.K., 2014).

2.3.4 Rebound and Safety

Distribution of loads is necessary in unexpected failure cases this will be possible by the incorporation of rebounding paths witch will prevent the failure of the entire structure. This is a very important principle for buildings with a very large surface area (Ching & Francis D.K., 2014).

2.3.5 Load Distribution

An equitable distribution of loads to structural elements such as columns, beams and floors to prevent the overcharge of any of these elements (Iano, Edward Allen and Joseph, 2013).

2.4 Reinforced Concrete

Reinforced concrete is a composite material, which combines the tensile strength which comes from steel reinforcements and the compressive strength from the concrete itself, these reinforcements are usually steel bars or mesh, they will be placed in the concrete, before it is dry. Combination of concrete and reinforcements given and durable and versatile material which will be used in several applications, structural, such as beams Columns, slabs and foundations (Ching & Francis D.K., 2014).

2.4.1 Composition of reinforced concrete

Reinforced concrete is composed of several key materials that allow to have durable and strong structures. Its main components are:

2.4.1.1 Cement

It acts as an assembly element when mixed with water, Portland cement is the most used (Neville, 2011). In Rwanda several types of cement are available such as Portland pozzolan cement (PPC) and Portland slag cement (PSC). The choice of the type of cement depends on its properties for the construction of our G+3 student apartment in Gisozi we decided to use Portland cement or pozzolan (PPC), Portland cement offers a certain resistance and durability hence the choice in the construction of multi-stories buildings, and PPC is adapts to environments with very aggressive conditions like Kigali where pollution and bad weather can occur at any time (Ministry of Infrastructure, 2019).

2.4.1.2 Aggregates

Aggregates Are the granular materials used in construction and constitute a large part of the concrete, as aggregates we have gravels, crushed stones and fine aggregates. Fine aggregates fill the voids between the coarse particles and improve workability while coarse aggregates provide stability and strength to the concrete. Aggregates are very important materials in the production of concrete contributing to the overall performance of the concrete and mechanical properties (Mehta, P.K., & Monteiro, P.J.M, 2014).

We distinguish two categories of aggregates:

2.4.1.2.1 Coarse aggregates

They are generally crushed stones and gravel They help to give the concrete volume and strength.

2.4.1.2.2 Fine aggregates

Used to fill the spaces between the coarse aggregates and increase workability, fine aggregates are generally sand (Mehta, P.K., & Monteiro, P.J.M, 2014).

Table 2.1: Aggregates classification by size and common use (Kemper, W.D., & Chepil, W.S., 1965)

Aggregate Size Range	Type of Aggregate	Common Uses
Coarse Aggregates		
> 19 mm	Crushed Stone (19-25mm)	Concrete production, road base, drainage
	Crushed Stone (25-38mm)	Concrete production, road base, drainage
9.5 mm - 19 mm	Gravel (9.5-12.5mm)	Concrete production, road construction, drainage
	Gravel (12.5-19mm)	Concrete production, road construction, drainage
4.75 mm - 9.5 mm	Gravel (4.75-6.35mm)	Concrete production, road construction,
		drainage
	Gravel (6.35-9.5mm)	Concrete production, road construction, drainage
Fine Aggregates		
2.36 mm - 4.75 mm	Fine Sand (2.36-2.95mm)	Concrete production, mortar, plaster, bedding material
	Fine Sand (2.95-4.75mm)	Concrete production, mortar, plaster, bedding material
0.075 mm - 2.36 mm	Medium Sand (0.075-1mm)	Concrete production, mortar, plaster, bedding material
	Fine Sand (1-2.36mm)	Concrete production, mortar, plaster, bedding material
< 0.075 mm	Fine Sand (0.075mm)	Concrete production, mortar, plaster, bedding material

2.4.1.3. Water

Water is very important to allow the chemical process of hydration to allow the cement to play its role of binding material. The durability and strength of concrete depends on the water-cement ratio, the water used in construction should be clean, free from impurities, and meet specific chemical requirements to ensure the structural integrity and durability of the building material (Neville, 2011).

2.4.1.4. Reinforcement

To resist traction loads, steel bars are integrated into the concrete, they are manufactured with ribs to increase the friction between the concrete and the reinforcements to improves the cohesion between the materials (Ching & Francis D.K., 2014).

2.4.1.4.1 Determination of the required steel reinforcement

Determination of the required steel reinforcement depends on several factors such as the structural design requirements, applicable building codes and the acting loads.

Here are the steps for determining the required steel reinforcement:

- **Structural Analysis:** In order to find all types of loads acting on the members, including live loads, dead loads and environmental loads (Iano, Edward Allen and Joseph, 2013).
- **Design Considerations:** The amount and placement of steel will depend on the design requirements such as durability, strength and ease of maintenance (Ching & Francis D.K., 2014).
- **Structural Engineering Principles:** to determine the area of steel to resist tensile forces, bending moment and shear stresses, we will use the principles and calculations of structural engineering (Mehta, P.K., & Monteiro, P.J.M, 2014).
- **Building Codes and Standards:**
  It is important to know the minimum reinforcement to be used and the specific utility of each reinforcement, we have to take as reference the building codes and standards such as the American Concrete Institute (ACI) or the Eurocode (Institution, 2004).
- **Construction Details:** Prepare sketches depending on the structure, showing the exact emplacement of the reinforcements, the place measurements and requirements, this process have the purpose of ensuring good coordination of reinforcement with the other elements of the structure (Ching & Francis D.K., 2014).

- **Quality Control**: weakness of some construction elements such as columns are often caused by the wrong placement, misalignment and poor consolidation of reinforcements inside the concrete; a quality control helps to avoid that (Mehta, P.K., & Monteiro, P.J.M, 2014).
- **Reinforcement Arrangement:** In order to use measurements and to have high accuracy during reinforcement installation, a reinforcement arrangement plan is required, these measurement elements include the size, spacing and configuration of the steel while taking into account factors such as cover requirements, steel lengths and cover lengths (Iano, Edward Allen and Joseph, 2013).

2.4.1.4.1 Type of reinforcement

Reinforcement in concrete structures can generally be categorized into several types based on their function and application. Here are the primary types of reinforcement:

1. Primary Reinforcement (Main Reinforcement): This type of reinforcement is used to carry the tensile stresses in the concrete structure. It is typically placed in areas where the concrete will experience tensile forces, such as the bottom of a beam or slab.
2. Secondary Reinforcement (Distribution or Shrinkage Reinforcement): This reinforcement is used to control cracking caused by shrinkage and temperature changes. It also helps distribute loads more evenly across the concrete element.
3. Shear Reinforcement: Often provided in the form of stirrups, shear reinforcement is used to resist shear forces in beams, slabs, and other concrete members. It prevents diagonal tension failures.
4. Torsional Reinforcement: This reinforcement is provided to resist torsional forces (twisting) in structural elements, such as beams subjected to eccentric loading or twisting actions.
5. Compression Reinforcement: In some cases, reinforcement is also used in compression zones, especially in columns or heavily loaded beams, to increase their load-bearing capacity.

2.4.1.4.2 Role of reinforcement

The role of reinforcement bars (rebar) in concrete includes:

- Tensile Strength: Concrete is strong in compression but weak in tension. Rebar is used to carry tensile forces in concrete structures, which helps resist bending and stretching stresses that the concrete alone cannot handle.
- Crack Control: Rebar helps control and limit the extent of cracking that can occur due to shrinkage, temperature changes, and other stress factors. By distributing the tensile forces more evenly, it minimizes the risk of large cracks.
- Structural Integrity: Reinforcement bars provide additional strength and stability to concrete structures, enhancing their load-bearing capacity and overall durability. They help ensure that structural elements like beams, slabs, and columns can support the imposed loads.
- Ductility: The presence of rebar improves the ductility of concrete, allowing it to deform more before failing. This characteristic is particularly important for seismic performance, as it helps structures absorb and dissipate energy during an earthquake.
- Shear Resistance: Rebar also contributes to resisting shear forces within structural elements, such as beams and slabs. This helps prevent shear failure, which can be critical for maintaining the structural safety and performance (Joseph Iano and Richard J.C. Metha, 2014).

2.4.1.5. Admixtures

Are chemicals used to modify the properties of concrete such as improving durability, accelerating or delaying the setting time, improving workability and adapting the concrete to environmental conditions.

Table 1.2: *Various types of admixtures in concrete technology (Dodson, ,V.H., 2013)*

Admixture Type	Properties	Composition
Water Reducers (Plasticizers)	- Improve workability and flow - Reduce water content - Enhance strength development	- High-range water reducers: Polycarboxylate ethers - Mid-range water reducers: Melamine-based or lignosulfonate-based

Air-Entraining Admixtures	- Introduce microscopic air bubbles - Improve freeze-thaw resistance - Enhance workability	- Natural or synthetic surfactants
Accelerators	- Speed up setting time and early strength gain - Useful in cold weather concreting	- Calcium chloride (for non- reinforced concrete) - Non-chloride accelerators
Retarders	- Delay setting time	- Lignosulfonates

The reason why we will refrain from using admixtures in our study is to avoid potential risks in the construction process. Improper use of admixtures would have great consequences during the execution of the project because they contain new variables and dependencies that can cause problems during batching, placement, hardening and curing. In addition, if we take into account the performance of local workers the use of admixtures is not familiar to them, also the availability of materials and the project budget, by not using admixture we have insurance a simple construction process without errors and delays (Kemper, W.D., & Chepil, W.S., 1965).

Summary of the composition of concrete

- cement: binder for durability and strength
- fine aggregates: fills voids and increases workability
- coarse aggregates: for compressive strength and volume
- water: setting of cement and hydration
- steel reinforcement: for tensile strength
- admixtures (optional): Modify the properties of concrete

2.5 Reinforced concrete elements

2.5.1 Beam

A beam is a horizontal structural element whose role is to resist bending and transfer loads to vertical elements such as walls and columns. The materials used for its construction can be steel, wood, or concrete but with a mandatory addition of reinforcement to improve its strength and durability (Ching & Francis D.K., 2014).

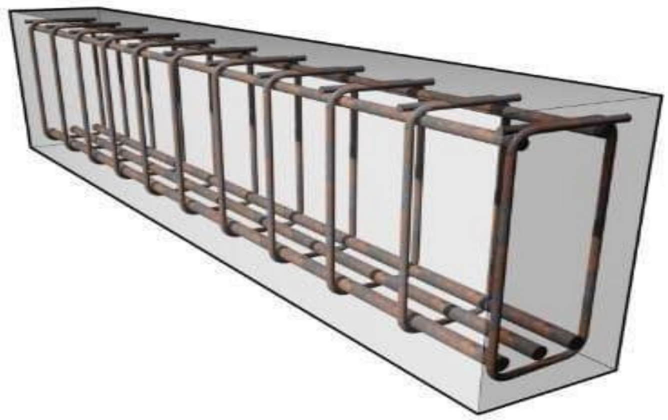


Figure 2.1 :*Reinforced concrete beam (Mosley, 1990)*

Key structural components in building are primary and secondary beams, each of which has a specific function in guaranteeing stability and supporting loads. This is a quick synopsis.

2.5.1.1 Primary Beams

Primary beams, sometimes referred to as main or principal beams, serve as a structure's primary horizontal supports. They directly transfer loads to the columns from the secondary beams and floor slabs. They bear the majority of the load, which includes any applied loads as well as the weight of the structure above them. Usually found in the main structural grid, these beams cover greater distances (Ching & Francis D.K., 2014)

2.5.1.2 Secondary Beams

Often referred to as distribution or joist beams, secondary beams serve the purpose of supporting floor slabs and transferring their loads to the main beams. They transfer the weights from the floor slabs to the main beams by carrying them. Usually positioned perpendicular to the principal beams, these beams span shorter distances between them (Ching & Francis D.K., 2014).

2.5.1.3 Cantilever beam

A cantilever beam is defined as a beam that is fixed at one end and free at the other, creating an overhanging structure. The fixed end provides stability and resists rotation, while the free end extends outward without additional support. This design results in significant bending moments and shear forces, particularly near the fixed end, which must be carefully considered in the design and reinforcement of the beam. Cantilever beams are commonly used in applications such as bridges, overhangs, and balconies, allowing structures to extend outward while supporting loads effectively (Joseph Iano and Richard J.C. Metha, 2014)

2.5.2 Column

Column Are vertical structural elements intended to resist first to axial compression loads, it transfers the weights coming from the beams and slabs to the foundations. Columns are important to ensure the stability of structures such as buildings and bridges. They are often made of materials such as concrete steel and even wood according to the infrastructure (Ching & Francis D.K., 2014). Based on the behavior and the analysis method used we have these types of column:

2.5.2.1. Short columns

A short column is a structural element Main subjected to axial decompression loads with the minimum of bending movement because of their short length compared to their lateral dimensions they present axial deformations in case of overload. They are characterized by slenderness ratio which shows us the stability of the column under compression, it is calculated by the ratio between the effective length and least lateral dimension, slenderness ration must not exceed 12 (Ching & Francis D.K., 2014).

2.5.2.2. Long column

A column is identified as long when the slenderness ration which is the ratio between the effective length and least lateral dimension is greater than the critical value of 12, because of their slender proportion the long columns are vulnerable to buckling under compressive loads (Ching & Francis D.K., 2014).

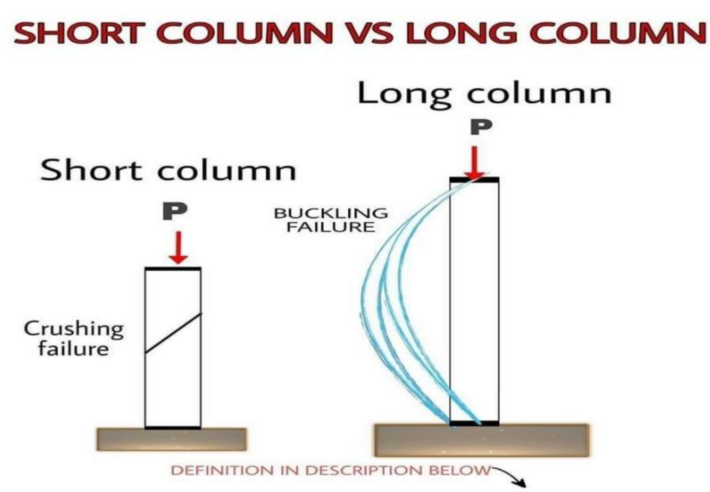


Figure 1.2 : *Short and Long Column (Jonathan Strahan, 2011)*

2.5.2.3. Slender columns

Are columns with the largest slenderness ratio, it means that their effective length is large compared to the lateral dimension, which makes them greatly vulnerable to buckling effects under loads, it is because of that they are analyzed considering the buckling effects. Slender columns are used where the Aesthetics and functional requirements match with the properties of the slender column (Ching & Francis D.K., 2014).

2.5.2.4 Fixed-End Columns

Are columns in which the ends are not free, but attached to other structures such as Walls and floors. This means that the columns are spared from rotational and lateral movements. During their analysis it is important to consider the effects of axial compression and bending (Ching & Francis D.K., 2014).

2.5.2.5 Eccentrically loaded columns

Are columns whose load is not applied directly to the center of the cross-section, this means that the load is offset from the central axis of the column. The deflection and deformation of the column are due to this eccentricity which causes not only flexion (bending moment) but also compression in the column (Ching & Francis D.K., 2014)

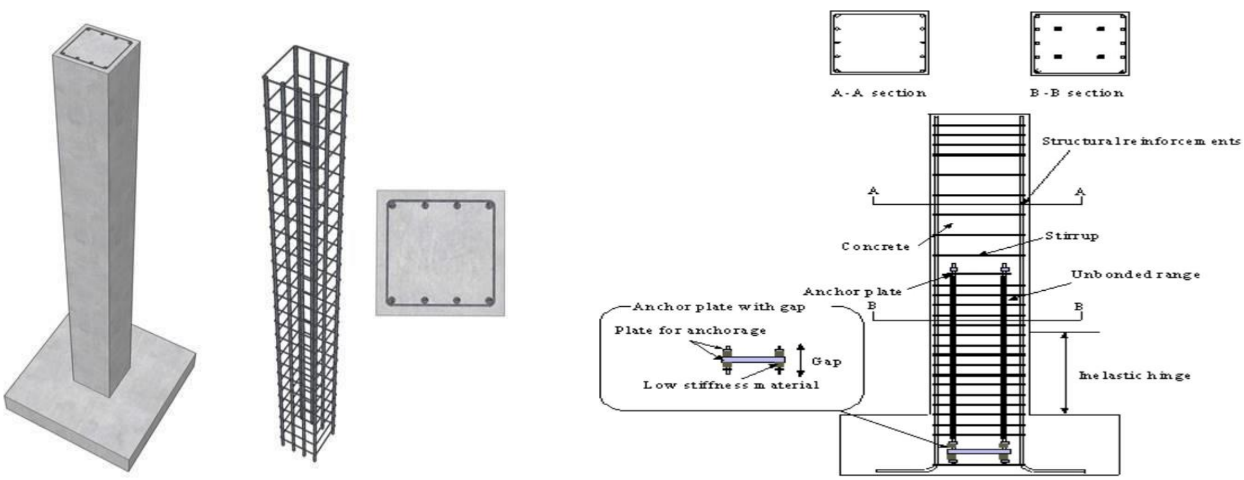


Figure 2.3: Reinforced concrete column (Elwood, K.J.,& Eberhard, M.O., 2009)

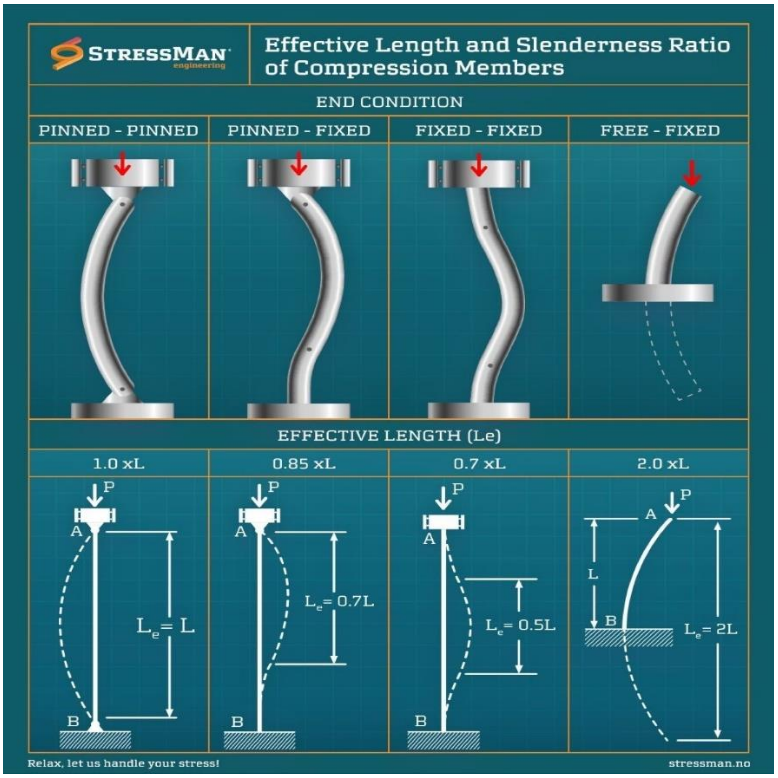


Figure 2.4: *Effective length and Slenderness Ratio of Compression Members (Jonathan Strahan, 2011)*

2.5.3 Slab

Slab is a flat plate of material concrete, typically rectangular with the length significantly greater than the width and thickness. They are used to make the floors of houses and buildings. The support terms might be one or two-way support. They are used to support the loads coming from the walls and beams to the supporting columns or walls. The additional strength is provided by embed reinforcement over the slabs to resist cracking (Ching & Francis D.K., 2014).

2.5.3.1 Types of slab

In the philosophy of the way the loads are distributed and transferred weakly into the structure of the slab we have these type of slab:

2.5.3.1.1. One-way slab

It is a slab that supports the charges in a single and unique direction, which means that the charges are supported by column located below. The reinforcement is located in the direction of the charge. This form of slab is commonly used for the production of planks. Because the charges are applied in a specific direction (Nilson, Arthur H., Darwin, David, & Dolan, Charles W., 2006).

2.5.3.1.2. Two-way slab

A slab designed to carry loads from two perpendicular directions, as opposed to a one-way slab, which only supports weights in one direction. Their application improves weight distribution and the overall stability of the structure (Nilson, Arthur H., Darwin, David, & Dolan, Charles W., 2006).

2.5.3.1.3. Flat slab

Unlike standard slabs, flat slabs do not contain internal beams or columns. Instead, they are supported by external columns and have a flat upper surface. They are frequently employed when interior space flexibility is required (Nilson, Arthur H., Darwin, David, & Dolan, Charles W., 2006).

2.5.3.1.4. Waffle slab

A slab with crossed beams and ribs that generate cavities similar to waffles. It is frequently selected to increase strength while decreasing the amount of materials needed. This makes it useful in the creation of extremely big slabs (Nilson, Arthur H., Darwin, David, & Dolan, Charles W., 2006).

In two-way slab, the ratio of longer span (l) to shorter span (b) is less than 2; i.e. Longer span (lx)/Shorter span (ly) < 2 (Nilson, Arthur H., Darwin, David, & Dolan, Charles W., 2006)

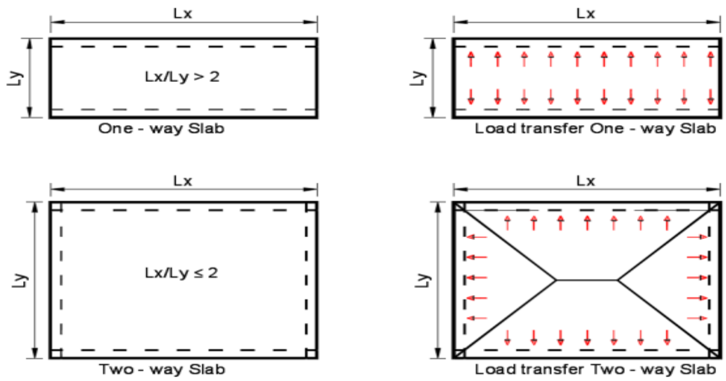


Figure 2.5: *One way and two-way slab load transfer and differences (Wang, 1979)*

Slabs are categorized as follows according to how they are supported:

2.5.3.1.5. Simply Supported Slab

A slab that is supported by beams, walls, or columns on its two opposing edges. The slab can flex when put under pressure and spans between supports. For narrow spans, simply supported slabs are commonly used in building construction (Gambhir, M. L., 2008).

2.5.3.1.6. Continuous Slab

A slab that extends without intermediate walls or beams across numerous supports. Continuous slabs reduce bending moments and deflections by transferring loads to supports more uniformly and effectively. They are suitable for bigger loads and greater spans (Gambhir, M. L., 2008).

2.5.1.7 Cantilever Slab

Slab with one end supported and extending freely over the edge of the support is called a cantilever slab. Slabs that cantilever are used in places like balconies and overhangs where complete edge support is not feasible. According to Gambhir (M. L., 200), the support needs to be properly engineered to withstand bending and shear pressures (Gambhir, M. L., 2008).

2.5.4 Wall

Walls are vertical structural components of a building that help support the building horizontally. Weight-bearing walls bear the load from above and conduct it to the ground. Not to be confused with load-bearing, non-load-bearing walls witch simply divide one room from another without taking any weight. Common materials used in making walls include concrete, masonry and steel (Ching & Francis D.K., 2014).

2.5.5 Footing

Footings are structural members used to distribute loads from columns, walls or other structural members to the underlying soil or rock. They provide support for structure and prevent excessive settlement of the structure. Footings usually consist of reinforced concrete designed to spread loads over a larger area thereby reducing soil bearing pressure (Ching & Francis D.K., 2014).

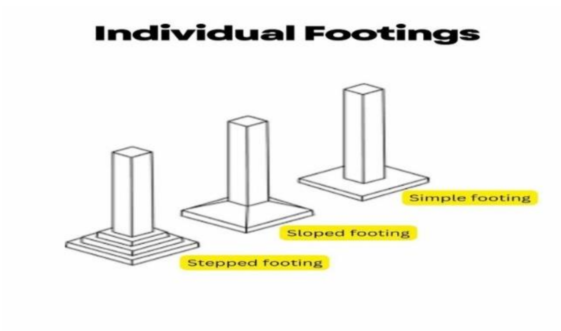


Figure 2.2 : Footing shape (Jonathan Strahan, 2011)

2.5.5.1 Footing types

2.5.5.1.1 Spread Footing

The most prevalent kind, spread footings are sometimes referred to as isolated footings or pads. They disperse the weight over a bigger area of earth rather than onto a single column or wall. Depending on the column loads and soil conditions, spread footings might have a square, rectangular, or circular shape (J.E. Bowles, 1996).

2.5.5.1.2 Strip Footing

Continuous footings that sustain several walls or columns in a row are known as strip footings. They are employed when the soil has a limited bearing capacity or when the loads from nearby walls or columns overlap. Strip footings are long and extend the whole length of the structure they support (J.E. Bowles, 1996).

2.5.5.1.3 Combined footing

When two or more columns are near to one another and their individual footings would overlap or merge, combined footings are utilized. Multiple columns can be supported by combined footings, which also effectively distribute the load to the earth. Depending on how the columns are arranged, they might have a rectangular, trapezoidal, or irregular shape (J.E. Bowles, 1996).

2.5.5.1.4 Mat or Raft Foundation

The entire building is supported by these sizable, robust slabs. They are employed when the structure is subjected to unequal or fluctuating loads, or when the soil has a low bearing capability (J.E. Bowles, 1996).

2.5.5.1.5 Pile Foundation

In situations where the soil is unstable or weak at the surface, pile foundations are utilized. Long, thin structural components called piles are pushed or cast into the ground to shift weights to rock or deeper, more solid soil layers. Based on its material (concrete, steel, or timber) and installation technique (driven, drilled, or cast in situ), pile foundations can be divided into several varieties (J.E. Bowles, 1996).

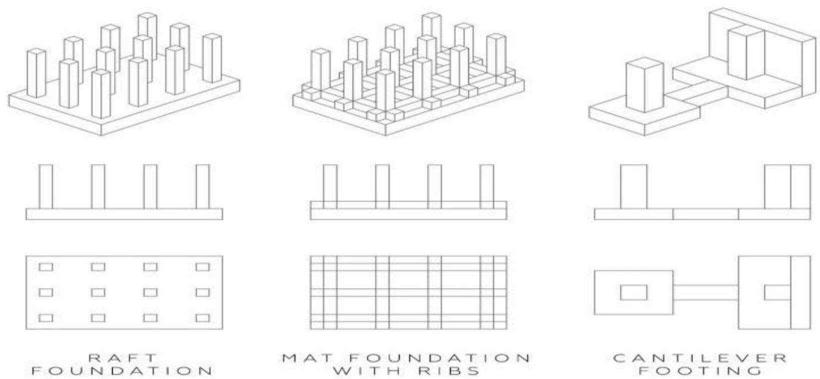


Figure 2.3 : *Types of foundation (Jonathan Strahan, 2011)*

2.5.6 Stair

A stair is a set of sequential steps that are used to enable vertical access between floors or levels of a building (Gambhir, M. L., 2008).

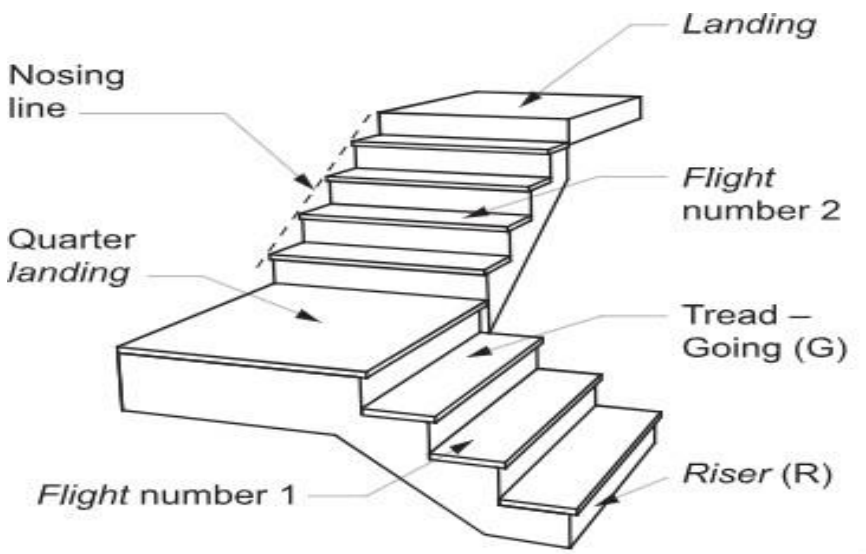


Figure 2.4: Stair components (Gambhir, M. L., 2008)

2.5.6.1 Type of stair

The types of stairs are generally classified based on their design and structure. The main types include:

1. Straight Staircase: A simple, linear design with a straight flight of steps. It is the most basic and straightforward type of staircase.
2. L-Shaped Staircase: Comprises two straight flights of stairs joined at a right angle, typically with a landing in between. It provides a change in direction and can be used to save space.

3. U-Shaped Staircase: Consists of two parallel flights of stairs connected by a landing or a platform, creating a U-shaped configuration. It is efficient in terms of space and often used in residential and commercial buildings
4. Spiral Staircase: Features a helical design with steps arranged around a central column. It is compact and ideal for limited spaces but can be less practical for heavy traffic.
5. Curved Staircase: Similar to spiral staircases but with a more gradual curve. It provides an elegant and flowing design and is often used in high-end residential or public buildings.
6. Quarter-Turn Staircase: Includes a landing at a 90-degree turn, which helps in changing direction and is often used in tight spaces or where a sharp turn is needed (Gambhir, M. L., 2008).

2.6 Reinforced Concrete Properties

The composite material known as reinforced concrete combines the tensile strength of steel reinforcement with the compressive strength of concrete. These are its principal properties:

2.6.1 High Compressive Strength

Concrete can hold large weights because of its exceptional compression strength. The design of the mix, the curing environment, and the age of the concrete all affect the compressive strength of concrete, which is commonly expressed in mega-pascal (MPa) (Gambhir, M. L., 2008).

2.6.2 Good Tensile Strength with Reinforcement

Concrete lacks tensile strength on its own, thus to increase its resistance to tensile forces, steel reinforcement such as rebar or mesh is incorporated into the concrete. Reinforced concrete can successfully withstand both compressive and tensile loads because of the mix of steel and concrete (Gambhir, M. L., 2008).

2.6.3 Durability

Abrasion, chemical assault, and weathering are just a few of the environmental stresses that reinforced concrete can resist. Its long-term endurance is influenced by appropriate mix design, sufficient cover over the reinforcement, and sound construction techniques (Gambhir, M. L., 2008).

2.6.4 Fire Resistance

Concrete possesses strong fire resistance qualities and is non-combustible. It can keep the building's structural integrity intact for a longer amount of time by shielding the embedded steel reinforcement from high temperatures during a fire (Neville, A. M., 1995).

2.6.5 Versatility

For structural and architectural applications, reinforced concrete is extremely adaptable as it can be cast into nearly any shape. Building beams, columns, slabs, walls, foundations, and other structures can all be done with it (Neville, A. M., 1995).

2.6.6 Maintenance:

In comparison to other materials, reinforced concrete structures require less upkeep. A reinforced concrete structure's longevity and safety can be guaranteed by routine inspections and small repairs (Neville, A. M., 1995).

2.6.7 Economic Efficiency:

The components of reinforced concrete, such as steel, cement, and aggregates, are often affordable and easily obtainable. For many building projects, reinforced concrete is a preferred option due to its overall cost-effectiveness (Gambhir, M. L., 2008).

Table 2.2: : Concrete and Steel Property (Neville, A. M., 1995)

	CONCRETE	STEEL
Strength in tension	Poor	Good
Strength in compression	Good	Good but not for slender bars
Strength in shear	Fair	Good
Durability	Good	Good but corrodes if unprotected
Fire resistance	Good	Poor for high temperature

2.7 Student apartment's architectural layout

The term "student apartment" usually describes an off-campus living arrangement created especially for students. These apartments are typically found close to college campuses and feature features like study areas, common areas, and easy access to public transportation that are specifically designed with students' needs in mind. Features like separate leases for each bedroom, furnished living areas, and rent that includes utilities are common in student apartments. Dorms and apartments differ in that whereas dorms frequently have shared rooms and common areas, apartments typically offer more privacy, with separate bedrooms and occasionally private bathrooms (Blimling, G. S., 2015).

2.7.1 Essential student apartment elements with standard dimension

Essential components of a standard-sized student flat when designing a student apartment, it's important to include features that guarantee comfort, safety, and functionality. The following are the main components along with their typical sizes:

2.7.1.1 Living Room

The living area Students can rest and mingle in the living room as a common area. Typical Sizes: According to The American Institute of Architects (2016), a student apartment's living room typically has a size of between 12 and 18 square meters (The American Institute of Architects, 2016).

2.7.1.2 Kitchen

Essential equipment and storage should be accommodated in a small but efficient kitchen found in a student apartment. According to Joseph De Chiara and Michael J. Crosbie (2001), the standard kitchen dimensions should be at least 6 to 10 square meters (Joseph De Chiara and Michael J. Crosbie, 2001).

2.7.1.3 Double bedroom

A bedroom with two beds, there is enough space in a double bedroom for two students to study and sleep. Standard Size: 12 to 15 square meters, on average (The American Institute of Architects, 2016).

2.7.1.4 Single bedroom

Just one bedroom and individual study space are provided by single bedrooms. Approximate standard dimensions are between 9 and 12 square meters (Joseph De Chiara and Michael J. Crosbie, 2001).

2.7.1.5 Corridors

Corridors in order to comply with construction requirements for egress, corridors must offer clear, safe passage. Standard Dimensions: According to the International Code Council (ICC), 2021, a minimum width of 1.2 meters (International Code Council (ICC), 2021).

2.7.1.6 Windows

Windows ought to let in fresh air and natural light. Standard Measurements: 0.6 to 1.2 meters in width and a minimum height of 1 meter, depending on the space (International Code Council (ICC), 2021).

2.7.1.7 Doors

For both safety and accessibility, doors need to be the right size. Standard Dimensions: According to the International Code Council (ICC), 2021, outside doors must measure at least 0.9 meters wide, while interior doors must measure at least 0.8 meters wide (International Code Council (ICC), 2021).

2.7.1.8 Full Bathroom

Complete Bathroom Ba design should provide enough space to meet basic hygienic requirements. Standard Dimensions: According to The American Institute of Architects (2016), full bathrooms normally have between 3.5 and 5 square meters (The American Institute of Architects, 2016).

2.7.1.9 Exit ways

Exit methods must be followed to guarantee a prompt and safe evacuation in case of emergency. Standard Dimensions: The distance from any place in the building to the closest exit should not be greater than 3 meters, with a minimum width of 1.2 meters (International Code Council (ICC), 2021).

2.8 Importance of Architectural Drawing to structural design

The value of architectural drawings in structural engineering as the fundamental blueprints that describe the general arrangement, measurements, and spatial relationships of different building components, architectural drawings are essential to structural design. By guaranteeing that the load-bearing walls, beams, and columns, among other structural elements, are smoothly interwoven with the architectural vision, these drawings enable precise and effective building operations. They offer thorough specifications that help structural engineers create support systems that are both secure and visually beautiful, avoiding expensive mistakes and guaranteeing adherence to building rules (International Code Council (ICC), 2021).

2.9 General requirements of good architectural design

Context integration, sustainability, beauty, and utility are all components of good architectural design. It should be user-friendly, accommodating, and practical in order to fulfill the needs of its users. It must blend in with its surroundings harmoniously, enriching the local area and reflecting historical and cultural circumstances. Sustainability, which reduces environmental effect by using eco-friendly materials and energy-efficient systems, is essential. In addition, the design must be robust enough to endure both natural and artificial difficulties. Highlighting these principles, The American Institute of Architects' "Architectural Graphic Standards" is a thorough handbook for architects and designers (The American Institute of Architects, 2016).

2.10 Applicable load on the building

When a force is given to a structure or component either statically or dynamically causing stresses and deformations, the structure or component is said to be under load. These forces can be produced by a wide range of variables, including gravity, wind, seismic activity, temperature changes, and live loads like people or moving machines. The primary types of loads include dead loads, living loads, wind loads, and seismic loads. These are the specifics for every kind:

2.10.1 Dead load

The constant, static forces operating on a structure are known as dead loads. The weight of the fixed fixtures and structural components is one of these forces. The weight of the walls, ceilings, floors, and permanent fittings are typical figures. Concrete, for instance, weighs about 24 kN/m3 (International Code Council (ICC), 2021).

2.10.2 Live load

Live loads" are temporary or movable pressures that the structure has to support, such people, furniture, and mobile equipment. The Normal Values for ICC (International Code Council) in 2021: For residential buildings, the live load is typically 1.92 kN/m^2 for floors and 4.79 kN/m^2 for corridors (International Code Council (ICC), 2021).

2.10.3 Wind load

The forces that wind pressure applies to the outside surfaces of a building are known as wind loads. Normal Values: Building height, exposure type, and wind speed are among the variables that are used to calculate wind loads. For instance, many locations typically experience winds of 40 m/s (American Society of Civil Engineers (ASCE), 2017).

2.10.4 Seismic load

The forces that an earthquake applies to a building's construction are known as seismic loads. Normal Values: The base shear must be calculated and applied through the building's height in seismic design. This is dependent upon variables including the location of the building, the kind of soil, and the significance factor (Michael R. Linderburg and Kurt M. McMullin, 1990).

2.10.5 Snow load

The weight of all the snow that has collected on the roof is referred to as the "snow load. “Means: The American Society of Civil Engineers (ASCE) states that there can be significant geographical variations in the ground snow load, which can range from 0.48 kN/m^2 to over 2.87 kN/m^2 (American Society of Civil Engineers (ASCE), 2017).

2.11 Safety of reinforced concrete structures

For reinforced concrete constructions to be safe and useful, they must follow a set of rules. Usually, these needs include:

2.11.1 Strength requirements

Concrete elements have to be built strong enough to support loads including wind, gravity, and seismic forces without collapsing. In order to avoid failure, this entails making sure that the stresses in the concrete and reinforcing bars stay below specific thresholds (Jack C. McCormac and Russell H. Brown, 2015).

2.11.2 Serviceability

In addition to being strong, structures also need to meet serviceability requirements, like keeping vibrations and deflections within reasonable bounds. While severe vibrations can cause pain or even structural damage, excessive deflections can impair the structure's appearance and functionality (MacGregor, James K. Wight and James G., 2012).

2.11.3 Durability

Over the course of their intended service life, concrete structures must be able to tolerate environmental conditions such moisture, chemical exposure, and temperature changes. To guarantee long-term endurance, proper concrete mix design, cover thickness, and 34 protective measures are necessary (Edward G. Nawy).

2.11.4 Construability

To guarantee the project's timely and economical completion, the design should take into account the ease of building as well as the availability of labor and supplies. During the design process, practical considerations such formwork design, reinforcing detailing, and construction sequencing should be made (MacGregor, James K. Wight and James G., 2012).

2.12 Reinforced Concrete Method

Reinforced concrete (RC) structures are designed using numerous approaches tailored to certain structural aspects and aims. Some common design methods are:

2.12.1 Working Stress Method

This classic method assesses material stresses under working loads and ensures they are within acceptable limits. The process involves estimating concrete and reinforcement stresses under service loads and comparing them to permitted stresses (Athur H. Nilson, David Darwin, and Charles W. Dolan).

2.12.2 Ultimate Strength Design (USD)

Also known as Load and Resistance Factor Design (LRFD), aims to ensure a structure can withstand ultimate loads with adequate safety margins. According to Jack C. McCormac and Russell H. Brown (2015), reinforcement requirements are determined based on material strength, load combinations, and resistance (Jack C. McCormac and Russell H. Brown, 2015).

2.12.3 Limit State Design (LSD)

Takes into account both the ultimate limit state (ULS), where the structure can collapse or become dangerous, and the serviceability limit state (SLS), where the structure may experience excessive deflections or vibrations. The goal is to guarantee the structure is safe and functional under all loading circumstances (MacGregor, James K. Wight and James G., 2012).

2.12.4 Finite Element Method (FEM)

Finite Element Method is a numerical technique for studying complicated structural systems. It divides the system into smaller elements and solves for their behavior. This enables more precise simulation of non-linear behavior and interaction effects in RC structures (Zdenek P. Bazant and Luigi Cedolin).

The decision between design methods is based on structural complexity, design objectives, and applicable building rules and standards. Each method has advantages and limits.

2.13 Important structural concepts

2.13.1 Finishes, services and partition

- **Finishes**

Finishes refer to the final layers or surfaces applied to the walls, floors, ceilings, and other parts of a building. These layers are what is visible and touchable, and they serve both aesthetic and functional purposes (Ching & Francis D.K., 2014).

Examples: Wall paint, flooring materials like tiles or carpets, ceiling finishes like plaster or suspended ceilings, and exterior finishes such as cladding or stucco. Finishes can also include elements like trim, molding, and surface treatments that protect the underlying structural elements and enhance the appearance of the space.

- **Services**

Services in a building context refer to the essential systems that ensure the building functions properly and meets the needs of its occupants. These systems are integral to the operation, safety, and comfort of the building (Ching & Francis D.K., 2014).

Examples: Electrical wiring, plumbing systems, heating, ventilation, and air conditioning (HVAC), fire protection systems, lighting, and telecommunications. These services are often concealed within walls, floors, and ceilings but are critical for the building's usability and performance.

- **Partitions**

Partitions are non-load-bearing walls or dividers that separate spaces within a building. They do not support structural loads but are essential for creating rooms, corridors, and other enclosed spaces within the interior layout (Ching & Francis D.K., 2014).

Examples: Gypsum board (drywall) partitions, glass partitions, or movable partitions like office cubicles. Partitions can be permanent or demountable, allowing for flexibility in how spaces are configured. They also often contain elements like doors, windows, and openings to facilitate movement and light.

2.13.2 Moment

Moment is defined as the tendency of a force to cause rotation about a specific point or axis. It is a measure of the turning effect produced by a force acting at a distance from a point of reference, typically the center of a structural element like a beam or column (Ching & Francis D.K., 2014).

2.13.3 Area of Steel Required:

This is the calculated amount of steel reinforcement needed to safely resist the tensile forces in a concrete element. It is determined based on the design loads, material strengths, and the element's geometry (Ching & Francis D.K., 2014).

Purpose: Ensures that the concrete structure can handle the expected loads without excessive cracking or failure

2.13.4 Area of Steel Provided

This refers to the actual amount of steel reinforcement that is placed in the concrete element. It should meet or exceed the required area of steel to ensure the structural integrity of the element.

Purpose: To verify that the design intent is met during construction, ensuring the structure will perform as expected (Ching & Francis D.K., 2014).

2.13.5 Minimum Area of Steel:

This is the least amount of reinforcement steel that must be provided in a concrete element, regardless of the calculated requirements, to control cracking and ensure ductility. The minimum area is often specified by building codes or standards.

Purpose: Ensures that even if the calculated required steel is very low, there is enough reinforcement to handle unexpected loads or to limit crack widths (Ching & Francis D.K., 2014).

2.13.6 Maximum Area of Steel:

This is the upper limit of steel reinforcement that can be placed in a concrete element. The maximum area is limited to ensure that the concrete can properly bond with the steel and that the structure does not become too rigid, leading to potential issues such as brittle failure.

Purpose: Prevents over-reinforcement, which could lead to reduced structural ductility and other practical issues such as difficulties in placing and vibrating concrete (Ching & Francis D.K., 2014).

2.13.7 Importance in Structural Design

Ensuring the right balance between the required, provided, minimum, and maximum areas of steel is critical in designing safe, efficient, and durable concrete structures (Ching & Francis D.K., 2014).

2.13.8 Moment of resistance (MRC)

The moment of resistance refers to the capacity of a structural element, such as a beam or slab, to resist bending moments. It is essentially the internal moment that the element can develop to counteract the external loads applied to it, ensuring that the structure remains stable and does not fail (Ching & Francis D.K., 2014).

2.13.9 Deflection

Deflection refers to the degree to which a structural element, such as a beam, slab, or column, bends or displaces under a load. It is a measure of how much a structural element deforms due to applied forces, such as the weight of the building materials, occupants, and other loads (Ching & Francis D.K., 2014).

2.13.10 Shear Force

Shear force is a force that acts parallel to the cross-section of a structural element, causing it to shear or slide over an adjacent section. In beams, shear forces arise from loads applied perpendicular to the element, such as distributed loads on a beam (Ching & Francis D.K., 2014).

2.13.11 Ultimate Shear

Ultimate shear refers to the maximum shear force a structural element can withstand before failure occurs. This is a critical design consideration to ensure that the element does not fail under expected loads (Ching & Francis D.K., 2014).

2.13.12 Pushing Shear

This term is less commonly used, but it generally refers to a shear force that pushes or compresses parts of a structural element against each other, potentially leading to a shear failure (Ching & Francis D.K., 2014).

2.13.13 Face Shear

Face shear typically refers to the shear stress that occurs at the interface between different materials or components, such as where a beam connects to a column or where a slab interfaces with supporting walls (Ching & Francis D.K., 2014).

2.13.14 Stair Members

These are the various structural elements that make up a staircase, including treads, risers, stringers, and landings. Each member serves a specific function in supporting and providing access between floors (Ching & Francis D.K., 2014).

2.13.15 Goings

The going is the horizontal distance from the front of one tread to the front of the next tread, essentially the depth of each step excluding the nosing. Proper going dimensions ensure comfortable stair use (Ching & Francis D.K., 2014).

2.13.16 Risers

Risers are the vertical elements between each tread in a staircase. They determine the height of each step and are critical in ensuring that stairs are both safe and comfortable to use (Ching & Francis D.K., 2014).

2.13.17 Landing

A landing is a flat platform located between flights of stairs or at the top or bottom of a staircase. Landings provide rest areas, change of direction, or access points (Ching & Francis D.K., 2014).

2.13.18 Flight

A flight is a continuous series of steps without a landing. Stairs can have one or more flights depending on the building design (Ching & Francis D.K., 2014).

2.13.19 Crack Control

Crack control refers to measures taken in the design and construction of concrete structures to prevent excessive cracking due to tensile stresses. This may include appropriate reinforcement and control joints (Ching & Francis D.K., 2014).

2.13.20 Lever Arm Factor

This is a factor used in the calculation of bending moments in reinforced concrete design. The lever arm is the distance between the line of action of the force and the point about which the moment is being calculated (Ching & Francis D.K., 2014).

2.13.21 Ultimate Moment

The ultimate moment is the maximum moment that a structural element can withstand before it fails in bending. It's a critical factor in the design of beams and slabs (Ching & Francis D.K., 2014).

2.13.23 Factored Load:

A factored load is the design load that has been multiplied by a load factor to ensure a safety margin in structural design. This load considers potential uncertainties and increases the reliability of the structure (Ching & Francis D.K., 2014).

2.13.24 Unfactored Load

The actual or nominal load that the structure is expected to carry under normal conditions, without any safety factors applied (Ching & Francis D.K., 2014).

2.13.25 Tributary Area of Column

The tributary area is the area of the floor or roof that contributes load to a specific column. It's used to calculate the load that each column must support (Ching & Francis D.K., 2014).

2.13.26 Real Pressure

This refers to the actual pressure exerted on a structural element, typically considering both dead loads (permanent) and live loads (temporary). It's the pressure that needs to be resisted by the element (Ching & Francis D.K., 2014).

2.13.27 Design Stress

Design stress is the stress that a material or structural element is expected to resist during its lifetime, considering safety factors. It is usually lower than the material's ultimate stress to ensure durability and safety (Ching & Francis D.K., 2014).

2.14 Cost and estimation

The overall construction cost was calculated using a blend of the unit cost method, the quantity takeoff technique, and the bottom-up estimating approach. The integration of these three methodologies was crucial in attaining the desired result. We have not to forget that the first floor is identical the second and the third and on the third we just have additional railings on the top part.

2.14.1 Calculation of material Quantities

2.14.1.1 Reinforced concrete

The amount of material in each cubic meter of reinforced concrete varied based on local construction practices and other criteria, such as the required strength. The reinforced concrete was measured in cubic meters.

Depending upon the particular structural needs of the project, the quantity of reinforcement contained in a cubic meter of concrete can vary significantly. However, the amount of steel reinforcement in a typical reinforced concrete construction could range from 80 to 250 kg per cubic meter of concrete. Reinforcement can take several forms, including wire mesh, steel bars, and other structural steel components. We'll take into account 170 kg of reinforcements on average per cubic meter.

Item	Amount	Unitary price	Total price
Cement (kg)	400	232,5	93.000
Aggregates (kg)	1000	85	102.000
Water (l)	160	Negligible	Negligible
Steel reinforcements(kg)	170	1.500	255.000
Total			450.000

Note that these are approximations and could vary depending on the project's specifics, local material availability, and the necessary strength of the concrete. Around 450.000 Rwf is the approximate cost of one meter of reinforced concrete. Concrete reinforced with steel was used to make slabs, beams, columns, and the base footings of the columns.

A. Beam

- Length of beams on one floor: 271.8m
- Beams thickness: 0.4m
- Beam height: 0.55m
- RC volume needed for one floor: $271.8 * 0.65 * 0.3 = 70.6 \approx 71m^3$

  The amount of m^3 to be used on balconies beam is include this rounding quantity.

B. Column

- Cross section area of column: $0.16m^2$
- Height of column: 3m

- RC volume needed: 3m * 0.16 = 0.48 m^3
- RC volume needed for all columns on one floor = 0.48 * number of columns

= 0.48 *39

=18.72 $m^3 \approx 19\ m^3$

C. Slab

- Slab thickness: 0.15m

Ground floor

- Slab length: 22.19m
- Slab width: 19.4m
- RC volume needed: 0.15 * 22.19 * 19.4 = 64.6 $m^3 \approx 65\ m^3$

Frist floor

- Area of slab: Ground slab + balconies slabs(10.2m^2) *4=471.48 m^2
- RC volume needed: 0.15 * 471.48 = 70.722$m^3 \approx 71\ m^3$

D. Footing

- Footing area: 6.25m^2
- Footing depth: 0.6m
- RC volume needed: 6.25 * 0.6 = 3.75m3 for one concrete pad footing
- RC volume needed for all footings provided = 3.75m^3 * number of footings

=3.75m^3 * 39 = 146.25 $m^3 \approx 147\ m^3$

2.14.1.2 Wall plastering, floor tilling and painting

For wall plastering and painting the unit to be used is square meter as the plaster and the painting is going to be applied on surfaces. We will consider the m^2 which will not be used (reserved for balconies) for plastering and painting as the wastage in order to be sure the entire surfaces are well plastered or painted. The price for plaster to be applied on 1m^2 is 15.000 Rwf, the price of paint to be applied on 1m^2 is 45.000 Rwf and the price of floor tilling per square meter is 80.000 Rwf.

A. Wall plastering

Length of walls

- Ground floor: 271.8 m
- First floor: 271.8m+balconies wall length= 271.8m+40.8=312.6m

We have different height for application of plaster:

- For balconies = 40.8m*1m= 40.8m^2
- For normal wall = 271.8m*3m= 815.4m^2
- Total area to be plastered= 40.8+815.4=856.2m^2

As plastering will be done for interior and exterior: 856.2m^2*2= 1712.4 m^2

B. Wall painting

The area to be painted is equal to the area to be plastered=1712.4 m^2

C. Floor tiling

For the ground floor= 430.68 m^2

For the first floor= 471.48 m^2

2.14.1.3 Masonry walls

The masonry wall was evaluated as followWall length: 271.8m

To calculate the volume of bricks and mortar needed to build a wall with a length of 271.8 meters and a wall thickness of 20 cm (0.2 meters), we need to consider the dimensions of the wall and the area of the individual components (bricks and mortar). Let's break down the calculation step by step:

A. Bricks amount

Ground floor

- Wall length: 271.8 m
- Wall height: 3m
- Wall area: 815.4 m^2
- Standard brick dimension: 215mm*102.5mm*65mm
- Area of one brick including joints: (0.215+0.01) *(0.065+0.01) = 0.01685 m^2
- Number of bricks on one side of wall: area of wall/area of one brick= 815.4/0.01685=

48 392 bricks

- On the two side of a wall of 20 mm= 48392*2= 96 784 bricks
- Wastage (5%)= (96 784*5)/100= 4840 bricks
- Total amount of brick on Ground floor= 96 784+4840= 101 624 bricks

Frist floor

Total amount of bricks on first floor= amount of bricks on ground floor+ amount of bricks of balconies

Balconies bricks amount

- Wall length= 40.8 m
- Wall height= 1m
- Area of wall= 40.8 m^2
- Number of bricks on one side of the wall= 40.8/0.01685 m^2=2422 bricks
- On two side of a wall= 2422*2=4844 bricks
- Wastage (5%)= (4844*5)/100= 243 bricks
- Total amount of bricks = 5087 bricks
- Total amount of bricks on the first floor= 101 624+5087= 106 711 Bricks

1000 bricks cost 120000 Rwf

B. Volume of Mortar

Ground floor

The volume of mortar to be used correspond to volume occupying by joint in a floor:

- Area = 815.4m^2
- Volume of walls= 815.4*0.2=163.08 m^3
- Volume of one brick= 0.215*0.1052*0.065= 0.00147017 m^3
- Number of bricks= 163.08/0.00147017= 110 926 bricks
- Volume of one brick with joints= (0.215+0.01)*(0.1052+0.01)*0.065= 0.0016848 m^3
- Number of bricks= 163.08/0.0016848= 96795 bricks
- Difference= 110926-96795= 14131 bricks
- Volume of mortar= 14131*0.00147017= 20.77 m^3

First floor

- Area = 815.4+40.8= 856.2 m^2
- Volume of walls= 856.2*0.2=171.24 m^3
- Volume of one brick= 0.215*0.1052*0.065= 0.00147017 m^3
- Number of bricks= 171.08/0.00147017= 116 477 bricks
- Volume of one brick with joints= (0.215+0.01) *(0.1052+0.01) *0.065= 0.0016848 m^3
- Number of bricks= 171.08/0.0016848= 101639 bricks
- Difference= 110926-96795= 14838 bricks

  Volume of mortar= 14838*0.00147017= 21.81 m^3

2.14.1.4 Unit elements

Several elements were taken as unit; they are listed below with their prices

Doors

- Wooden door: 130 000 Rwf(0.9m*2.8m)
- Double entrance door (only on ground floor): 220 000 Rwf
- Double Sliding door: 180 000 Rwf(2.8m*2.8m)

Windows

Double hung-window:

- 150 000 Rwf(1.5m*1m)
- 75 000 Rwf(0.5m*0.5m)

Preliminary works

- Site clearing: (26.743m*43.684m)= 1168.24 m^2

1 m^2 cost 2000 Rwf

- Enclosure, shack and office: 2.000.000 Rwf

Sanitary appliances

Supply and installation of WC with all accessories and all requirements: 250.000 Rwf

Supply and installation ion of ceramic wash hands basin complete with accessories and all requirements: 100.000 Rwf

Earthwork

Excavation and site leveling: 6.500.000 Rwf

2.14.1.5 Curtain wall

Ground floor

- **front curtain wall**

Height= (height of wall+ bottom Slab thickness) = 3m+0.15m= 3.15m

Length= 5m+5m= 10m

Area= 10m*3.15m= 31.5 m^2

- **back curtain wall**

Height= 3.15 m^2

Length= 5+5+3= 13m

Area=40.95 m^2

Total area of curtain walls= 40.95 m^2+31.5 m^2=72.45 m^2

Frist floor

- **front curtain walls and back**

Height= (height of wall+ bottom Slab thickness) = 3m+0.15m= 3.15m

Length= 5m+5m+3m= 13m

Area= 13m*3.15m= 40.95 m^2

Total area of curtain walls= (40.95 m^2) *2=81.9 m^2

1m^2 of curtain wall cost 60 000 Rwf

2.14.1.6 Railing

First floor and on the top of third floor

Length on a floor= 10.2m*4= 40.8 m

Length on top of third floor= 36.8m+26.8+11.8m= 75.4m

1m of railing with glass cost 75 000 Rwf

Project Details:

Project Name: Architectural and structural design of a G+3 student apartment building: case of study Gasabo, Gisozi sector

Project Location: Kigali city

CHAPTER 3: METHODOLOGY

3.1 Introduction

The approach utilized to achieve the research objectives is described in this chapter. In order to gather all the information required for this study, a variety of data collection techniques were employed, including documentation, data collection from multiple sources, British standard design for the various structural elements, and various cost estimation techniques to determine the project's total cost. This chapter covers all of these techniques.

3.2 Description of the study area

The GIS4Mobile-X program was utilized to establish an overview of the study area's location. A flexible tool for geographic information system (GIS) applications is GIS4Mobile-X. It makes it possible for users to effectively gather, organize, and evaluate spatial data. Fieldwork and research projects benefit greatly from the app's many features, which include data capture, map viewing, and real-time data sharing. (Micheal N. DeMers, 2017)

The investigation was conducted in the Gisozi sector, Gasabo district, and Kigali City, one site point geographic coordinate: (-1.9170257,30.0564875). With a strong emphasis on the planned building location which is marked by a prominent blue figure that serves to highlight its significance within the larger context, the image below provides an exemplary illustration of the specified area for the building's location. It focuses on the intended building space, which is neatly defined by a conspicuous blue figure.

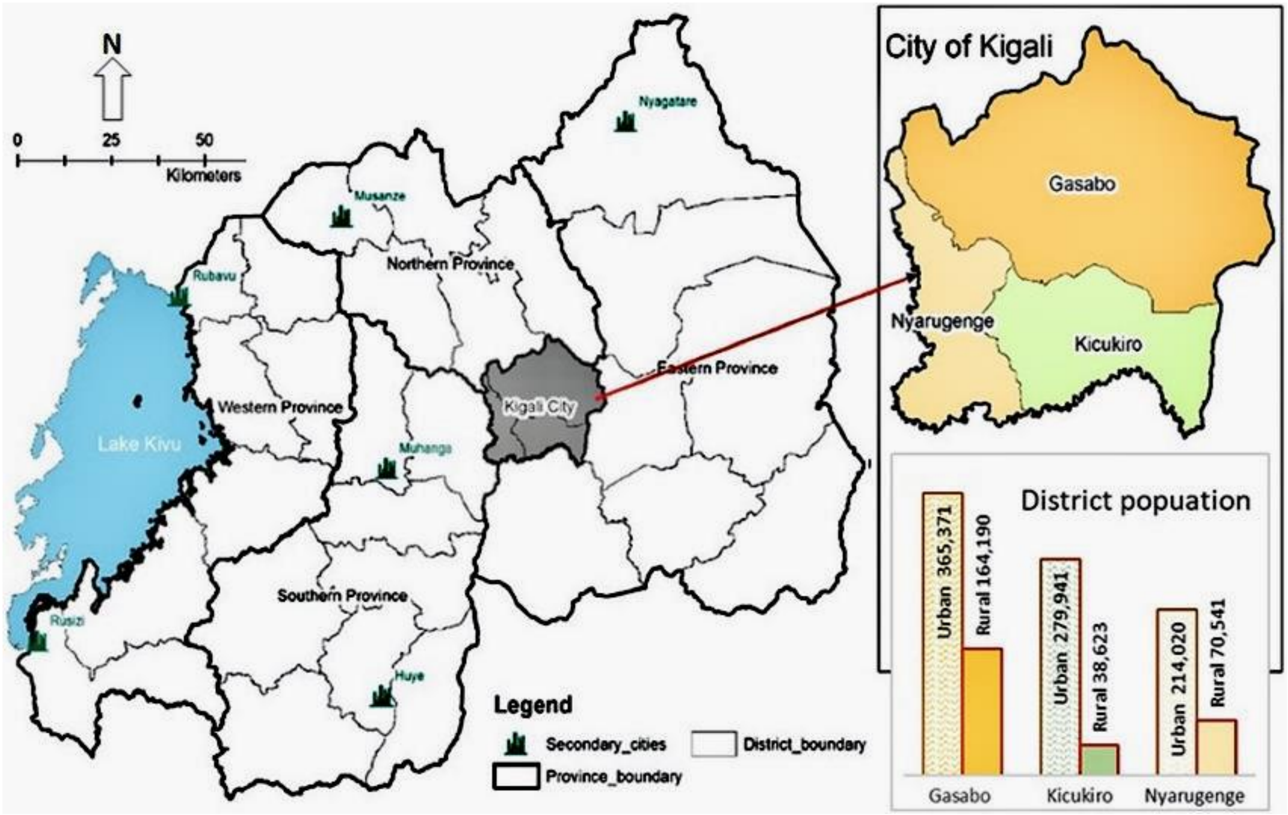


Figure 3.1: Map of Rwanda, Kigali and Gasabo

Figure 3.2: Site Location

3.3 Architectural design

Comprehensive architectural designs were carefully constructed after a thorough review of all building criteria. This ensures that the finished structure not only meets its intended purpose, but also has an aesthetically pleasing and harmonious design. Archicad software was used to rigorously develop these designs, which made the design process quick and easy. Using Archicad, architects were able to digitally model the building, accurately and completely capturing the intended construction's spatial layout, structural details, and aesthetic appeal. Through the careful blending of functional elements and artistic sensibility, the architectural drawings served as an essential medium for communicating the design purpose and facilitating fruitful cooperation with clients, engineers, and other stakeholders involved in the building process.

3.4 Structural Design

Prismatic sections are a typical element in multi-story buildings, especially in developing nations, where they are used to successfully resist applied stresses with minimal distortion between parts. The main objectives of structural design are to provide utility, serviceability, feasibility, aesthetics, and safe load receiving and transmission for the structure. By taking both economics and safety into account, the design process seeks to make the structural elements 20 beautiful, efficient, and cost-effective. Because of its adaptability, durability, fire resistance, and mold ability, reinforced concrete is widely used in a variety of structures, including buildings, tunnels, bridges, and more. Any construction can benefit from the design concepts covered here, given that data on axial force, shear, and moments are accessible along the length of each member. The design of our multistory building incorporates components that work well together, such as footings, beams, columns, and slabs. When used in accordance with best principles, concrete is a vital and dependable building material.

3.4.1 Slab design

The following guidelines and procedures were used in order to design the slab:

3.4.1.1 Slab choice

Selecting a slab panel First, the largest panel, known as the critical panel, have to selected in order to begin slab design.

3.4.1.2 Determination of type of slab

Condition:

If $l_y/l_x \leq 2$, the slab is a two-way slab

If $l_y/l_x > 2$, the slab is a one-way slab

Where:

Ly is long span and lx is the short span

3.4.1.3 Slab thickness

The thickness of the slab needs to fall between panel lx/20 and panel lx/40, where lx is the panel's shorter side and ly is the panel s longer side, slab thickness is represented by the letter (d).

3.4.1.4 Slab Effective height

Effective height (h_o)= slab thickness-concrete cover.

3.4.1.5 Load calculation

Slab holds two different load: dead load and live load.

3.4.1.5.1 Dead load

Dead load(GK) is the total weight of the slab, permanent fixtures, partitions, and non-movable building components like walls, columns, and mechanical systems. Live load refers to the transient and fluctuating loads brought on by individuals moving around the building, furnishings, equipment, and occupancy.

It divided into:

$w_c = 1.4 * d * \gamma_c * b$

Where:

w_c : is the self-weight of the slab

d: thickness of slab

γ_c: unit weight of slab

b: breath of slab(1m)

- Finishes= q+b

Where:

q: Self-weight of the slab

GK= w_c+ Finishes

3.4.1.5.2 Live load or imposed load

QK= 1.6* Imposed load from table of BS 6399: 1-1996

Where:

QK: live load

3.4.1.5.3 Design load

Design load is the addition of dead load and live load

n= GK+QK

where n is the design load

3.4.1.5.4 Bending moment calculation

The first step in calculating the bending moment was figuring out if the slab was one way or two ways. Than to identified the long and the short span because they have different formula for bending moment calculation, the bending moment was calculated respectively using the following formulas:

$Msx= \beta_{sx}*n*(l_x)^2$

$Msy= \beta_{sy}*n*(l_y)^2$

Where:

βsx and βsy are moment coefficient from table 3.14 of the code (BS 8110: 1-1997), they depend on the type of panel and value of l_y/l_x, and n is design load.

- l_x is the short side of the panel
- l_y is the long side of the panel

It important to know that during the design for moment we have to design for maximum moment among negative moment (M_{sx}^- and M_{sy}^+) and maximum moment among positive moments ($M_{sx}^+$and M_{sx}^-).

When we are doing slab design the following options for moment are adopted:

Option 1: Design of all moments (M_{sx}^-, M_{sx}^+, M_{sy}^- and M_{sy}^+)

Option 2: Design for all maximum moments (M_{sx}^- and M_{sy}^-) and maximum moment among positive moments (M_{sx}^+, M_{sy}+)

Four our design the option two will be use.

3.4.1.5.5 Shear Force calculation

The formula used to calculate shear force over the long span and the short span are:

$V_{sx}= \beta_{vx}*n*l_x$

$V_{sy}= \beta_{vy}*n*l_y$

Where: V_{sx} and V_{sy} are shear force coefficient from 3.15 of the code BS 8110-1:1997

Table 3.2: Ultimate bending moment and shear force in one-way spanning slab

	End support/ slab connection				At first interior support	Middle interior span	Interior support
	Simple		Continuous				
	At the outer support	Near middle of end span	At outer support	Near middle of end span			
Moment	0	0.086FL	-0.04FL	-0.075 FL	-0,086FL	-0.063FL	-0.063FL
Shear	0.04F	-	0.046F	-	0.6F	-	0.5F

Where:

- F is Ultimate design load (1.4 GK+1.6 QK)
- L is Effective span

3.4.1.5.6 Important data about the slab

- Span is a distance between to slab support (column)
- GK (dead load): According to BS 648:1964: “Schedule of weights of building material” and BS EN 1991-1-1:2002: “Eurocode 1: Action on Structures-Part 1-1: General Actions-Densities, self-weight, imposed loads for buildings” the density of reinforcement concrete is approximately 24 kn/m^3 and the thickness of slab to be used will be of 0.15 m.

  GK= 24 kn/m^3*015= 3.6 kn/m^2

  QK (imposed load) : is 1.5 Kn/m^2 (British Standard BS 6399-1:1996, "Loading for buildings. Code of practice for dead and imposed loads.")

3.4.1.5.7 Moment of resistant of concrete(MRC)

The maximum amount of force that a concrete segment can withstand without breaking is known as its moment of resistance. Ensuring that the structure can safely withstand the imposed loads is a crucial idea in structural design. (Ching & Francis D.K., 2014)

MRC= 0.156 $f_{cu}*b*d^2$ (fcu: compressive strength of concrete, b: width(1m), d: thickness of slab)

If M<MRC, no compression bars required

3.4.1.5.8 Slab area of steel calculation(As)

Known as the "steel ratio" or "reinforcement ratio," the area of steel reinforcement needed for a concrete slab is an essential component of structural design that guarantees the slab can bear applied loads without experiencing undue deformation or failure (Ching & Francis D.K., 2014).

K=M/(fcu*b*d^2), Kbal= 0.156, if K<Kbal there is no compression.

With: K: Lever arm factor

z= d(0.5+$\sqrt[2]{0.25 - \frac{K}{0.9}}$) $< 0{,}95d \text{ , } if\ not\ z = 0.95d$

As req= $\frac{M}{0.95 * fy * z}$, with As req: area of steel required

Area of steel provided will be find according to the Area of steel required by checking in the table of areas of groups of bars.

3.4.1.5.9 Slab Spacing calculation

Slab spacing, sometimes called slab joint spacing, is the term used to describe the typical space between joints in concrete slabs.

Spacing=As pro/ Area of steel

Area of steel=$\frac{\pi D * D}{4}$

Spacing= min(Smax,3h/4,16d)

Where

- Smax: Maximum spacing given by the standard (3d, with d effective depth)
- h: thickness of slab
- d: diameter of steel bar

As min= $\frac{0.13\ AC}{100}$ with AC=bd

As max=$\frac{4 * AC}{100}$

As min<As< As max condition is verified

If As< As min, (consider As=As min)

If As> As max, we have to redesign

3.4.1.5.10 Design for shear

The internal force that acts parallel to a slab's cross-sectional area is known as shear, and it is frequently the result of applied loads or responses. It is important for structural design because improper accounting for high shear forces can result in structural failure.

After choosing the section on which we will design for shear we have to make sure that we know if shear reinforcement is required or not, by comparing applied shear force we shear capacity.

- w=v=$\frac{V}{bd}$

With w or v: Applied shear force

- Ve=wc=$\frac{0.79(\frac{100\ As\ prov}{bd})^{\frac{1}{3}}(\frac{400}{d})^{\frac{1}{4}}(\frac{fcu}{25})^{\frac{1}{3}}}{1.25}$ with ve shear capacity

  Conditions:

i. $(\frac{100\ As\ prov}{bd})^{\frac{1}{3}}<3$

ii. $(\frac{400}{d})^{\frac{1}{4}}>1$

iii. $(\frac{fcu}{25})^{\frac{1}{3}} > 1$

If v<ve than no shear reinforcement required

3.4.1.5.11 Deflection check

Monitoring and controlling deflection is crucial to maintaining the structural integrity, functionality, and appearance of a building. Excessive deflection can lead to cracking, misalignment of finishes, and discomfort for occupants.

Basic span to effective depth ratio was found in the table 3-9 of the code BS 8110-1:1997.

M.F for tension reinforcements

- M.F= 0.55 +$\frac{477-fs}{120(0.9+\frac{M}{bd^2})}\leq 2.0$

  With : fs= $\frac{2}{3}fy*\frac{As\ req}{As\ prov}*\frac{1}{Bb}$

  Allowable span/d = basic span/d* M.F

  Actual span/d = span/d

  If allowable span/d< actual span/d the slab is satisfactory with respect to deflection.

3.4.1.5.12 Crack control

Long-term performance and longevity of the slab can be greatly enhanced by putting into practice efficient crack control techniques, such as appropriate reinforcing details, usage of control joints, and guaranteeing high-quality construction standards. The spacing between bars should not be greater than 3d, where d is effective depth.

3.4.2 Beam design

Design of beams The following procedures and conditions were followed in the beam design:

3.4.2.1 Initial design

The beam's basic dimensions, including its width, height, and flange, were determined through the preliminary design process. The following are the equations and requirements that influenced the first design:

The total height (ht) must fall in the range below:

(ly/15) ≤ ht ≤ (lx/8)

Where: Between two successive beams, Ly is the largest span.

The beam's breadth, or the width of the section, varies between:

0.5 ≤ (bw/ht) ≤ 1

The beam's flange (bf ') is to be the smaller of :

1. ly/3
2. lx/2
3. 12ht + bw

Cross-section of the T-beam is assumed to be:

$(ly/15) \leq h \leq (ly/10)$

3.4.2.2 Loading

Filling up If the following criteria are met, we can use the precise coefficients listed in table 3.14 of the BS code to determine the load on the beam.

3.4.2.3 Conditions

a) Characteristic Imposed load Qk can't go over the typical dead load Gk.

b) Over three or more spans, loads should be generally consistently distributed.

c) Variations in span length shouldn't go above 15% of the longest.
Dead load Gk is the total of

- Weight of slab = slab thickness * slab width * concrete unit weight
- Weight of down stand: bw* h* concrete unit weight
- Finishes

Imposed load = characteristic imposed load * slab width.

Uniformly distributed load, W= (1.4Gk +1.6Qk)

Design load per span, F= W*span

3.4.2.4 Reinforcement

The following formulas were used to compute the reinforcements once the ultimate bending moments and shear forces were determined:

3.4.2.5 Effective depth

The following formula was used to find the effective depth (d), or the distance between the top surface of the beam and the centroid of the tensile reinforcement: $f_{cu}bd^2$

$d = h - cover - \emptyset_{link} - (\emptyset_{main}/2)$

3.4.2.6 Calculating the lever arm factor (K)

$K = (M/ f_{cu}bd^2)$

3.4.2.7 Lever arm

$$\frac{Z}{d} = 0.5 + \sqrt[2]{0.25 - \frac{K}{0.9}} > 0.95$$

Where:

Z: The distance along the cross-section of the beam between the extreme fiber in compression and the centroid of the tensile reinforcement.

d: The beam's effective depth.

K: Lever arm factor, as previously mentioned in the answers.

In essence, the statement sets a requirement that the Z to d ratio must satisfy to guarantee that the beam would behave correctly when bent. This requirement aids in making sure that the concrete and tensile reinforcement cooperate well to withstand bending forces and offer structural stability.

3.4.2.8 Tensile reinforcement calculation

The necessary sum of tensile reinforcement can be computed with the following expression. This formula aids in figuring out how many and what size reinforcing bars are required to securely support any bending moments the beam might encounter over its service life.

$$As = \frac{M}{0.95\, f_y\, Z}$$

3.4.2.9 Shear reinforcements

The area of tensile steel reinforcement in the beam determines the number and spacing of shear reinforcements.

3.4.2.9.1 Shear stress calculation

- U =V=$\frac{V}{bd}$

With U or V: Shear stress

Where:

The shear stress is represented by U.

The highest shear force applied to the beam is shown by v.

The value b denotes the cross-sectional breadth of the beam. This refers to the beam's horizontal dimension that is perpendicular to its length.

d: This is the cross-sectional height (or depth) of the beam. It is the beam's vertical dimension.

3.4.2.9.1 Shear capacity

A formula for determining the critical shear stress in a reinforced concrete beam is represented by. In structural engineering, this formula is frequently used to determine a beam's cross-sectional shear capacity.

- Ve=wc=$\frac{0.79(\frac{100\ As\ prov}{bd})^{\frac{1}{3}}(\frac{400}{d})^{\frac{1}{4}}(\frac{fcu}{25})^{\frac{1}{3}}}{1.25}$ with ve shear capacity

Conditions:

iv. $(\frac{100\ As\ prov}{bd})^{\frac{1}{3}}<3$

v. $(\frac{400}{d})^{\frac{1}{4}}>1$

vi. $(\frac{fcu}{25})^{\frac{1}{3}} > 1$

If U<Ve than no shear reinforcement required

3.4.2.9.2 Shear ranges check

(Ʊc + 0.4) < Ʊ <0.8$\sqrt{f_{cu}}$

This statement aids in guaranteeing that the shear stress in the cross-section of the beam is contained within a range that is both safe and appropriate.

Uc: This stands for the critical shear stress, or the shear stress at which shear forces are anticipated to cause the beam to break. In terms of shear analysis, it's a crucial design parameter.

U: This is the shear stress that the imposed loads really cause the beam to experience. It is computed using the beam's size, external loads, and additional variables.

fcu: This represents the concrete's compressive strength in the beam.

- （Uc+0.4）<U

The critical shear stress (Uc) and an extra margin of safety (0.4) are included in this condition, which guarantees that the computed shear stress (U) is greater than a specific minimum value. To avoid shear failure, it is crucial to make sure that the actual shear stress is greater than this lower limit.

Ʊ < 0.8√(fcu)

This requirement establishes the maximum permissible shear stress (U) by taking the square root of the concrete's compressive strength (fçu). To avoid overstressing the beam's capacity, it is imperative to make sure that the shear stress stays below this upper limit.

3.4.2.10 Compression Modification factor

The steel reinforcement positioned within the compression zone of a reinforced concrete element, like a beam or column, is referred to as compression reinforcement. Compression reinforcement serves to improve the load-carrying capacity and ductility of the concrete part under compression, whereas tension reinforcement is intended to manage tensile stresses.

3.4.2.6.11 Modification factor of compression reinforcement

$$\mathbf{MF=1+}\frac{\frac{100\,As'\,prov}{bd}}{\frac{3+100As'\,prov}{bd}} \leq \mathbf{1.5}$$

Allowable span to effective depth ratio= Basic span to effective depth ratio* M.F tension reinforcement* M.F compression reinforcement

Actual span to effective depth ratio= Effective span/d

If allowable span to effective depth ratio is greater than actual span to effective depth ratio, the beam is satisfactory with respect to deflection.

After getting M, we continue with the same steps of the slab to get area of steel M.R.C, we compare it with M, we calculate as required and As provided, then we compare As provided with As max and As min, crack control and reinforcement details.

3.4.2.6.12 Check the Permissible Effective Span/Depth Ratio

- Depth ratio for a rectangular or flanged beam = 20.8
- Permissible Effective Span/Depth Ratio = Depth ratio*MF
- Calculate Actual Span/Depth Ratio:

Actual span/depth ratio = lx / d

- Span/Depth Ratio Comparison:

If the calculated actual span/depth ratio is less than the permissible ratio the span-to-depth ratio is within acceptable limits.

3.4.3 Column design

The design of the column involved identifying the most loaded internal column by calculating its influence area and total load on each floor segment of the column.

(Lex/h) < 15 and (Ley/b) < 15

3.4.3.1 Effective Height Calculation

An effective height calculation is based on the unbraced length (*L*o) and a coefficient (β) that considers the column's end conditions and lateral bracing. The relationship Le = βLo is used in structural engineering to determine if a column is classified as short.

Where:

- Le: stands for the column's effective height.
- Lo: stands for the column's unbraced length, or the separation between the braced points the places where the column is restrained from moving laterally.
- β: This coefficient, which is often referred to as the "slenderness ratio factor," describes how the column is supported and held in place to prevent lateral movement. Depending on the kind of column end conditions, it changes. The factor value of 0.75 indicates that our column is entirely constrained, as indicated by its classification in End condition 1.

The table 3.19 and table 3.20 of the code show the value of β for braced column and unbraced column respectively. In order to control cracking in the column β should be depend to $\frac{N}{bh\,fcu}$ this value will be found table 3.22 of the code

3.4.3.2 Load calculation

The overall load of the building's components and inhabitants is the load that our column is designed to support. Both transient (live load) and permanent (dead load) weights are included in this load. In order to safely support these loads, engineers compute and design columns that take reinforcement, size, and materials into account. This adds to the overall stability and safety of the structure by guaranteeing the column won't break or distort under the applied forces.

- Dead Load (Gk): The overall weight of the building's fittings, finishes, and structural components. It comprises additional immovable parts as well as the column's own weight.
- Live Load (LL): The varying and momentary loads brought on by people using the space, furnishings, machinery, and other transient loads. According to the BS regulation for apartment buildings, our building's live load value was 2 kN/m^2. However, the roof, which

was inaccessible save for maintenance, had a live load of 0.75 kN/m^2.

The necessary steel reinforcements were found by computing the unfactored and factored loads from the fourth floor to the ground floor.

3.4.3.3 Reinforcement calculation

$$AS = \frac{N - 0.35 * fcu * AC}{0.7 * fy}$$

Where:

As: This is the square millimeter (mm^2) area that needs to be filled with tensile reinforcement.

N: This is the axial load (given in Newton N) applied to the concrete member.

fcu: This is the concrete's compressive strength, which is commonly expressed in megapascals (MPa).

Ac: This indicates the concrete member's cross-sectional area, which is typically expressed in square millimeters (mm^2).

fy: This is the yield strength of the reinforcement steel, typically in megapascals (MPa)

The formula determines the area of tensile reinforcement needed to maintain equilibrium between the compressive strength of the concrete and the effects of the axial load. We guarantee that the member can sustain axial and bending stresses without losing its structural integrity by offering sufficient tensile reinforcement.

3.4.4 Foundation design

Footing area calculation

Footing area = (serviceability load +10% of serviceability load)/bearing capacity of soil

Footing real pressure calculation

Real pressure=$\frac{Unfactored\ load\_+10\%\ unfactored\ load}{footing\ area}$

The load per unit area that is really communicated from the foundation or footing of the structure to the underlying soil is referred to as footing real pressure, also known as actual bearing pressure or applied bearing pressure. It is computed by dividing the footing's total load by the area of the footing that is in contact with the ground. The real loads from the structure dead loads, living loads, and any additional imposed loads are included in this computation.

Ultimate bearing pressure(Pu) calculation

Ultimate bearing pressure=$\frac{Factor\ load}{Footing\ area}$

Pu stands for ultimate bearing pressure, which is the highest load per unit area that soil can support without experiencing undue settling or failure.

Reinforcement calculation

Calculation of reinforcements in structural engineering, the required area of tensile reinforcement for a reinforced concrete footing subjected to bending moment (M) is determined by applying the equation As=$\frac{M}{0.87\, fy\, z}$.

To make sure the footing can safely withstand the bending stresses and preserve its structural integrity, utilize this equation.

3.4.4.1 Check for face shear

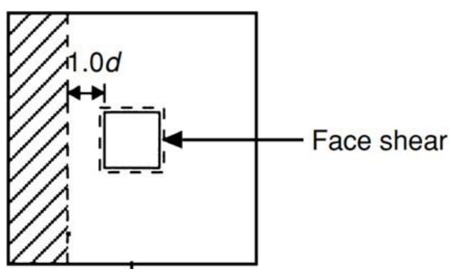


Figure 3.3: Face shear critical section (Chandrakant S. Arya, 2022)

Maximum shear stress Ʊ max occurs at face of column. Hence

$$Ʊmax = \frac{N}{\text{Column perimeter} * d}$$

Ʊ max must be inferior to $permissible\ shear\ which\ is$ $0.8\sqrt{fcu}$

3.4.4.2 Check for transverse shear

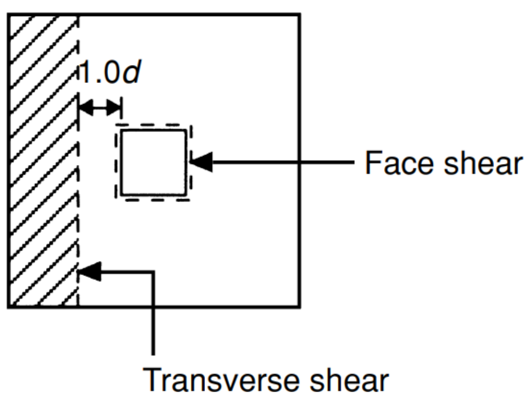


Figure 3.4 : Critical section for transverse and face shear (Chandrakant S. Arya, 2022)

*Ultimate shear force (V) = load on shaded area = earth pressure * area*

Design shear stress U is U= $\frac{V}{bd}$

If Uc>U no shear reinforcement will be required, if not provide shear reinforcements.

3.4.5 Stair Design

The staircase needs to be built with comfort in mind for people climbing it. It is necessary to verify the staircase's compliance. See if 550-2R+T<700, where T is the tread and R is the riser.

Keep in mind that T+1=R.

Procedures for Design:

Step 1: Determine the steps' effective length.

Step 2: Determine the steps' effective depth by calculating the L/d ratio.

Step 3: Determine the stair loadings

Step 4: Determine the Maximum Shear Force and Bending Moment

Step5: Verify the depth in relation to the bending moment

Step 6: Determine the necessary steel bars (As)

3.4.5.1 Loads on the staircase

Self-weight safety factor x thickness of the equivalent horizontal slab x 1m x 1m x unit weight of reinforced concrete.

Finish safety factor * finish thickness.

live load-safety factor (1.6) x live load of the stair

3.4.5.2 Required reinforcements

$$As= \frac{M}{0.95\, fy\, Z}$$

CHAPTER 4: RESULT AND DISCUSSIONS

4.1 Project description

With the increasing arrival of international students, the architectural and structural design of student apartments in regions like Gisozi faces several challenges. These challenges include accommodating cultural diversity, ensuring security, and providing an environment conducive to education, all within the constraints of budgetary and regulatory requirements. As Rwanda continues to develop its educational infrastructure, it is vital to establish living spaces that meet modern standards while promoting sustainable practices. This project, titled "Architectural and Structural Design of a G+3 Student Apartment," seeks to address these challenges and contribute to the enhancement of student living standards in Kigali, specifically in the Gisozi area, thereby supporting Rwanda's broader educational goals.

Architectural and Structural Design Solutions

The design of the G+3 student apartment building has been carefully crafted to address the multifaceted challenges identified in the problem statement. The building is designed to provide a high standard of living for both local and international students, incorporating features that cater to cultural diversity, security, and educational needs, while also being mindful of budgetary and regulatory constraints.

4.2 Architectural Design description

Each of the four apartments per level is designed to be a self-contained unit that balances privacy with community living, essential for fostering a culturally diverse environment.

- Bedrooms: The two bedrooms in each apartment, measuring 4.2m by 3.6m and 4.2m by 3.4m, are designed to accommodate students from various cultural backgrounds, providing a personal space where they can study and rest. These rooms are equipped with necessary amenities, ensuring that the living conditions are comfortable and conducive to academic success. The dimensions of the rooms are optimized to provide adequate space for movement and storage, ensuring that students from different cultures, who may have varying needs for personal space and belongings, feel accommodated.

- Living and Dining Area: The combined living and dining area (7.4m by 5m) serves as a communal space where students can interact, share meals, and engage in group studies. This space is crucial for fostering a sense of community among students from different cultural backgrounds. By providing a large, flexible area for social interaction, the design encourages the sharing of ideas and experiences, which is vital in a culturally diverse environment.
- Kitchen: The kitchen (1.8m by 5m) is designed with efficiency and sustainability in mind, equipped with modern appliances that are energy-efficient. This not only meets the needs of students who may wish to prepare their own meals according to their cultural preferences but also aligns with sustainable practices, an important consideration in modern architectural design.
- Bathroom: The bathroom (2.2m by 2.7m) is centrally located to ensure easy access from both bedrooms, featuring high-quality fixtures that are durable and easy to maintain. The design prioritizes hygiene and comfort, addressing the diverse needs of students from different cultures who may have varying expectations of bathroom facilities.
- Corridor: The 3-meter-wide central corridor not only facilitates movement but also serves as a crucial safety feature. It provides a clear escape route in case of emergencies, ensuring the security of all residents, a key consideration in student housing.
- Staircase: The central staircase (4m in length, 3m in height per flight) is designed for both safety and accessibility. Its location and design ensure easy movement between floors while contributing to the building's structural stability. This is particularly important in a student residence, where ease of movement and safety are paramount.
- Balconies: The inclusion of balconies starting from the first floor to the third floor provides students with private outdoor spaces, offering a place for relaxation or individual study. This feature is particularly appealing to international students who may appreciate private outdoor areas similar to those they are accustomed to in their home countries.
- Windows and Doors: The building is designed to maximize natural light and ventilation, with large windows (1.5m by 1m) that create a bright and airy interior environment. This is not only energy-efficient but also contributes to the well-being of the students, an important aspect of modern living standards.

4.3 Structural Design description

The structural design of the building is focused on ensuring safety, durability, and sustainability, all while keeping within budgetary and regulatory limits. The use of reinforced concrete in the columns, beams, and slabs ensures the building's resilience against both dead and live loads, including seismic forces, which is critical in ensuring the long-term safety of the residents.

- Foundation: The foundation is designed to support the building's weight and withstand the soil conditions specific to the Gisozi area. This is crucial in ensuring the building's stability, particularly in an area that may experience varying soil conditions.
- Load-Bearing Elements: The building's load-bearing elements are designed to distribute stress evenly, ensuring the structure's integrity and longevity. This design consideration is particularly important in a student residence, where the building will experience significant daily use.
- Roof: The flat roof is designed without access to enhance safety and reduce maintenance needs. It is constructed to be water-resistant and insulated, providing protection against the elements while contributing to the building's overall sustainability.
- Entrance: The main entrance features a 3-meter-wide door, designed to handle the flow of residents and guests efficiently. This feature is essential in ensuring that the building remains secure while also providing easy access for all residents.

This G+3 student apartment building is more than just a place to live; it is a carefully considered solution to the challenges posed by the arrival of international students in Kigali. By addressing the need for cultural diversity, security, and educational support, while adhering to budgetary and regulatory constraints, this project contributes to improving the standard of living for students in Gisozi. It aligns with Rwanda's educational objectives by providing a modern, sustainable living environment that supports both local and international students, ensuring that they have a safe, comfortable, and conducive place to live and study.

4.4 Structural design

The following table provides essential information for the structural design of an apartment building, including relevant design codes, characteristic strength of materials, intended use of the building, and general loading conditions:

Table 4.1: *Design description*

Relevant codes	BS 8110 -1-1997, BS 6399 -1-1996, BS 00648-1964-1999
Characteristic strength	Concrete: fcu= 25 MPa; fy= 460 MPa
Intended use of the building	Apartment building
Design codes	BS 8110 - 1:1997; Structural use of concrete - Part 1: code of practice for design and construction BS 6399 - 1:1996; Loading for buildings - Part 1: code of practice for dead and imposed loads BS 00648-1964-1999: weight of building materials
Soil Condition	Allowable bearing capacity: 300kN/m2(average bearing capacity of soil in the city of Kigali)
General loading conditions	Characteristic Live load: 2kN/m^3 Characteristic live load for a roof without access except for maintenance= 0.75kN/m^2 Finishes= 1KN/m^2 Services=1KN/m^2 Partitions=1KN/m^2 Unit weight of concrete = 24kN/m^3

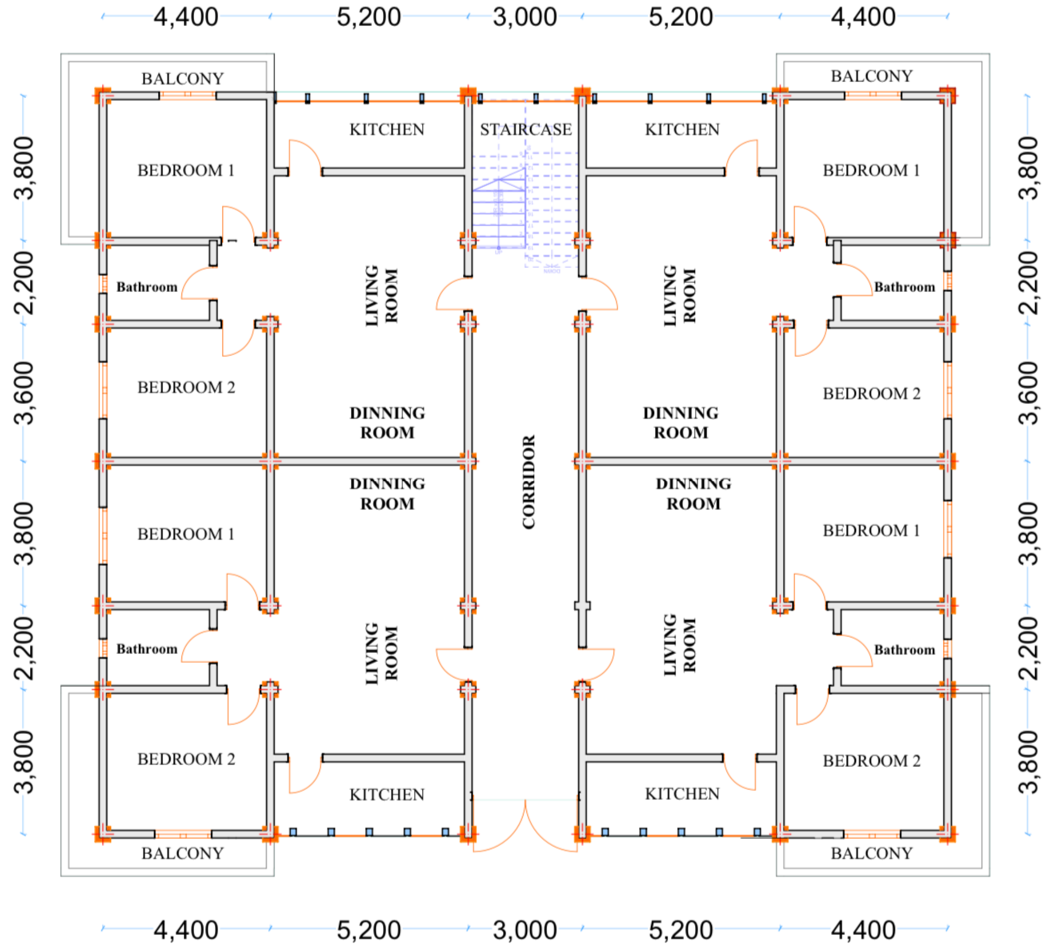


Figure 4.1 : Floor plan

The illustration above showcases the ground floor plan of the building, and since all the levels are uniform, it serves as a comprehensive representation of the floor plans for the entire building. The only difference is the entrance door and balconies. The entrance door is replace by curtain wall.

Figure 4.2: building perspective 1

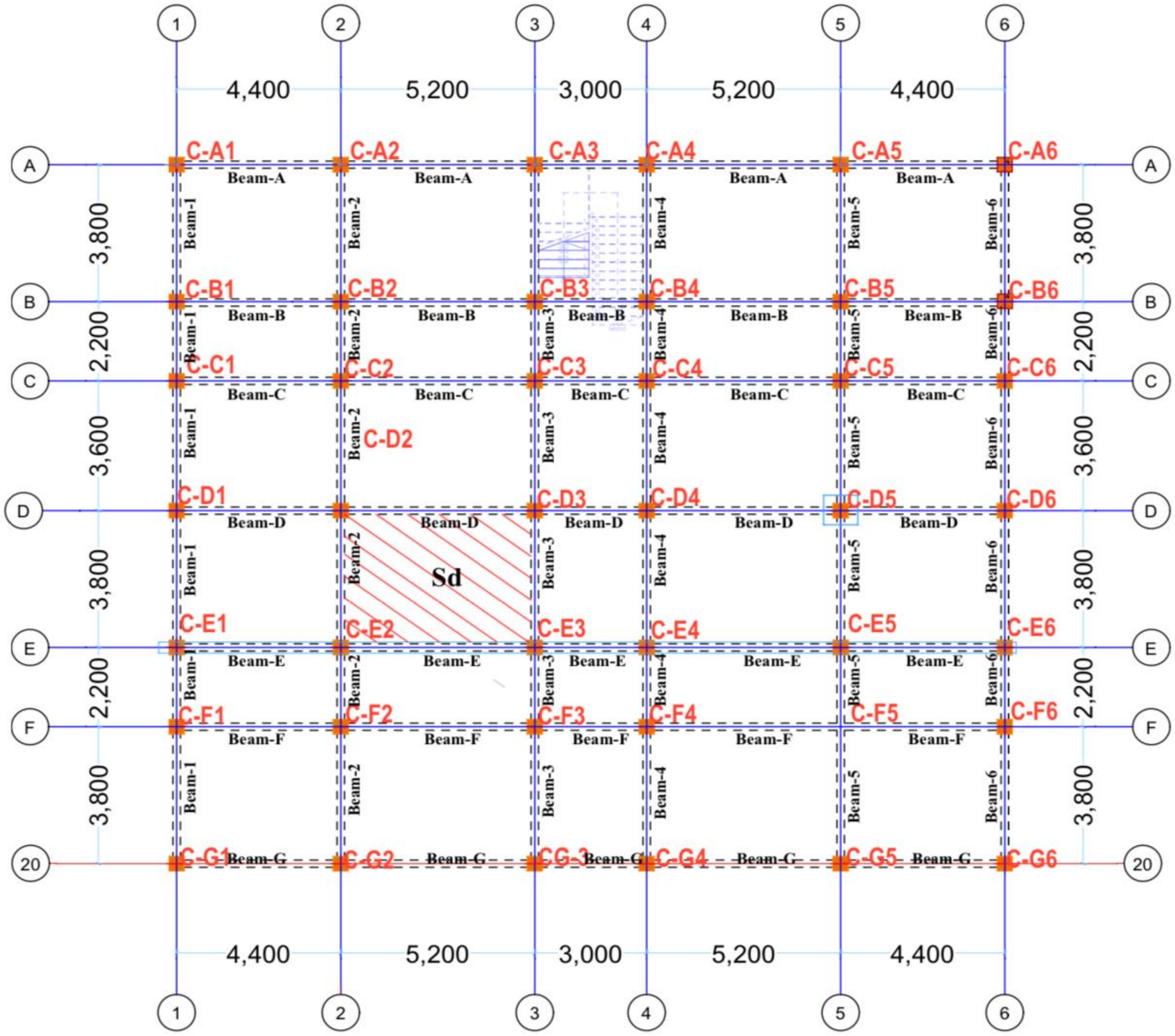


Figure 4.3: structural layout plan

Figure illustrate the structural layout plan with structural element to be design highlighted

4.4.1 Slab design

4.4.1.1 Assumption:

Cover :25mm

Bar diameter: 10mm

Choice of slab panel

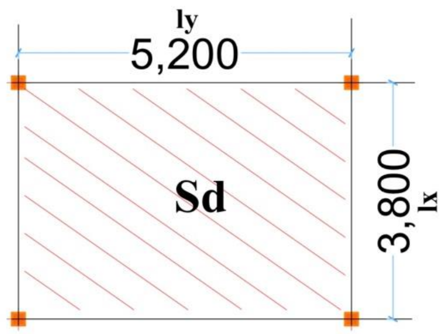


Figure 4.4 ***: Critical slab***

The slab panel to be design (critical panel) is the biggest panel in order to get the maximum slab thickness. We denote it by (sd) in the structural plan layout.

4.4.1.2 Type of slab

ly= 5.2m and lx=3.8m, ly/lx=5.2/3.8= 1.36<2, hence the slab is two-way

A two-way slab spanning in both x and y direction.

4.4.1.3 Preliminary sizing of slab

Thickness of slab(h)

H have to be between lx/40 and lx/20, lx/40= 0.095m and lx/20=0.19m. But let use the general range 12cm≤h≤20cm, let take h=15cm

Effective depth(d)

d=thickness of slab-nominal cover-$\frac{\Phi main\ bar\ diameter}{2}$ =15cm-2.5cm-$\frac{0.1cm}{2}$=12.45cm=124.5mm

4.4.1.4 Loading

Self-weight of the slab= γ concrete*thickness of slab= 24*0.15=3.6 kn/m^2

Characteristic dead load GK= Self-weight of slab+finishes+services+partitions

=3.6+1+1+1=6.6 kn/m^2

Design load(n)= (1.4*6.6+1.6*2) =9.24+3.2=12.44 kn/m^2

QK=2kn/m^2

For 1m width, n= 12.44 kn/m^2*1m=12.44 kn/m

4.4.1.5 Bending moment

Coefficient of bending moment corresponding to a interior panel, knowing ly/lx= 1.36 corresponding to 1.4

βsx^-=0.050 βsx^+=0.037

βsy^-=0.032 βsy^+=0.024

Msy= βsy*n*ly^2 and Msx= βsx*n*lx^2

Msy^-=0.032*12.44*5.2^2=10.76 knm

Msy^+=0.024*12.44*5.2^2=8.07 knm

Msx^-=0.050*12.44*3.8^2=8.98 knm

Msx^+=0.037*12.44*3.8^2=6.64 knm

As min=0.0013*b*h=0.0013*1000*150= 195 mm^2/m

4.4.1.6 Reinforcement calculation

4.4.1.6.1 Maximum moment is 8.07 knm (M max +ve)

MRC=0.156*fcu*b*d^2=0156*25*1000*124.5^2=60.45 knm

M< MRC, no compression bars are required

K=$\frac{M}{fcub^2}$ = $\frac{8.07*10^6}{25*1000*124.5^2}$ =0.02<0.156(kbal), no compression bars.

Z= d(0.5+$\sqrt{0.25-\frac{K}{0.9}}$) <0.95d = 0.98d>0.95d

Let us take Z=0.95d=0.95*124.5=118.275 mm

As req= $\frac{M}{0.95fyZ}$ = $\frac{8.07*10^6}{0.95*460*118.275}$ =156.13 mm^2

As min= $\frac{0.13\ AC}{100}$ =$\frac{0.13*h*b}{100}$ =$\frac{0.13*150*1000}{100}$ =195 mm^2

As max= $\frac{4\ AC}{100} = \frac{4*150*1000}{100}$ =6000 mm^2

As min>As req<As max the condition is not verified, As provide should be between As max but close to As min. As provide=262 mm^2 T10@300 c/c.

Panel	My(+)	K	Z/d	Z	As req	Select
1	8.07knm	0.02	0.98	118.275mm	156.13mm^2	T10@300c/c

4.4.1.6.2 Check for deflection (My(+))

M max(+ve) =8.07knm

Basic span/d= 26

M/bd^2=$\frac{8.07*10^6}{1000*124.5^2}$ =0.52

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

fs=$\frac{2}{3}$ $*$fy$*$ $\frac{As\ req}{As\ prov}*\frac{1}{Bb}$ =$\frac{2}{3}$ $*$460$*$ $\frac{156.13}{262}*\frac{1}{1}$ =239.39

M.F=0.55+$\frac{477-239.39}{120(0.9+0.52)}$ =0.55+1.39=1.94<2 OK!!!

Allowable span/d= basic span/d*M.F= 26*1.94=50.44

Actual span/d=lx/d=$\frac{3800mm}{124.5mm}$=30.52

Allowable span/d>Actual span/d, the slab section is satisfactory with respect to deflection.

4.4.1.6.3 M max(-ve) = 10.76knm

MRC=0.156*fcu*b*d^2=0156*25*1000*124.5^2=60.45 knm

M< MRC, no compression bars are required

K=$\frac{M}{fcub^2} = \frac{10.76*10^6}{25*1000*124.5^2}$ =0.02<0.156(kbal), no compression bars.

Z= d(0.5+$\sqrt{0.25-\frac{K}{0.9}}$) <0.95d = 0.98d>0.95d

Let us take Z=0.95d=0.95*124.5=118.275 mm

As req= $\frac{M}{0.95fyZ} = \frac{10.76*10^6}{0.95*460*118.275}$ =208.17 mm^2

As min= $\frac{0.13\ AC}{100}$ =$\frac{0.13*h*b}{100}$ =$\frac{0.13*150*1000}{100}$ =195 mm^2

As max= $\frac{4\ AC}{100}$ = $\frac{4*150*1000}{100}$ =6000 mm^2

As min>As req<As max the condition is not verified, As provide should be between As max but close to As min. As provide=262 mm^2 T10@300 c/c.

Panel	My(-)	K	Z/d	Z	As req	Select
1	10.76knm	0.02	0.98	118.275mm	208.17mm^2	T10@300c/c

4.4.1.6.4 Check for deflection (My(-))

M max(+ve) =10.76knm

Basic span/d= 26

M/bd^2=$\frac{10.76*10^6}{1000*124.5^2}$ =0.69

M.F=0.55+$\frac{477-fs}{120(0.9+\frac{M}{bd^2})}$ ≤ 2

fs=$\frac{2}{3}$ *fy* $\frac{As\ req}{As\ prov}$*$\frac{1}{Bb}$ =$\frac{2}{3}$ *460* $\frac{208.17}{262}$*$\frac{1}{1}$ =254.33

M.F=0.55+$\frac{477-254.33}{120(0.9+0.69)}$ =0.55+1.16=1.71<2 OK!!!

Allowable span/d= basic span/d*M. F= 26*1.71=44.46

Actual span/d=lx/d=$\frac{3800mm}{124.5mm}$=30.52

Allowable span/d>Actual span/d, the slab section is satisfactory with respect to deflection.

4.4.1.6.5 Mxs+= 6.64 knm

MRC=0.156*fcu*b*d^2=0156*25*1000*124.5^2=60.45 knm

M< MRC, no compression bars are required

K=$\frac{M}{fcub^2}$ = $\frac{6.64*10^6}{25*1000*124.5^2}$ =0.017<0.156(kbal), no compression bars.

Z= d(0.5+$\sqrt{0.25-\frac{0.017}{0.9}}$) <0.95d = 0.98d>0.95d

Let us take Z=0.95d=0.95*124.5=118.275 mm

As req= $\frac{M}{0.95fyZ} = \frac{6.64*10^6}{0.95*460*118.275}$ =128.46mm^2

As min= $\frac{0.13\ AC}{100} = \frac{0.13*h*b}{100} = \frac{0.13*150*1000}{100}$ =195 mm^2

As max= $\frac{4\ AC}{100} = \frac{4*150*1000}{100}$ =6000 mm^2

As min>As req<As max the condition is not verified, As provide should be between As max but close to As min. As provide=201 mm^2 T10@300 c/c.

Panel	Mxs(+)	K	Z/d	Z	As req	Select
1	6.64knm	0.017	0.98	118.275mm	128.46mm^2	T10@300c/c

4.4.1.6.6 Mxs-= 8.98 knm

MRC=0.156*fcu*b*d^2=0156*25*1000*124.5^2=60.45 knm

M< MRC, no compression bars are required

K=$\frac{M}{fcub^2} = \frac{8.98*10^6}{25*1000*124.5^2}$ =0.02<0.156(kbal), no compression bars.

Z= d(0.5+$\sqrt{0.25 - \frac{0.02}{0.9}}$) <0.95d = 0.98d>0.95d

Let us take Z=0.95d=0.95*124.5=118.275 mm

As req= $\frac{M}{0.95fyZ} = \frac{8.98*10^6}{0.95*460*118.275}$ =173.74mm^2

As min= $\frac{0.13\ AC}{100} = \frac{0.13*h*b}{100} = \frac{0.13*150*1000}{100}$ =195 mm^2

As max= $\frac{4\ AC}{100} = \frac{4*150*1000}{100}$ =6000 mm^2

As min>As req<As max the condition is not verified, As provide should be between As max but close to As min. As provide=262 mm^2 T10@300 c/c.

Panel	Msx(-)	K	Z/d	Z	As req	Select
1	8.98knm	0.02	0.98	118.275mm	173.74mm^2	T10@300c/c

4.4.1.6.7 Check for shear

Vsx= βvx*n*lx=0.43*12.44*3.8=20.32 kn

Vsy= βvy*n*ly=0.33*12.44*5.2=21.34 kn

V max=21.34 kn

U=$\frac{Vmax}{bd}$ =$\frac{21.34*10^3}{1000*124,5}$ = 0.17 N/mm^2

Vu=0.8$\sqrt{fcu}$=4.73 N/mm^2

U<Vu, then ultimate shear ok!!!

Vc=$\frac{0.79}{1.25}(\frac{100As}{bd})^{\frac{1}{3}}\ (\frac{fcu}{25})^{\frac{1}{3}}(\frac{400}{d})^{\frac{1}{4}}$

Vc=$\frac{0.79}{1.25}(\frac{100*262}{1000*124.5})^{\frac{1}{3}}\ (\frac{25}{25})^{\frac{1}{3}}(\frac{400}{124.5})^{\frac{1}{4}}$

Vc=0.63*058*1*1.33=0.48

Condition:

- $(\frac{100As}{bd})^{\frac{1}{3}}$<3 ok!!
- $(\frac{fcu}{25})^{\frac{1}{3}}$=1 ok!!
- $(\frac{400}{d})^{\frac{1}{4}}$>1 ok!!

U<Vc, 0.17 N/mm^2<0.48 N/mm^2, no shear reinforcement required.

4.4.1.6.8 Crack control

Allowed 3d spacing= 3*124.5=373.5mm

Maximum spacing=300 mm, spacing ok!!

The structure is satisfactory with respect to cracking

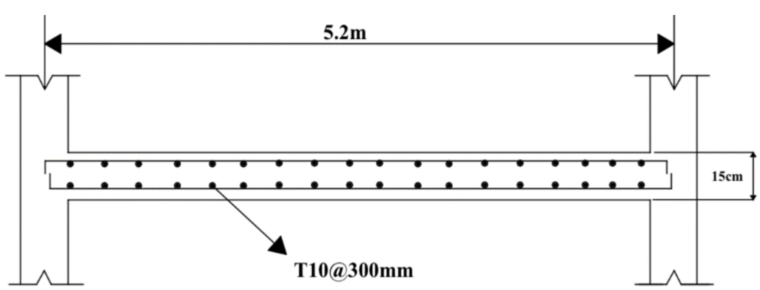


Figure 4.5: slab section details

4.3.1 Beam design

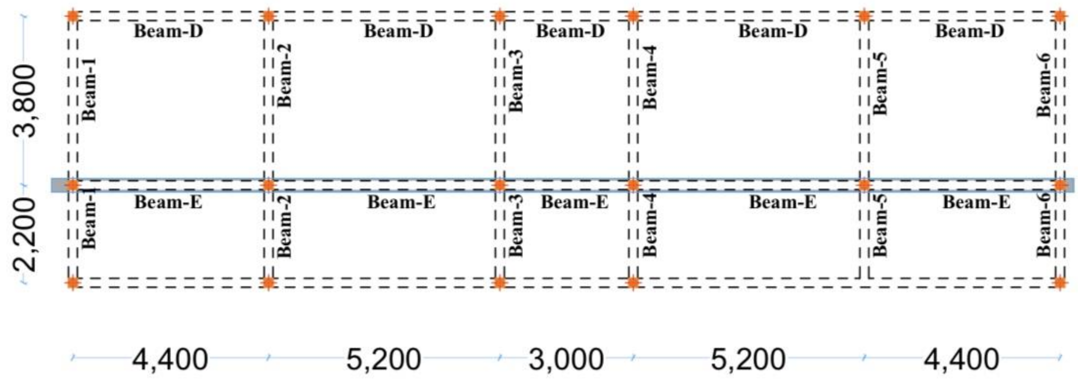


Figure 4.6: ***beam representation***

The total height (ht) of the beam has to be in range below:

$\frac{ly}{15} \leq$ ht $\leq \frac{ly}{8}$, $\frac{520cm}{15} \leq$ ht $\leq \frac{520cm}{8}$,34.66cm $\leq$ht$\leq$65cm

Let take ht as 65cm

The breadth of the section (width of the web) of the beam varies between:

$0.5 \leq \frac{bw}{ht} \leq 1$, 0,5*65 ≤ bw ≤ 1*65

32,5 ≤ bw ≤ 65

The breadth or width of the web of beam bw = 40 cm

The height of beam = 65 cm and width of beam=40cm

Dimension of beam T-section

bw= 40 cm

ht= 65 cm

4.4.2.1 Loading

Specific coefficients provided in BS

Conditions:

a) Characteristic imposed load Qk may not exceed characteristic dead load Gk.

b) Loads should be substantially uniformly distributed over three or more spans;

c)Variations in span length should not exceed 15 % of longest.

Dead load Gk is the sum of:

Weight of slab: slab thickness*slab width*Unit weight of concrete:0.15*3.6*24=12.96 kn/m

Weight of down stand: bw*h*unit weight of concrete: 0.4*0.4*24=3.84 kn/m

Finishes: 1.5*3.6= 5.4kn/m

Gk=12.96+3.84+5.4=22.2kn/m

Imposed load: characteristic Imposed load*slab width

Qk=2*3.6=7.2 knm

Design uniformly distributed load, w=(1.4Gk+1.6Qk)=31.08+11.52=42.6 kn/m

Design load per span, F=w*span= 42.6*5.2=221,52 kn

4.4.2.2 Design moment and shear forces

- Support A

Bending moment=0kn/m

Shear force, V=0.45*F=0.45*221.52=99.68 kn

- Span AB and EF

Bending moment=0.9*Fl=0.9*221.52*5.2=103.67 knm

Shear force, V=0kn

- Support B and E (Penultimate support)

Bending moment=-0.11*Fl=-0.11*221.52*5.2=126.70 knm

Shear force, V=0.6*F=0.6*221.52=132.91 kn

- Span BC, CD and DE

Bending moment=0.07*Fl=0.07*221.52*5.2=80.63knm

Shear force, V=0kn

- Support (C, D) Interior

Bending moment=-0.08*Fl=-0.08*221.52*5.2=-92,15knm

Shear force, V=0.55*F=0.55*221.52=121.83 kn

4.4.2.3 Reinforcement calculation

4.3.2.3.1 Span AB and ED (End Spans-bottom reinforcements)

Bending moment= 103.67knm

Effective flange width= bw+$\frac{0.7\,L}{5}$ =bw+$\frac{0.7*5200}{5}$ =1128 mm

The concrete cover on 8 mm links is 25 mm and if 16 mm main bars in vertical pairs are required, the effective depth will be:

d=h-cover-Φlinks-$\frac{\Phi main}{2}$ =650-25-8-16/2=609 mm

K=$\frac{M}{fcubd^2}$ = $\frac{103{,}67*10^6}{25*1128*609^2}$ = 0.0099< Kbal=0,156

No compression reinforcement required.

Z= d(0.5+$\sqrt{0.25-\frac{0.02}{0.9}}$) <0.95d = 0.98d>0.95d

Let us take Z=0.95d=0.95*609=578.55 mm

As=$\frac{M}{0{,}95fyZ}$ = $\frac{103.67*10^6}{0.95*460*578.55}$ = 410.04 mm^2

Provide 3T16(603 mm^2)

As min=$\frac{0{,}13\,Ac}{100}$ = $\frac{0{,}13*400*650}{100}$ =338 mm^2

As max=$\frac{4\,Ac}{100}$ = $\frac{4*400*650}{100}$ =10400 mm^2

As min<As req<As max ok!!

4.4.2.3.2 Support B and E (Penultimate support)

Bending moment= -126.70 knm

Effective flange width= bw+$\frac{0.7\,L}{5}$ =bw+$\frac{0.7*5200}{5}$ =1128 mm

The concrete cover on 8 mm links is 25 mm and if 16 mm main bars in vertical pairs are required, the effective depth will be:

d=h-cover-Φlinks-$\frac{\Phi main}{1}$ =650-25-8-16=601 mm

Since the beam is hogging, b= 400 mm

Mu=0.156*fcu*b*d^2=0.156*25*400*601^2=563.47 knm

Mu>M (126.70 knm) no compression reinforcement is required

Tension steel

K=$\frac{M}{fcubd^2}$ = $\frac{126.70*10^6}{25*400*609^2}$ = 0.03< Kbal=0,156

No compression reinforcement required.

Z= d(0.5+$\sqrt{0.25-\frac{0.03}{0.9}}$) >0.95d = 0.96d>0.95d

Let us take Z=0.95d=0.95*601=570.095 mm

As req=$\frac{M}{0,95fyZ}$ = $\frac{126.70*10^6}{0.95*460*570.95}$ = 507.8 mm^2

Provide 3T16(603 mm^2)

As min=$\frac{0,13\ Ac}{100}$ = $\frac{0,13\ *400*650}{100}$ =338 mm^2

As max=$\frac{4\ Ac}{100}$ = $\frac{4*400*650}{100}$ =10400 mm^2

As min<As req<As max ok!!

4.4.2.3.3 Span BC, CD and DE (Interiors span)

Bending moment= 80.63 knm

From above, effective depth= 609 mm and effective width of beam, b= 1128 mm, Z=578.55

As req=$\frac{M}{0,95fyZ}$ = $\frac{80.63*10^6}{0.95*460*578.55}$ = 318.91 mm^2

Provide 2T16(402 mm^2)

Let' provide for all beams 3T16 in tension (603 mm^2)

Shear reinforcements

The amount and spacing of shear reinforcement depends on the area of tensile steel reinforcement present in beam. The minimum tension steel at any point in 3T16, hence As provided= 603 mm^2

The maximum shear is at support B and E (V= 132.91 kn)

U=$\frac{Vmax}{bd}$ =$\frac{132.91*10^3}{400*601}$ = 0.55 N/mm^2

Vu=0.8$\sqrt{fcu}$=4 N/mm^2

U<Vu, then ultimate shear ok!!!

Vc=$\frac{0.79}{1.25}(\frac{100As}{bd})^{\frac{1}{3}}\ (\frac{fcu}{25})^{\frac{1}{3}}(\frac{400}{d})^{\frac{1}{4}}$

Vc=$\frac{0.79}{1.25}(\frac{100*603}{400*601})^{\frac{1}{3}}\ (\frac{25}{25})^{\frac{1}{3}}(\frac{400}{601})^{\frac{1}{4}}$

Vc=0.632*0.63*1*0.9= 0.358 N/mm^2

V>Vc, no shear reinforcement.

$As=2\frac{\pi\Phi^2}{4}$ Where Φ= 8mm

$As=2\frac{3.14*8^2}{4}$ = 100.48 mm^2

$sv=\frac{As*0.87*fy}{bw(U-Vc)} = \frac{100.48*0.87*460}{400(0.55-0.35)}$= 502.65 mm

sv max= 0.75d= 0.75* 601= 450.75 mm

Use spacing of sv= 200 mm

4.4.2.4 Check for deflection

$\frac{width\ of\ web}{effective\ depth\ of\ flange} = \frac{400}{1128}$=0.3

Basic span/effective depth ratio for a rectangular or flanged beam= 20.8

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

$\frac{M}{bd^2}=\frac{103.67*10^6}{1128*609^2}$ =0.247

$fs= \frac{2}{3}*fy*\frac{As\ req}{As\ prov}*\frac{1}{Bb} = \frac{2}{3}*460*\frac{410.04}{603}*\frac{1}{1}$ = 312.8

$M.F=0.55+\frac{477-312.8}{120(0.9+0.247)}$ =1.74<2

Permissible effective span/ depth= 20.8*1.74= 36.192

Actual span/depth ratio=lx/609=8.53

Actual span/d < permissible span/d, hence ok!!

We will use stirrups of 8mm diameter

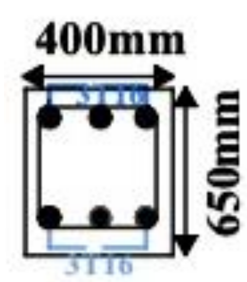


Figure 4.7: beam section details

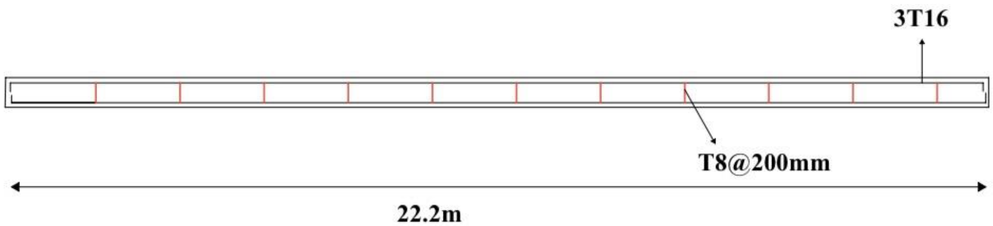


Figure 4.8 : beam elevation details

4.3.2 Column design

Here down is the most loaded column figure and its loaded area. The most loaded column is identified as the one witch support the largest slab.

For our case is C-D5

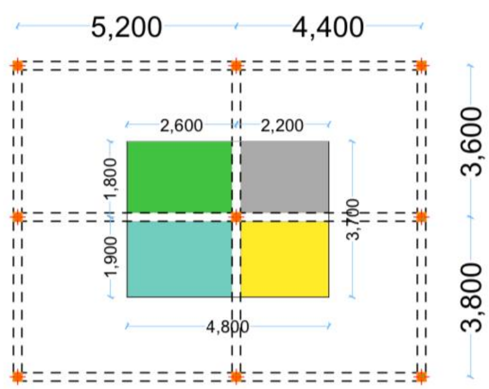


Figure 4.9 : *Column representation with influence areas*

Dimensions

We assume a 400 mm* 400 mm

The column is classified as being short if:

$\frac{lex}{h}$<$15 < \frac{lex}{h}$

Where:

lex: effective height in respect of the major axis

ley: effective height in respect of the minor axis

b: width of a column(dimension of cross-section perpendicular to h)

h: depth of cross-section measured in the plane under consideration

lex: overall height of the column-height of beam

ley: overall height of the column- effective depth of beam

overall height of the column= 3m= 3000 mm

h= 650 mm and d= 609 mm

lex= 3000 mm-650mm= 2350 mm

ley= 3000mm-609 mm= 2391 mm

$\frac{2350}{400}$<15 and $\frac{2391}{400}$<15

5.875<15 and 5.977<15

Our column is braced short column

le=βlo

where lo= clear height of column=overall height of the column-depth of the beam

=3000-609= 2391 mm

This coefficient, often called the "slenderness ratio factor," accounts for how the column is braced and restrained against lateral movement. It varies based on the type of column end conditions. Our column was classified the End condition 1 which signifies that the column is fully restrained and by that the value of the factor is 0.75

β=0.75

le=βlo= 0.75* 2391= 1793.25 mm

slenderness ratio λ=$\frac{le}{a}$ where a is the side of column

λ=1793,25/400=4.48

4.4.3 Loading

4.4.3.1 Column from roof to 3th floor

- **Load calculation on roof slab**

Self-weight of slab=24*0.15=3.6 kn/m2

Finishing under slab=1kn/m^2

Characteristic dead load GK=3.6+1=4.6 kn/m2

Characteristic live load for a roof without access except for maintenance= 0.75kN/m

Unfactored loads = 4.6 kn/m2

Factored loads :(1.4*4.6) +(1.6*0.75) = 7.64 kn/m^2

- **Load calculation on beam**

Self-weight of beam= 0.4*0.65*24= 6.24 kn/m

Unfactored loads:6.24kn/m^2

Factored loads:1.4* 6.24= 8.736 kn/m

- **Area and length of tributary area of column**

Loading area of column= 3.7*4.8= 17.76 m^2

Total length beam= 3.7+4.8= 8.5m

Load calculation on column

Table 4.2: ***loads calculation on column (roof to 3th floor)***

Unfactored loads	Factored loads
Roof slab= 4.6*17.76=81.696 kn	7.64*17.76= 135.68 kn
Beam=6.24*8.5= 53.04 kn	8.736*8.5= 74.25 kn

Self-weight of column=0.4*0.4*3*24= 11.52 kn	4.52*1.4=16.128 kn
Total=146.256 kn	226.058kn

Unfactored loads: 146.256 kn

Factored loads: 226.058 kn

Short braced columns supporting an approximately symmetrical arrangement of beams

N=0.35fcuAc+0.7Asfy

As=$\frac{N-0.35*fcu*Ac}{0.75*fy}$ where Ac= b*h= 400*400=160 000 mm^2

N: factored loads

As=$\frac{226.58*10^6-0.35*25*160000}{0.75*460}$=-3645 mm^2

Negative area means that there is not reinforcement required but we provide the minimum which is equal to o.4% Ac= 640 mm^2.

Let's provide 4T16(804 mm^2) check in the table: area of groups bars**.**

4.4.3.2 Column from 3th floor to 2th floor

- **Load calculation on roof slab**

Self-weight of slab=24*0.15=3.6 kn/m2

Finishing under slab=1kn/m^2

Characteristic dead load GK=3.6+1=4.6 kn/m2

Characteristic live load Qk= 2kN/m^2

Unfactored loads = 4.6 kn/m2

Factored loads :(1.4*4.6) +(1.6*2) = 9.64 kn/m^2

- **Load calculation on beam**

Self-weight of beam= 0.4*0.65*24= 6.24 kn/m

Unfactored loads:6.24kn/m^2

Factored loads:1.4* 6.24= 8.736 kn/m^2

- **Load calculation on wall self-weight of wall**

3*18*0.2=10.8kn/m^2,γ of brick wall= 18kn/m

Unfactored loads= 10.8 kn/m^2

Factored loads= 1.4*10.8= 15.12kn/m^2

- **Area and length of tributary area of column**

Loading area of column= 3.7*4.8= 17.76 m^2

Total length beam= 3.7+4.8= 8.5m

Load calculation on column

Table 4.3 : ***loads calculation on column(***from 3th floor to 2th floor)

Unfactored loads	Factored loads
Roof slab= 4.6*17.76=81.696 kn	9.64*17.76= 171.20 kn
Beam=6.24*8.5= 53.04 kn	8.736*8.5= 74.25 kn
Self-weight of column=0.4*0.4*3*24= 11.52 kn	4.52*1.4=16.128 kn
Wall=10.8*8.5=91.8kn	15.12*8.5=128.52 kn
Load from upper floor=146.256 kn	226.058
Total=377.312kn	616.128 kn

Unfactored loads: 377.312 kn

Factored loads: 616.128 kn

Short braced columns supporting an approximately symmetrical arrangement of beams

N=0.35fcuAc+0.7Asfy

As=$\frac{N-0.35*fcu*Ac}{0.75*fy}$ where Ac= b*h= 400*400=160 000 mm^2

N: factored loads

As=$\frac{616.128*10^6-0.35*25*160000}{0.75*460}$=-2434$mm^2$

Negative area means that there is not reinforcement required but we provide the minimum which is equal to o.4% Ac= 640 mm^2.

Let's provide 4T16(804 mm^2) check in the table: area of groups bars

4.4.3.3 Column from 2nd floor to 1st floor

- **Load calculation on roof slab**

Self-weight of slab=24*0.15=3.6 kn/m2

Finishing under slab=1kn/m^2

Characteristic dead load GK=3.6+1=4.6 kn/m2

Characteristic live load Qk= 2kN/m^2

Unfactored loads = 4.6 kn/m2

Factored loads :(1.4*4.6) +(1.6*2) = 9.64 kn/m^2

- **Load calculation on beam**

Self-weight of beam= 0.4*0.65*24= 6.24 kn/m

Unfactored loads:6.24kn/m^2

Factored loads:1.4* 6.24= 8.736 kn/m^2

- **Load calculation on wall self-weight of wall**

3*18*0.2=10.8kn/m^2,γ of brick wall= 18kn/m

Unfactored loads= 10.8 kn/m^2

Factored loads= 1.4*10.8= 15.12kn/m^2

- **Area and length of tributary area of column**

Loading area of column= 3.7*4.8= 17.76 m^2

Total length beam= 3.7+4.8= 8.5m

Load calculation on column

Table 4.4: ***loads calculation on column (***from 2nd floor to 1st floor)

Unfactored loads	Factored loads
Roof slab= 4.6*17.76=81.696 kn	9.64*17.76= 171.20 kn
Beam=6.24*8.5= 53.04 kn	8.736*8.5= 74.25 kn
Self-weight of column=0.4*0.4*3*24= 11.52 kn	4.52*1.4=16.128 kn
Wall=10.8*8.5=91.8kn	15.12*8.5=128.52 kn
Load from upper floor=377.312 kn	616.128
Total=615.368 kn	1006.204 kn

Unfactored loads: 615.368 kn

Factored loads: 1006.204 kn

Short braced columns supporting an approximately symmetrical arrangement of beams

N=0.35fcuAc+0.7Asfy

As=$\frac{N-0.35*fcu*Ac}{0.75*fy}$ where Ac= b*h= 400*400=160 000 mm^2

N: factored loads

As=$\frac{1006.204*10^6-0.35*25*160000}{0.75*460}$=-1222.96 mm^2

Negative area means that there is not reinforcement required but we provide the minimum which is equal to o.4% Ac= 640 mm^2.

Let’s provide 7T16(1407mm^2) check in the table: area of groups bars.

4.4.3.4 Column from to 1st floor to ground floor

- **Load calculation on roof slab**

Self-weight of slab=24*0.15=3.6 kn/m2

Finishing under slab=1kn/m^2

Characteristic dead load GK=3.6+1=4.6 kn/m2

Characteristic live load Qk= 2kN/m^2

Unfactored loads = 4.6 kn/m2

Factored loads :(1.4*4.6) +(1.6*2) = 9.64 kn/m^2

- **Load calculation on beam**

Self-weight of beam= 0.4*0.65*24= 6.24 kn/m

Unfactored loads:6.24kn/m^2

Factored loads:1.4* 6.24= 8.736 kn/m^2

- **Load calculation on wall self-weight of wall**

3*18*0.2=10.8kn/m^2,γ of brick wall= 18kn/m

Unfactored loads= 10.8 kn/m^2

Factored loads= 1.4*10.8= 15.12kn/m^2

- **Area and length of tributary area of column**

Loading area of column= 3.7*4.8= 17.76 m^2

Total length beam= 3.7+4.8= 8.5m

Load calculation on column

Table 4.5: ***loads calculation on column (1st floor to ground floor)***

Unfactored loads	Factored loads
Roof slab= 4.6*17.76=81.696 kn	9.64*17.76= 171.20 kn
Beam=6.24*8.5= 53.04 kn	8.736*8.5= 74.25 kn
Self-weight of column=0.4*0.4*3*24= 11.52 kn	4.52*1.4=16.128 kn
Wall=10.8*8.5=91.8kn	15.12*8.5=128.52 kn

Load from upper floor=615.368 kn	1006.204
Total=853.424 kn	1396.274 kn

Unfactored loads: 853.424 kn

Factored loads: 1396.274 kn

Short braced columns supporting an approximately symmetrical arrangement of beams

N=0.35fcuAc+0.7Asfy

As=$\frac{N-0.35*fcu*Ac}{0.75*fy}$ where Ac= b*h= 400*400=160 000 mm^2

N: factored loads

As=$\frac{1396.274*10^6-0.35*25*160000}{0.75*460}$=11.57 mm^2

Let's provide the minimum reinforcement 4T16(804 mm^2) check in the table: area of groups bars.

4.4.4 Stirrups

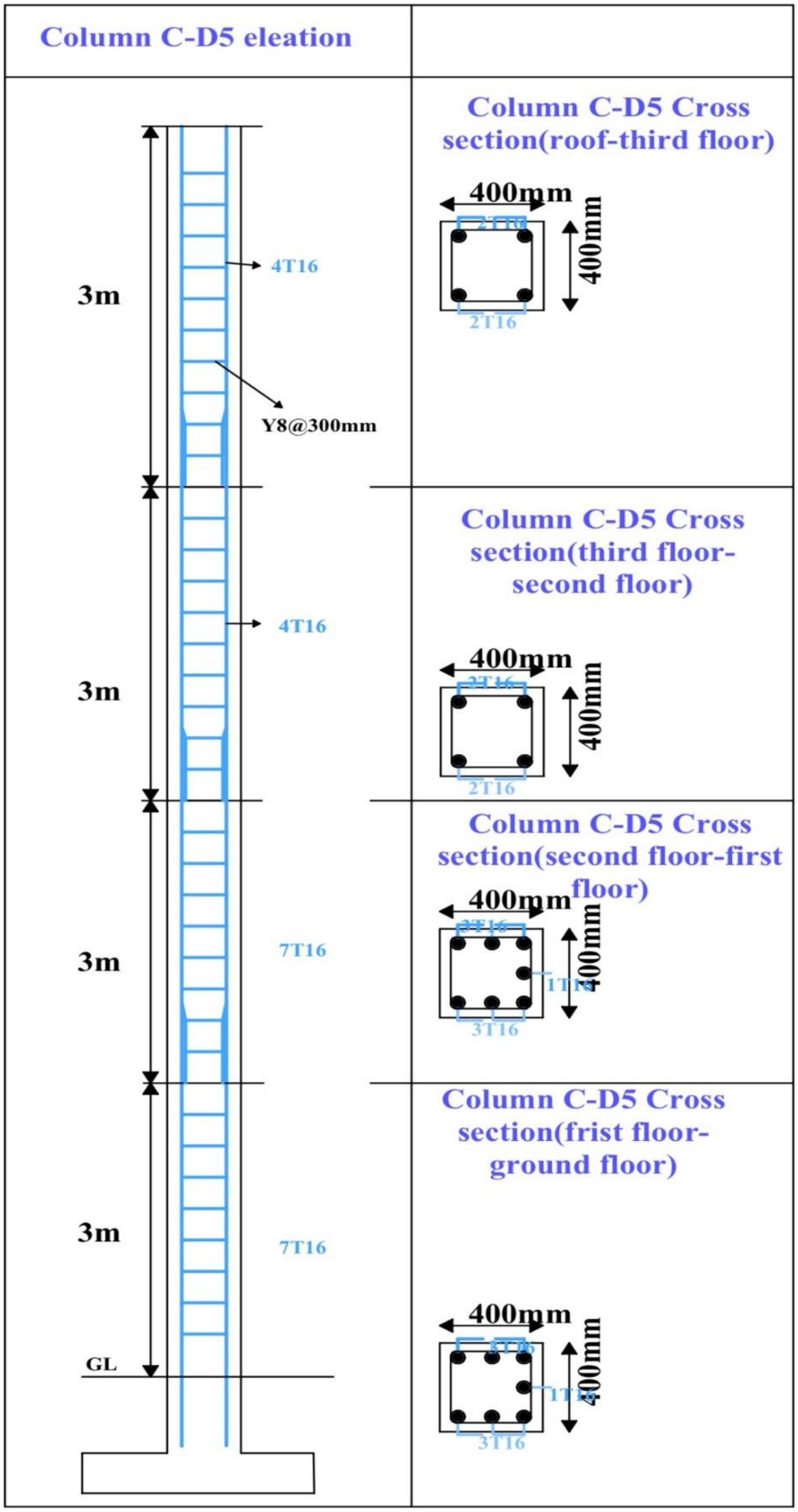
Size or diameter of stirrups=1/4 Φ of the largest bar=16/4= 4 mm

Use stirrups of 8 mm

- Spacing: spacing is at least
- 12*Φ main bar= 12*16= 192 mm
- The smallest cross-sectional dimension of column= 400 mm

Stirrups of 8 mm diameter and spaced at 192 mm , let use 200 mm.

Table 4.6 : Column design details



4.4.5 DESIGN OF FOOTING

4.4.5.1 Dimension specification

The column: 400 mm* 400 mm

The safe bearing capacity is assumed to be 300 kn/m^2

Serviceability load Nn= 853.424 kn

Ultimate load= 1396.274 kn

Footing area =(serviceability load+10% of serviceability load)/bearing capacity of soil

Footing area =$\frac{853.424+85.342}{300}$ =3.12 m^2

Side of footing =$\sqrt{3.12}$=1.76, let take 2.5 m square footing, to have our foundation safe.

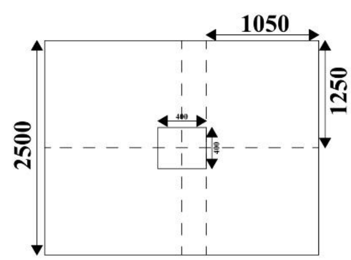


Figure 4.10 : footing representation

B=2.5 m and L=2.5 m

Real pressure=853.424/2.5^2= 136.54 kn/m^2

The ultimate bearing pressure =1396.274/2.5^2=223.40.kn/m^2

Design stress<bearing capacity the foundation is safe

4.4.5.1.2 Bending reinforcement

Length of the beyond the face of the column = (2.5– 0.4)/2 ≈ 1 m

Resultant load =349.06*1.05*2.5=916.28 kn

The critical section at the column face is shown in the figure below:

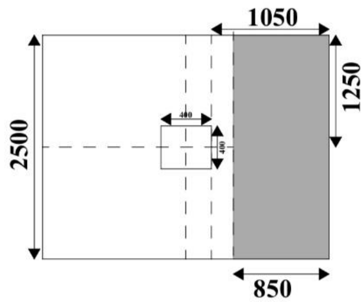


Figure 4.11: *The critical section at the column face*

Moment along x-axis equal moment along y-axis as it's a square footing.

Mx=$\frac{pu*B*L}{8}$=$\frac{223.40*2.5*2.5^2}{8}$=436.32 knm

d=$\sqrt{\frac{M}{0.156fcub}}$==$\sqrt{\frac{436.32*10^6}{0.156*25*1000}}$=334.48 mm

K=$\frac{M}{fcubd^2}$= $\frac{436*10^6}{25*1000*334.48^2}$ =0.155< Kbal=0.156

No compression reinforcement required.

Z= d(0.5+$\sqrt{0.25-\frac{0.155}{0.9}}$) <0.95d = 0.78d<0.95d

Let take Z=0.78d= 260.89 mm

As=$\frac{M}{0,95fyz}$=$\frac{436.32*10^6}{0.95*460*260.89}$= 3827.06 mm^2

T25@125mm As provide= 3930 mm^2

4.4.5.3 Check for punching shear

Earth pressure= 223.40 kn/m^2

Critical perimeter =(3d+400)*4=(3*334.48+400)*4=5613.76 mm

Area within perimeter=(2500*2500)-(3d+400)^2= 4.28 m^2

Punching force= pu*critical area= 223.40*4.28= 956.152 kn

Punching shear stress V=$\frac{Punching\ force}{critical\ perimeter*d}$ = $\frac{956.152*10^3}{5613.76*334.48}$ =0.509 N/mm^2

$Vc=\frac{0.79}{1.25}(\frac{100*Asp}{b*d})^{\frac{1}{3}}\ (\frac{400}{d})^{\frac{1}{4}}$

$Vc=\frac{0.79}{1.25}(\frac{100*3930}{1000*334.48})^{\frac{1}{3}}\ (\frac{25}{25})^{\frac{1}{3}}(\frac{400}{334.48})^{\frac{1}{4}}$

Vc=0.632*1.05*1.04= 0.690 N/mm^2

Vc<U the footing will fail under punching; we need to increase the thickness of footing.

Punching shear check using d= 600 mm

Z= d(0.5+$\sqrt{0.25-\frac{0.155}{0.9}}$) <0.95d = 0.78d<0.95d

Let take Z=0.78d= 468 mm

$As=\frac{M}{0,95fyz}=\frac{436.32*10^6}{0.95*460*468}$= 2133.42 mm^2

T25@200 mm As provide= 2450mm^2

Critical perimeter = (3d+400) *4= (3*600+400) *4=8800mm

Area within perimeter= (2500*2500) -(3d+400)^2= 1.41m^2

Punching force= pu*critical area= 223.40*1.41= 314.99 kn

Punching shear stress $V=\frac{Punching\ force}{critical\ perimeter*d}=\frac{314.99*10^3}{8800*600}$ =0.059N/mm^2

$Vc=\frac{0.79}{1.25}(\frac{100*Asp}{b*d})^{\frac{1}{3}}\ (\frac{400}{d})^{\frac{1}{4}}$

$Vc=\frac{0.79}{1.25}(\frac{100*2450}{1000*600})^{\frac{1}{3}}\ (\frac{25}{25})^{\frac{1}{3}}(\frac{400}{600})^{\frac{1}{4}}$

Vc=0.632*0.74*0.9= 0.42 N/mm^2

Vc>U the footing will resist under punching shear

4.4.5.4 Face shear

Maximum shear stress Umax occurs at face of column, hence

$Umax=\frac{N}{Column\ punching*d}=\frac{1396.274*10^3}{(4*400)*600}$=1.45< permissible=0.8*$\sqrt{40}$=5.05

Transverse shear

Ultimate shear force(U)= load on shaded area= earth pressure

Area= 223.40*(0.45*2.5)= 251.325 kn

Design shear stress U is U= $\frac{V}{bd}$ =251.325/1000*600=0.41<Vc

No shear reinforcement is required

4.4.5.5 Cracking

The bar spacing 750mm or 3d minimum reinforcement is less than 0.3%

Allowable clear spacing

Clear spacing≤4700/fs

Where

fs=$\frac{2*fy*As\ required}{3*As\ pro}*\frac{1}{\beta b}$,βb= 1 and fs is the design

fs=$\frac{2*460*2170.53}{3*2454}*\frac{1}{1}$= 271.24

Then clear spacing≤$\frac{4700}{fs}$≤300

Clear spacing = 173.27 mm≤3d

Let take clear spacing of 125 mm according to the table of groups bars

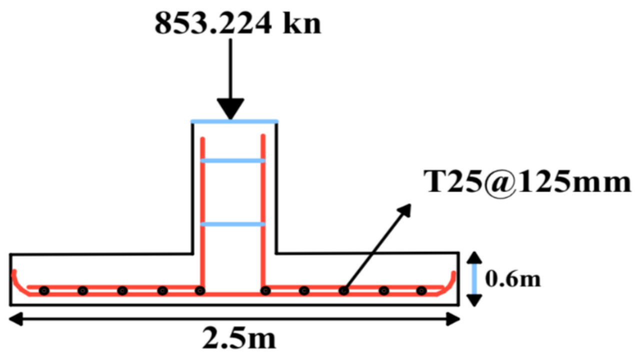


Figure 4.12: footing details

4.4.6 DESIGN OF STAIR

Preliminary sizing of stair case members

Height from ground floor slab to first floor slab= 3000 mm

Height from ground floor to landing= 3000/2= 1500mm

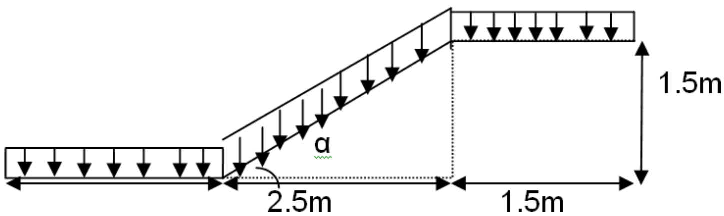


Figure 4.13: stair representation

tanα=$\frac{1.5}{2.5}$=0.06, tan^{-}(0.06)=30.96°

Flight^2= 2.5^2+1.5^2=2.9 let take 3 m

4.4.6.1 Rises

Assuring a suitable rise when average rise is between 150 mm and 300 mm, let us take 150mm.

Number of rise= flight/150=20 rises

4.4.6.2 Goings

550<2R+G<700 let take 600 mm

2R+G= 600 mm

G= 300 mm

Number of going = riser-1=20-1=19 goings

Waist of the slab(h)

h=le/20

where le= effective span

the effective span of simply-supported stair case without stringer beams should be taken as the horizontal distance between supports.

Le=4000 mm

h=4000/20=200 mm

average thickness of the staircase

t=2Y+R/2

Where R= 150 mm

Y=h($\frac{\sqrt{G^2+R^2}}{G}$)

Y=200($\frac{\sqrt{300^2+150^2}}{300}$)=223.6 mm let take 224 mm

t=$\frac{2*224+150}{2}$=299 mm

Average thickness of stair case=300 mm

4.4.6.3 Landing

Self-weight of slab= unit weight of concrete * waist of landing=24*0.2=4.8 kn/m^2

Finishing=1 kn/m^2

Dead load= 4.8+1=5.8 kn/m^2

Design load, n=(1.4*Gk) +(1.6*Qk)=11.32 kn/m^2

Consider 1m width, nd= n*1m=11.32kn/m^2*1m= 11.32 kn/m

Design load for landing(n)= 11.32 kn/m

w= (load landing) +load from staircase

w= (11.32*1*6) +11.32=29.432 kn/m

Vmax=Wl/2= $\frac{29.432*4}{2}$ =58.86 kn

Mmax=Wl^2/8= $\frac{29.432*4^2}{8}$ =58.86 knm

Maximum shear V= 58.86 kn

Maximum moment M= 58.86 knm

Let assume Φ main bar

d=h-cover-$\Phi/2$= 200-25-12/2=169 mm

K=$\frac{M}{fcubd^2}$ = $\frac{58.86*10^6}{25*1000*169^2}$ = 0.082< Kbal=0,156

No compression reinforcement required.

Z= d(0.5+$\sqrt{0.25 - \frac{0.082}{0.9}}$) <0.95d = 0.89d<0.95d

Let us take Z=0.89d=0.89*169=150.41 mm

As req=$\frac{M}{0{,}95fyZ} = \frac{126.70*10^6}{0.95*460*150.41}$ = 895.49 mm^2

Provide T12@125 mm(905 mm^2)

As min=$\frac{0{,}13\ Ac}{100} = \frac{0{,}13\ *1000*169}{100}$ =219.7 mm^2

As max=$\frac{4\ Ac}{100} = \frac{4*1000*169}{100}$ =6760mm^2

As min<As req<As max The condition is verified

4.4.6.4 Check for shear

U=$\frac{V}{bd} = \frac{58.86*10^3}{1000*169}$ = 0.34 N/mm^2

Vu=0.8$\sqrt{fcu}$=4 N/mm^2

U<Vu, then ultimate shear ok!!!

Vc=$\frac{0.79}{1.25}(\frac{100As}{bd})^{\frac{1}{3}}\ (\frac{fcu}{25})^{\frac{1}{3}}(\frac{400}{d})^{\frac{1}{4}}$

Vc=$\frac{0.79}{1.25}(\frac{100*901}{1000*169})^{\frac{1}{3}}\ (\frac{25}{25})^{\frac{1}{3}}(\frac{400}{169})^{\frac{1}{4}}$

Vc=0.632*0.81*1*1.24=0.634 N/mm^2

Shear capacity=0.634N/mm^2>shear stress=0.34N/mm^2 hence no shear reinforcement is required.

4.4.6.5 Check for deflection

Modification factor for tension reinforcement M.F:

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

$\frac{M}{bd^2} = \frac{58.86*10^6}{1000*169^2}$ =2.06

fs= $\frac{2}{3}$ *fy* $\frac{As\ req}{As\ prov}*\frac{1}{Bb} = \frac{2}{3}*460*\frac{895.49}{901}*\frac{1}{1}$ = 304.79

M.F=0.55+$\frac{477-304.79}{120(0.9+2.06)}$ =1.03<2

Permissible effective span/ depth= 20.8*1.03= 21.424

Actual span/depth ratio=lx/169=2500/169=14.79

Actual span/d < permissible span/d, hence ok!!

4.4.6.6 Flight

Self-weight of the slab= unit weight of concrete*average thickness= $24*300*10^{-3}$=7.2 kn/m^2

Finishing = 1kn/m^2

Dead load = 7.2+1=8.2 kn/m^2

Imposed load= 2kn/m^2

Design load n= (1.4*Gk)+(1.6*Qk)= 10.08+3.2= 13.28 kn/m^2

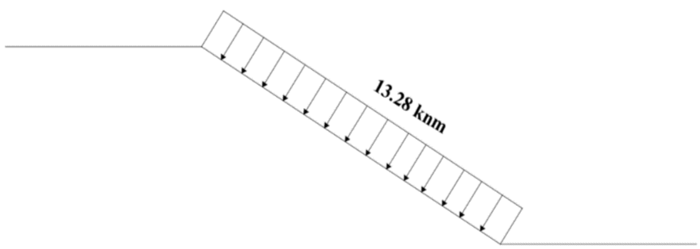


Figure 4.14: *stair's design load representation*

Design load of flight n= 13.28 knm

M=$\frac{Fle}{10}$

Where F=w*l=(13.28*2.5)= 33.2 kn

M=$\frac{33.2*4000}{10} = 13280kn = 13.28\ kn$

b=1000 mm and d= thickness of slab or waist-cover –Φ/2

The bar diameter Φ is assumed to be 12 mm.

d= 200mm-25mm-12/2= 169 mm

K=$\frac{M}{fcubd^2}$ = $\frac{13.28*10^6}{25*1000*169^2}$ = 0.018< Kbal=0,156

No compression reinforcement required.

Z= d(0.5+$\sqrt{0.25 - \frac{0.018}{0.9}}$) >0.95d = 0.97d>0.95d

Let us take Z=0.95d=0.95*169=160.55 mm

As req=$\frac{M}{0,95fyZ}$ = $\frac{13.28*10^6}{0.95*460*570.95}$ = 188.75 mm^2

Provide T12@300 mm(377mm^2)

As min=$\frac{0,13\ Ac}{100}$ = $\frac{0,13\ *1000*169}{100}$ =219.7 mm^2

As max=$\frac{4\ Ac}{100}$ = $\frac{4*400*169}{100}$ =6760mm^2

As min>As req<As max, The condition is not verified As provide will be between As min and As max but near As min.

As provide= 226 mm^2

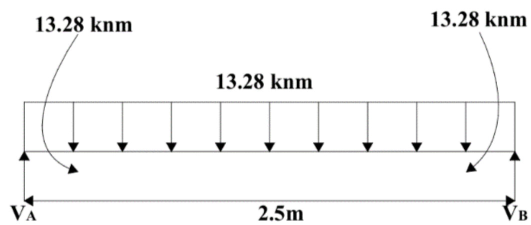


Figure 4.15 : Moment on stair

$\sum$M$_A$=0, 13.28+(V$_B$*2.5)-13.28-(13.28*$\frac{2.5^2}{2}$)

2.5V$_B$=-13.28+13.28+(13.28*3.125)

2.5V$_B$= 41.5

V$_B$=41.5/2.5=16.6 kn

$\sum$Fy=0, V$_B$+V$_A$=13.28*2.5

V$_B$+V$_A$=33.2

V$_A$=33.2-16.6= 16.6 kn

Max shear= 16.6 kn

4.4.6.7 Shear stress design

$U=\frac{V}{bd}=\frac{16.6*10^3}{1000*169}$ = 0.098N/mm^2

$Vu=0.8\sqrt{fcu}$=4 N/mm^2

U<Vu, then ultimate shear ok!!!

$Vc=\frac{0.79}{1.25}(\frac{100As}{bd})^{\frac{1}{3}}\ (\frac{fcu}{25})^{\frac{1}{3}}(\frac{400}{d})^{\frac{1}{4}}$

$Vc=\frac{0.79}{1.25}(\frac{100*226}{1000*169})^{\frac{1}{3}}\ (\frac{25}{25})^{\frac{1}{3}}(\frac{400}{169})^{\frac{1}{4}}$

Vc=0.632*0.511*1*1.24=0.38 N/mm^2

Shear capacity=0.38N/mm^2>shear stress=0.098N/mm^2 hence no shear reinforcement is required.

4.4.6.8 Check for deflection

Modification factor for tension reinforcement M.F:

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

$\frac{M}{bd^2}=\frac{13.28*10^6}{1000*169^2}$ =0.46

$fs=\frac{2}{3}*fy*\frac{As\ req}{As\ prov}*\frac{1}{Bb}=\frac{2}{3}*460*\frac{188.75}{226}*\frac{1}{1}$ = 256.12

$M.F=0.55+\frac{477-256.12}{120(0.9+0.46)}$ =1.9<2

Permissible effective span/ depth= 20.8*1.9=39.52

Actual span/depth ratio=lx/169=2500/169=14.79

Actual span/d < permissible span/d, hence ok!!

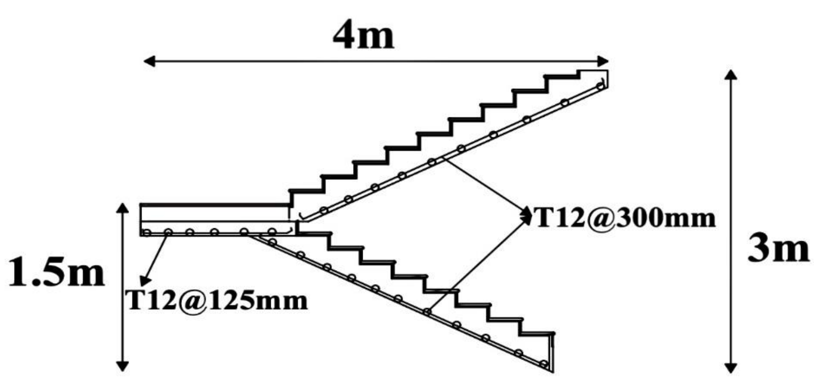


Figure 4.16 : stair representation Design

4.4.7 Discussion

4.4.7.1 Slab discussion

The slab design, with a thickness of 15 cm and a 25 mm cover, is tailored to effectively handle a design load of 12.44 kn/m^2. The reinforcement provided, consisting of T10 bars at 300 mm c/c, results in a reinforcement area of 262 mm^2, which is suitable for the load and dimensions of the slab. With an effective depth of 12.45 cm, the slab performs well in deflection checks, ensuring that deflections remain within acceptable limits, which is crucial for maintaining both structural integrity and user comfort. The design also accounts for maximum positive and negative moments, ensuring the slab's capacity to resist bending stresses in both directions. In terms of shear, the calculated shear stress of 0.17 N/mm^2 is significantly lower than the shear capacity of 0.48 N/mm^2, eliminating the need for additional shear reinforcement, which simplifies construction while maintaining safety. To control cracking, the reinforcement spacing of 300 mm, which is well within the allowable maximum of 3d (37.35 cm), ensures that cracks remain small, enhancing the slab's durability and long-term performance. Overall, the design is robust, meeting all structural and serviceability requirements, ensuring the slab's reliability under the specified loading conditions.

4.4.7.2 Beam Design

The beam design is meticulously crafted with a total height of 65 cm, which is within the recommended range of ly/15 to ly/8, ensuring the beam's depth is suitable for both strength and deflection control. The web width of 40 cm provides sufficient capacity to handle shear forces effectively, particularly in areas requiring composite action with the slab. The beam is designed to support a substantial design load of 221.52 kn per span, and to resist this load, reinforcement of 3T16 bars on the top and bottom, providing a total reinforcement area of 603 mm^2 each, was incorporated throughout. This reinforcement ensures the beam can resist the applied loads without experiencing excessive bending or failure. The calculated shear stress of 0.25 N/mm^2 is well below the shear capacity of 0.358 N/mm^2, indicating that the beam is safe from shear failure and does not require additional shear reinforcement, simplifying construction while ensuring safety. Regarding deflection control, the beam's effective depth was calculated at 8.53 cm, which is less than the permissible span-to-depth ratio of 36.192 cm, confirming that the beam will not experience excessive deflection under load, thereby maintaining structural integrity and user comfort. The longest beam in the structure was selected for this design analysis, ensuring that all shorter spans will also be adequately supported under the same loading conditions. Overall, the design is robust, with well-considered dimensions, sufficient reinforcement, and satisfactory performance in terms of shear and deflection, meeting all necessary structural requirements to safely support the intended loads without risking structural issues

4.4.7.3 column design

The design focuses on the most heavily loaded column, identified as column C-D5. We began by assuming a column dimension of 400 mm x 400 mm, which is a typical size that balances structural requirements and space efficiency. The effective height of the column was calculated with respect to the major axis (x-axis) as 2350 mm and with respect to the minor axis (y-axis) as 2391 mm. These dimensions were used to verify the column as a braced short column. The column was confirmed to be a short column based on the conditions that the effective length to height ratios, lex/h and ley/h, were both less than 15, with the clear height of the column being 2391 mm. For the loading analysis, we proceeded floor by floor, starting from the roof and moving down to the ground floor. We calculated the total unfactored load and the factored load by considering the contributions from the roof beams, walls, and the tributary area of the column. Based on these calculations, we determined that from the roof to the second floor, a reinforcement of 4T16 bars (providing a total reinforcement area of 804 mm^2) would be sufficient. However, from the first floor down to the ground floor, where the loads are greater, we increased the reinforcement to 7T16 bars (providing a total reinforcement area of 1407 mm^2) to safely carry the higher loads. Regarding the spacing of the reinforcement, we considered the diameter of the bars (16 mm) and determined a spacing of 192 mm. However, for practical reasons and ease of construction, we decided to use a slightly larger spacing of 200 mm, which still meets the design requirements. Additionally, we specified the use of 8 mm diameter stirrups, which are essential for holding the main reinforcement in place and providing shear resistance.

4.4.7.4 Footing discussion

The footing design was approached with careful consideration of the soil bearing capacity and load requirements. Given the average bearing capacity of soil in Kigali is 300 kn/m^2, and the serviceability load was 853.224 kn (unfactored load), the ultimate load was determined to be 1396.274 kn. To ensure proper load distribution and safety, we first calculated the required footing area using the serviceability load plus an additional 10% of this load, divided by the bearing capacity, which resulted in an area of 3.12 m². Initially, we chose a square footing based on this area, but this design did not meet the requirement to ensure that the design stress remained below the soil's bearing capacity. To address this, we opted for a square footing with a side dimension of 2.5 m. With this dimension, we provided T25@125mm bars (totaling 3930mm² of reinforcement) for the entire footing, which is adequate for handling the loads.

During the design process, we identified that the initial footing depth was insufficient to resist punching shear. To rectify this, we increased the footing depth to 600 mm, ensuring it meets the punching shear conditions. For face shear, no additional reinforcement was necessary, as the shear stress was within acceptable limits. The spacing of the reinforcement bars was calculated as 175 mm, but we have use of 125mm which is less than the maximum allowed spacing of 3d (3 x 600 mm = 1800 mm), ensuring adequate crack control and maintaining the structural integrity of the footing.

4.4.7.5 Stair discussion

The stair design was approached with detailed consideration of dimensions, load requirements, and structural performance. The height from the ground floor slab to the first floor slab is 3000 mm, and we have introduced a landing situated 1.5 m above the ground floor slab. The stair flight, extending 3 m horizontally, forms an angle of 30.96 degrees with the ground floor slab. To ensure comfort and functionality, we selected a rise of 150 mm, which is within the recommended range of 150 mm to 300 mm. This rise results in 20 risers and 19 goings, each with a dimension of 300 mm, providing a balanced and ergonomic staircase.

The average thickness of the staircase was determined to be 300 mm. For the landing, we provided T12@125mm bars (totaling 905 mm² of reinforcement), which is sufficient for the loads expected at this level. No additional shear reinforcement was required for the landing, as the calculated shear stress was below the shear capacity, ensuring safety and stability. Additionally, the landing was found to be satisfactory with respect to deflection, with the actual span-to-depth ratio being less than the permissible value. For the stair flight, we used T12@300mm bars (providing 226 mm² of reinforcement) to resist bending moments. The maximum moment was calculated to be 13.28 knm. The shear stress in the flight was also within safe limits, eliminating the need for additional shear reinforcement. The flight was satisfactory in terms of deflection, with the actual span-to-depth ratio again being less than the permissible value.

4.4.8 Cost and estimation

All cost figures are provided in Rwf.

The estimated costs are based on the information available at the time of estimation and may be subject to change.

Here is the Bill of quantity and cost estimation:

Substructure, ground and first floor cost

Table 4.7 : Bill of quantity and cost estimation Ground floor and first floor

SN	Description	Unit	Quantity	Rate (Rwf)	Total amount (Rwf)
	PRELIMINARY WORKS (provisional)				
	Site clearing	m^2	1168.24	2000	2.336.480
	Enclosure, shack and office	Nr	1		2.000.000
	SUBSTRUCTURE				
	EARTHWORKS (Provisional)				
	Excavation and site leveling				
	Excavation works and site leveling prior to setting out and foundation works to include hauling of excavated soil from construction site.	Nr	1		6.500.000
	Excavation works for foundation to include maintaining and supporting trenches sides and keeping them free from water, mud and fallen materials				
	For column bases (footings)	m^3	146.25	50.000	7.325.000
	FONDATION WORKS (Provisional)				
	Vibrated reinforced concrete for:				
	column bases (footings)	m^3	146.25	450.000	65.812.500

	SUB-TOTAL: SUBSTRUCTE				**83.973.980**
	SUPERSTRUCTURE				
	GROUND FLOOR				
	REINFORCED CONCRETE WORKS				
	Vibrated reinforced concretefor:				
	Columns	m^3	19	450.000	8.550.000
	Floor beams	m^3	71	450.000	31.950.000
	Slab	m^3	65	450.000	29.450.000
	Masonry wall				
	Bricks	Nr	101 624	120	12.194.880
	Mortar	m^3	21	200.000	4 200 000
	SUB-TOTAL: SUPERSTRUCTURE				**86.344.880**
	WALL FINISHES				
	WALL PLASTERING & PAINTING				
	Wall plastering External and Internal walls	m^2	1712.4	15.000	25.686.000
	Painting external and internal walls	m^2	1712.4	45.000	77.058.000
	Prepare and application of lime plaster to:				
	External and Internal walls	m^2	1712.4	5.000	8.562.000
	SUB-TOTAL: WALL FINISHES				111.306.000
	FLOORING				
	Floor tiling with corresponding tiles	m^2	430.68	80.000	34.454.400
	SUB-TOTAL: FLOORING and WALL FINISHES				**145.760.400**
	WINDOWS				

	Supply and fixation of glazed window with aluminum frames to include locking devices and accessories, painting and all requirements				
	Double-Hung Double Window(1.5m*1.5m)	Nr	12	130.000	1.560.000
	Double-Hung Double Window(0.5m*o.5m) for toilets	Nr.	4	70.000	280.000
	SUB-TOTAL: WINDOWS				**1.840.000**
	DOORS				
	Double entrance door(2.8m*2.8m)	Nr	1	220.000	220.000
	Wooden door(0.9m*2.8m)	Nr.	20	130.000	2.600.000
	SUB-TOTAL: DOORS				**2.820.000**
	SANITARY APPLIANCES				
	Supply and installation of WC with all accessories and all requirements	Nr.	4	220000	880.000
	Supply and installation ion of ceramic wash hands basin complete with accessories and all requirements.	Nr.	4	100.000	400.000
	SUB-TOTAL: SANITARY APPLIANCES				**1.280.000**
	Curtain wall	m^2	73	60.000	**4.380.000**
	SUB-TOTAL: GROUND FLOOR				**242.425.280**
	GRAND TOTAL: GROUNDFLOOR AND SUBSTRUCTURE				**326.399.260**
	FIRST FLOOR				
	REINFORCED CONCRETE WORKS				
	Vibrated reinforced concrete for:				
	Columns	m^3	19	450.000	8.550.000
	Floor beams	m^3	71	450.000	31.950.000

	Slab	m^3	71	450.000	31.950.000
	Masonry wall				
	Bricks	Nr	106 711	120	12.805.320
	Mortar	m^3	22	200.000	4.400.000
	SUB-TOTAL: SUPERSTRUCTURE				**89.655.320**
	WALL FINISHES				
	WALL PLASTERING & PAINTING				
	Wall plastering External and Internal walls	m^2	1712.4	15.000	25.686.000
	Painting external and internal walls	m^2	1712.4	45.000	77.058.000
	Prepare and application of lime plaster to:				
	External and Internal walls	m^2	1712.4	5.000	8.562.000
	SUB-TOTAL: WALL FINISHES				111.306.000
	FLOORING				
	Floor tiling with corresponding tiles	m^2	471.48	80.000	37.718.400
	SUB-TOTAL: FLOORING and WALL FINISHES				**149.024.400**
	WINDOWS				
	Supply and fixation of glazed window with aluminum frames to include locking devices and accessories, painting and all requirements				
	Double-Hung Double Window(1.5m*1.5m)	Nr	8	130.000	1.040.000
	Double-Hung Double Window(0.5m*o.5m) for toilets	Nr.	4	70.000	280.000

	SUB-TOTAL: WINDOWS				**1.320.000**
	DOORS				
	Wooden door(0.9m*2.8m)	Nr.	20	130.000	2.600.000
	Sliding Doors	Nr	4	180000	720 000
	SUB-TOTAL: DOORS				**3.320.000**
	SANITARY APPLIANCES				
	Supply and installation of WC with all accessories and all requirements	Nr.	4	220000	880.000
	Supply and installation ion of ceramic wash hands basin complete with accessories and all requirements.	Nr.	4	100.000	400.000
	SUB-TOTAL: SANITARY APPLIANCES				**1.280.000**
	Curtain wall	**m^2**	**81.9**	**60000**	**49.100.000**
	Railing	**m**	**37**	**75000**	**2.775.000**
	Railing on the top of third floor	**m**	**76**	**75000**	**5.700.000**
	SUB-TOTAL: FRIST FLOOR				**299.794.720**

External work

Table 4.8 : Bill of quantity and estimation of external works

SN	Description	Unit	Quantity	Rate (Rwf)	Total amount (Rwf)
1	Construction of fence	Item	1	10.000.000	10.000.000
2	Roads, parking's and footpaths	Item	1	8.000.000	8.000.000
3	Garden	Item	1	6.000.000	6.000.000
	GRAND TOTAL: EXTERNAL				**24.000.000**

Summary of cost and estimation of the building

Table 4.9 : summary of cost and estimation of the building

S.N.	**ITEM**	**AMOUNT (Rwf)**
1	FOUNDATION AND GROUND FLOOR	**326.399.260**
2	FIRST FLOOR	**299.794.720**
3	SECOND FLOOR	**299.794.720**
4	THIRD FLOOR	**305.494.720**
5	EXTERNAL WORK	**24.000.000**
	GRAND TOTAL	**1.255.483.719**

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The "Structural Design of a G+3 Student Apartment" project in Gisozi, Kigali, successfully achieves its general objective of providing an architectural and structural design that meets the needs of modern student accommodation in the Gasabo District. The building, with dimensions of 22 meters by 19.20 meters and an estimated total cost of 1,255,483,719 Rwf, addresses the urgent demand for secure, affordable, and culturally inclusive housing for students, particularly with the increasing number of international students. The structural design incorporates key elements to ensure the building's safety and stability. This includes slab reinforcement with T10@300 mm c/c and a thickness of 15 cm, beam reinforcement using 3T16 at the top and bottom with 8 mm stirrups spaced at 200 mm, and column reinforcement of 4T16 from the third to the second floor, increasing to 7T16 from the first floor to the ground floor, all with 8 mm stirrups spaced at 200 mm. The foundation features a square footing measuring 2.5 m by 2.5 m and a depth of 0.6 m, reinforced with T25@125 mm to withstand a load of 853.224 kN, ensuring structural integrity under load conditions. These comprehensive plans adhere to British Standards (BS 8110-1:1997 and BS 6399-1:1996), ensuring that the building is not only safe and functional but also cost-effective. Once selected and implemented by the government or other institutions, this project will effectively meet its objectives, significantly enhancing student living conditions in Gisozi. By providing affordable and high-quality housing, it will support Rwanda's broader educational goals and contribute to the overall well-being and academic success of the students, creating an environment conducive to both learning and personal development.

5.2 Recommendations

- Utilize Site-Specific Bearing Capacity: Use the actual site bearing capacity for designing structural elements based on a thorough geotechnical investigation.
- Adapt Foundation Type if Necessary: Change the foundation type or use soil stabilization techniques if the bearing capacity is insufficient.
- Employ Advanced Structural Software: Use software like Prokon for accurate calculations and modeling to minimize design errors.

- Use Block or Lime Bricks: Consider block or lime bricks based on project time management for faster construction and better insulation.

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APPENDICES