REPUBLIC OF RWANDA

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ACADEMIC YEAR 2018/2019

DEPARTMENT OF CIVIL ENGINEERING

YEAR PROJECT REPORT

Topic: Architectural and structural design of G+3 residentia house . Case study Kigali, Gisozi sector

Submitted in partial fulfillment of the requirements for the Award of
ADVANCED DIPLOMA IN CONSTRUCTION TECHNOLOGY

Presented by

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Under the guidance of

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Kigali, October 2024

DECLARATION

I, **Akonkwa Marara Joseph**, declare that the content of this project on Architectural and structural design of G+ 3 residential building, in Gisozi sector done at **ULK POLYTECHNIC INSTITUTE** is my original work and contribution to the fulfilment of the requirements for award of advanced diploma in construction technology. The content of this project should not be produced without the permission of the author and institution.

Date: 07/10/2024

Signature:

Akonkwa Marara Joseph

CERTIFICATION

This is to certify that project work entitled Architectural and structural design of G+ 3 residential building, in Gisozi sector is a work done by **AKONKWA MARARA JOSEPH**. In partial fulfilment of the requirement for the award of advanced diploma in civil engineering department, construction technology option at **ULK POLYTECHNIC INSTITUTE** during the academic year

2023-2024

Date: …. /…..../……..

Supervisor signature……………….

Eng. **MUKESHIMANA ANNONCEE**.

DEDICATION

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. He has been the source of my strength throughout this program and on His wings only I have soared. I also dedicate this work to my Mum and Dad who have encouraged me all the way and whose encouragement has made sure that I give it all it takes to finish that which I have started. To my siblings who have been affected in every way possible by this quest. Thank you. My love for you all can never be quantified. God bless you

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to everyone who contributed to the successful completion of this project. My heartfelt thanks go to my Final Year Project Supervisor, Eng. MUKESHIMANA ANNONCEE for her invaluable guidance and support throughout the project. I'm also deeply appreciative of the efforts and expertise of my colleagues, whose dedication and hard work were crucial to achieving my objectives.

I also acknowledge the support of ULK POLYTECHNIC INSTITUTE for providing the resources and facilities necessary for my research and development.

Finally, I extend my gratitude to our families and friends for their encouragement and understanding during the course of this project. Without the collective effort and support of all these individuals, this project would not have been possible.

ABSTRACT

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This project presents the architectural and structural design of a four-story residential house (Ground + 3 floors) that aims to offer a blend of modern design, functional living spaces, and structural integrity. Located in Gisozi sector, the design focuses on optimizing space usage while ensuring durability and aesthetic appeal.

The building has symmetricity in both directions as far as the layout of rooms is concerned. Therefore, the numbering of slab and beam is done for one quadrant and central stairs corridor only. The plan view, elevation view are done in ArchiCAD and Prokon perform the structural plan, then live load and dead load is determined according to BS code followed by the design of slab, beams, column, and footing. The structural design system involves preliminary analysis, proportioning of members, detailed analysis and evaluation.

The architectural design of the G+3 residential house integrates contemporary style with practical living solutions. The facade features a modern aesthetic with clean lines, a combination of natural and engineered materials such as glass, concrete, and steel, and a balanced use of shading devices to enhance energy efficiency. Each floor is thoughtfully designed to accommodate different functions: the ground floor includes communal areas and amenities, while the upper floors provide private residential spaces. Key architectural features include spacious balconies, large windows for natural light, and a rooftop terrace designed for recreational use. The design emphasizes connectivity between indoor and outdoor spaces, fostering a harmonious living environment.

The structural design incorporates a reinforced concrete frame system to ensure stability and support the multi-story configuration. The design includes a robust foundation system tailored to local soil conditions and seismic requirements. The use of reinforced concrete columns and beams, combined with concrete slab floors, provides the necessary load-bearing capacity while allowing for open floor plans. The structural framework supports the vertical load distribution and ensures the safety and durability of the building over its lifespan.

Sustainability is a key focus, with the design incorporating several energy-efficient features. High-performance insulation, low-E glass windows, and an advanced HVAC system are integrated to enhance thermal comfort and reduce energy consumption. The house is designed to maximize natural ventilation and daylight, reducing the reliance on artificial lighting and mechanical cooling. Additionally, rainwater harvesting systems and efficient water fixtures contribute to the overall sustainability of the home.

The architectural and structural design of the G+3 residential house effectively combines aesthetic sophistication with practical functionality. The project addresses modern urban living needs while ensuring structural reliability and environmental responsibility. By integrating innovative design solutions and sustainable practices, the project sets a new standard for residential architecture in urban contexts, offering a comfortable and efficient living space that meets contemporary standards of design and performance.

KEY WORDS

- Conceptual design
- Load analysis
- Structural analysis
- Element detailing
- Over loading
- Allowable load
- Sustainability and Efficiency
- Casting concrete
- Stability
- Durability and aesthetic appeal.

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NOTATIONS AND ABBREVIATIONS

By complying with the British standard code BS, we are going to use the following symbols all along the completion of this project.

R.C: Reinforced concrete

RCD: Reinforced concrete design

BS: British standard

Rwf: Rwandan francs

Partial safety factor for load

Partial RCC: Reinforced concrete

Safety factor for strength of materials

En : nominal earth load

AC : Total area of concrete

Asmax: maximum area of steel

Asmin: minimum area of steel

Asprov: area of steel provided

Asreq: area of steel required

As’: area of steel in compression

b: effective width of the section or flange in the compression zone

BSI: British standard institution

bw: web width of a flanged beam

d: effective depth of the tension reinforcement

d’: depth of the compression reinforcement

h: overall depth of the cross section of a reinforced member

hf: thickness of the flange

le: effective height of a column

lo: clear height of the column

lx: length of shorter side

ly: length of longer side

M: design ultimate moment

MF: modification factor

WSM: the working stress method

ULM: the ultimate load method

LSM: the limit state method

Msx: bending moment in X direction

Msy: bending moment in y direction

Mx: moment on the column in X direction

My: moment on column in y direction

N: design axial force

ϕ: diameter of steel

R: riser

G: going

Sv: spacing of links

V: design shear force due to ultimate load

Vsx, Vsy: design shear capacity of shear reinforcement

Z: lever arm

V: shear stress

Vc: shear capacity of concrete

Gk: Characteristic dead load

Qk: characteristic imposed load

WK: characteristic wind load

fcu: characteristic strength of concrete

FY: Characteristic strength of reinforcement

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CHAPTER 1: GENERAL INTRODUCTION

1.1.Introduction

This project involves the architectural and structural design of a four-story residential house (Ground + 3 floors) located in Rwanda, a country known for its vibrant culture, picturesque landscapes, and growing urban centres. As Rwanda continues to experience rapid urbanization and economic development, there is an increasing demand for residential buildings that are both functional and reflective of the country's unique architectural heritage.

In Rwanda, architectural design must balance modern needs with traditional influences and environmental considerations. The residential house is designed to harmonize with Rwanda's climate and cultural aesthetics, integrating contemporary design elements with local materials and architectural traditions. The design incorporates elements such as pitched roofs and veranda spaces that are common in Rwandan architecture, while also introducing modern features like expansive windows and open-plan interiors to suit contemporary lifestyles.

Given Rwanda's seismic activity and diverse geological conditions, the structural design of the G+3 residential house addresses these challenges through a robust and adaptable approach. The use of reinforced concrete and steel framing ensures the building's stability and safety while accommodating the dynamic loads of a multi-story structure. The design considers local soil conditions and seismic requirements to ensure durability and resilience.

The house is designed with an emphasis on integrating with its site. This includes considerations for the local topography, climate, and environmental impact. The design incorporates sustainable practices such as rainwater harvesting, efficient waste management, and the use of locally sourced, eco-friendly materials. The layout and orientation of the building optimize natural light and ventilation, reducing the reliance on artificial lighting and mechanical cooling systems.

Incorporating local cultural elements, the architectural design reflects Rwandan aesthetics through the use of traditional patterns and materials in a modern context. This approach not only respects and celebrates local heritage but also contributes to a sense of place and community identity.

The architectural and structural design of the G+3 residential house in Rwanda represents a thoughtful integration of modern design principles with local cultural and environmental considerations. The project aims to provide a high-quality living environment that meets contemporary needs while respecting and reflecting Rwanda's unique context. This approach ensures that the residential house will be a durable, efficient, and culturally resonant addition to the urban landscape.

1.2 Problem statement

The Republic of Rwanda has the fastest growing economy in the East African community. This rapid economic transformation is coupling with high demand in infrastructure of different kinds. this situation is characterized by improved living standards among the Rwandan population, what causes a high demand in living building. However, as the Rwandan citizen keep on growing in number the land for construction is also limited and is becoming very expensive, for a region like Kigali city, where the population still needs a big land for current activities there's a risk of wasting available land if there's no strategies for establishment of efficient and space saving residential buildings. This project is conducted in order to support the city of Kigali and the country in general in providing living spaces that are well equipped with all the human needs, with enough affordable dwelling units, therefore citizens need to be advice on the way they can live in a space saving apartment

1.3 Objectives

The main objective of this project is to provide an architectural and structural design of a residential building

1.4 Scope of project

- Architectural design of G+3 storey building
- Structural design of G+3 storey building
- Cost estimation of the entire project

1.5. Advantages of project

- As student, this project is going to provide an opportunity to integrate the knowledge and skills acquired throughout the academic journey.
- Projects involves solving real-world problems or implementing theoretical concepts into practical.
- Project allows to develop a wide range of skills, including research skills, project management skills, technical skills specific to their field, communication skills, and teamwork skills.
- The project will create job opportunities to the locale people
- Promote the development by providing good infrastructures in the city

1.6 Material and methods

- Internet for research and Microsoft word for typing

- ArchiCAD: ArchiCAD is another BIM software used for architectural design and documentation. It offers similar features to Revit, allowing users to create intelligent 3D models and generate detailed construction drawings and documentation
- Prokon: It is widely used by civil and structural engineers for the analysis, design, and detailing of a wide range of structures, including buildings, bridges, towers, and industrial structures.

CHAPTER 2: LITERATURE REVIEW

2.1. Apartment

An apartment is a self-contained housing unit that occupies part of a building. It typically includes several rooms such as a living area, bedrooms, a kitchen, and a bathroom. Apartments can vary in size and layout, from small studios to larger multi-bedroom units. They are usually rented or owned as part of a larger residential building or complex.

Apartments often come with shared amenities such as gyms, Apartments come in various types, and each suited to different needs and preferences. Here are some common types:
1. Studio Apartment**:** A small unit with an open floor plan combining the living, sleeping, and kitchen areas into one room, with a separate bathroom.

2. One-Bedroom Apartment**:** Features a separate bedroom, a living area, a kitchen, and a bathroom.
3. Two-Bedroom Apartment**:** Includes two separate bedrooms, a living area, a kitchen, and typically one or two bathrooms.
4. Loft Apartment**:** Known for its open space and high ceilings, often converted from industrial buildings with minimal interior walls.
5. Duplex Apartment**:** A unit spread over two levels connected by an internal staircase.

2.2. Architectural design

Architectural design involves creating plans for buildings and structures that are both functional and aesthetically pleasing. It encompasses various elements, including spatial layout, materials, lighting, and environmental impact. Key stages in architectural design typically include conceptual design, schematic design, design development, and construction documents. Effective architectural design balances form, function, and context, taking into account the desire of the users and the surrounding area.

i. Drawing by Computer aid design

Computer-Aided Design (CAD) is a technology used to create detailed and precise drawings and models of structures and objects. In architecture, CAD software helps in designing and visualizing building plans, elevations, and sections in a digital format. It allows engineers to draft, modify, analyze, and optimize their designs more efficiently than traditional methods.

ii. Floor Plan

A floor plan is a detailed drawing that outlines the layout of a building, showing the arrangement of rooms, walls, doors, and windows from a top-down perspective. For a residential house, the floor plan typically includes the following:

- Entrance and Foyer**:** Main entrance with a welcoming foyer or lobby area.

- Living Room**:** A spacious area for family gatherings, with direct access to outdoor spaces like a garden or patio.
- Dining Room**:** Adjacent to the living room, with sufficient space for a dining table and chairs.
- Kitchen**:** Positioned near the dining area, featuring modern appliances, countertops, and storage cabinets. Often includes a pantry or utility room.
- Guest Bathroom: A small bathroom with basic amenities for guests.
- Additional Rooms: Could include a study or office, storage rooms, or a guest bedroom depending on space.
- Outdoor Area: A patio or terrace for outdoor dining and relaxation, often accessible from the living room or kitchen.

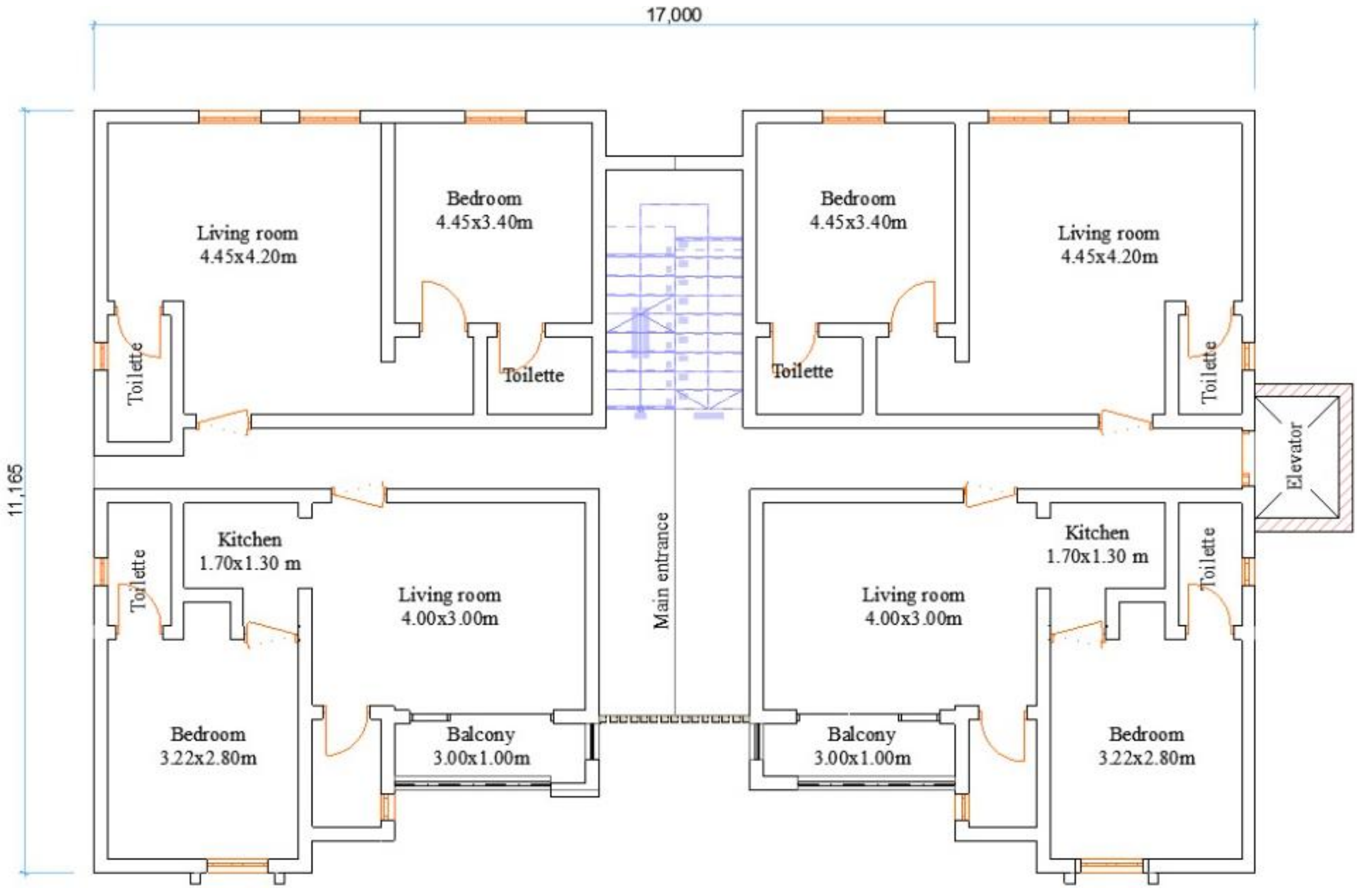


Figure 2.1 Floor plan

iii. Elevation

An elevation is a drawing that represents one side of a building from a straight-on view, providing a detailed view of its exterior appearance. Elevations are crucial in architectural design as they convey the building's facade, including its materials, textures, and overall aesthetic. They also show how the building integrates with its surroundings. Here's an overview of what is typically included in an elevation drawing for a residential building, such as a G+3 residential house:

1. Front Elevation (Facade)

- Main Entry: The design of the front door, including any architectural detailing, such as a portico, columns, or overhang.
- Windows: Placement, size, and style of windows, including any shutters or decorative elements. Windows may be grouped or asymmetrically arranged to enhance visual interest.
- Roofline: The shape and pitch of the roof, including any features like dormers, eaves, or chimneys. The roofing material might be shown, such as tiles, shingles, or metal.
- Materials: Exterior finishes, such as brick, stone, wood siding, or stucco. Material textures and patterns are often illustrated.
- Architectural Features: Elements such as balconies, verandas, or awnings. The design of these features, including railings and supports, is shown.
- Ground Level: Indications of steps, pathways, or landscaping elements around the entry.

2. Side Elevations

- Building Depth: Shows the building's depth and how it extends back from the main facade. These elevations reveal the side views of windows, doors, and any additional architectural features.
- Roofline and Slopes: The sloping angles of the roof on the sides, including any overhangs or changes in roof pitch.
- Side Features: Features such as side entrances, exterior staircases, or utility areas.
- Materials and Textures: Continuation of exterior materials and textures from the front elevation.

3. Rear Elevation

- Back Entry: If applicable, shows any rear doors or service entrances.
- Windows and Openings: Arrangement and size of windows on the rear side, which may differ from the front elevation.
- Terraces: Any outdoor living spaces such as a deck or terrace accessible from the rear.
- Roof and Exterior Details: Continuation of roof design and materials, including any rear-facing architectural features.

Key Elements in Elevation Drawings

- Scale: Elevations are drawn to scale, ensuring accurate representation of proportions and dimensions.
- Annotations: Labels and notes indicating materials, dimensions, and design details.
- Context: Sometimes, elevation drawings include surrounding elements like neighbouring buildings, landscaping, or topography to provide context.
- Shadows and Lighting: Optional, but shadows can be used to show depth and highlight architectural features.

Considerations for Elevation Design

1. Aesthetic Appeal: The design should complement the building's purpose and context while aligning with architectural styles and preferences.
2. Functional Elements: Incorporate practical aspects like window placement for natural light, roof overhangs for weather protection, and ventilation openings.
3. Integration with Environment: The building's elevation should harmonize with the surrounding environment and landscape, respecting local architectural styles and building codes.

iv. Section

A section in architectural drawing is a vertical cut-through of a building or structure that reveals the interior layout and spatial relationships between different floors and components. Sections provide a detailed view of the building's internal organization, construction elements, and how spaces connect vertically. Here's a detailed look at what a section drawing typically includes and how it's used:

Purpose of Section Drawings

- **Interior Layout:** Shows how different levels of the building are connected and how spaces are organized.
- **Structural Elements:** Reveals structural components such as walls, columns, beams, and floors.
- **Construction Details:** Provides information on materials, finishes, and construction methods.
- **Spatial Relationships:** Demonstrates the relationship between different parts of the building, including ceiling heights, floor levels, and staircases.

v. Isometric and oblique drawing

Isometric and Oblique Drawings are two types of pictorial drawings used in architecture and engineering to represent three-dimensional objects on a two-dimensional plane. Each method provides different visual perspectives and has its own set of applications and advantages.

An isometric drawing is a form of axonometric projection where the three principal axes of an object are equally inclined to the plane of projection. This means that all three dimensions of the object are represented at the same scale and angle.

An oblique drawing is a form of pictorial representation where the front view of an object is shown directly, and the other faces are projected at an angle. This type of drawing allows one side of the object to be depicted in true scale while other sides are distorted.

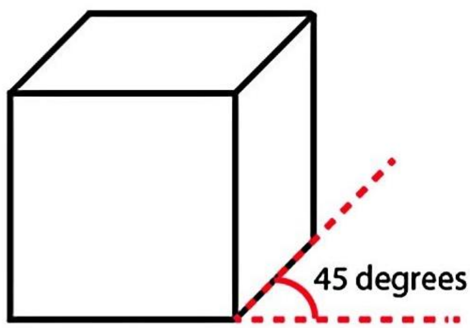


Figure 2.2 Oblique drawing

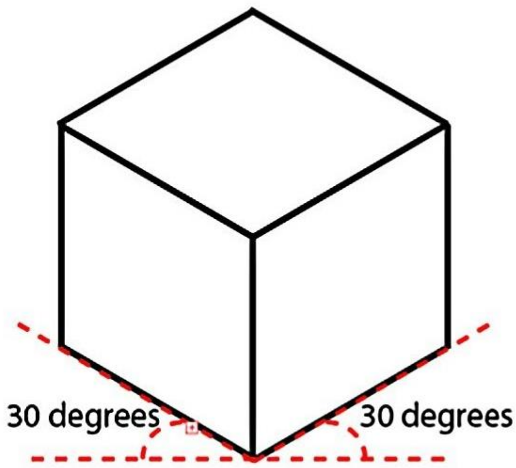


Figure 2.3 Isometric drawing

2.3. Structural design

Structural Design of a Reinforced Concrete Building

Designing a reinforced concrete (RC) building involves several critical steps to ensure safety, functionality, and durability. Reinforced concrete combines the compressive strength of concrete with the tensile strength of steel reinforcement, making it suitable for a wide range of structural applications. Here's a detailed guide to the structural design process for an RC building:

i. Project Planning and Requirements

- **Define Building Requirements:**
  - Objective: the project is considered to be a residential house which is primarily designed and used as a dwelling for individuals or families. It provides a private living space where people can reside, sleep, and carry out their daily activities
  - Occupancy: Assess the expected number of occupants and usage patterns to determine load requirements.
  - Height and Layout: Define the number of floors, room layout, and any special requirements.
- **Site Analysis:**
  - Geotechnical Survey: Evaluate soil properties, including bearing capacity and settlement characteristics.
  - Environmental Conditions: Consider climate, seismic activity, wind loads, and other environmental factors.
- **Regulatory Compliance:**
  - Building Codes: Ensure compliance with local and international codes (e.g. BS code) regarding design, safety, and construction practices.

ii. Conceptual and Preliminary Design

- **Structural System Selection:**
  - Load-Bearing Walls: Determine if the building will use load-bearing walls to support vertical loads.
  - Frames: Opt for a frame system comprising columns and beams for load distribution and stability.
  - Slabs: Decide on the type of slab (e.g., flat, ribbed, or waffle) based on span and load requirements.

- **Preliminary Layout:**
  - Floor Plans: Develop preliminary plans showing the placement of structural elements like columns, beams, and slabs.
  - Material Specifications**:** Choose concrete grade (e.g. C20, C25, C30, C37) and reinforcement types (e.g., high-strength steel).

iii. **Load Analysis and Structural Analysis**

- **Load Calculation:**
  - Dead Loads: Include the self-weight of structural elements (e.g., walls, floors, roofs) and fixed equipment.
  - Live Loads: Account for variable loads from occupants, furniture, and movable equipment.
  - Environmental Loads: Calculate loads from wind, snow, seismic activity, and thermal effects.
- **Structural Analysis:**
  - Modelling: Use structural analysis software (e.g. Prokon, ETABS, and SAP2000) to model the building and apply loads.
  - Load Distribution: Analyses how loads are distributed through the structure and calculate internal forces.
  - Stress and Deflection: Determine stress levels and deflections in structural members to ensure they are within acceptable limits.

iv. Detailed Design of Structural Components

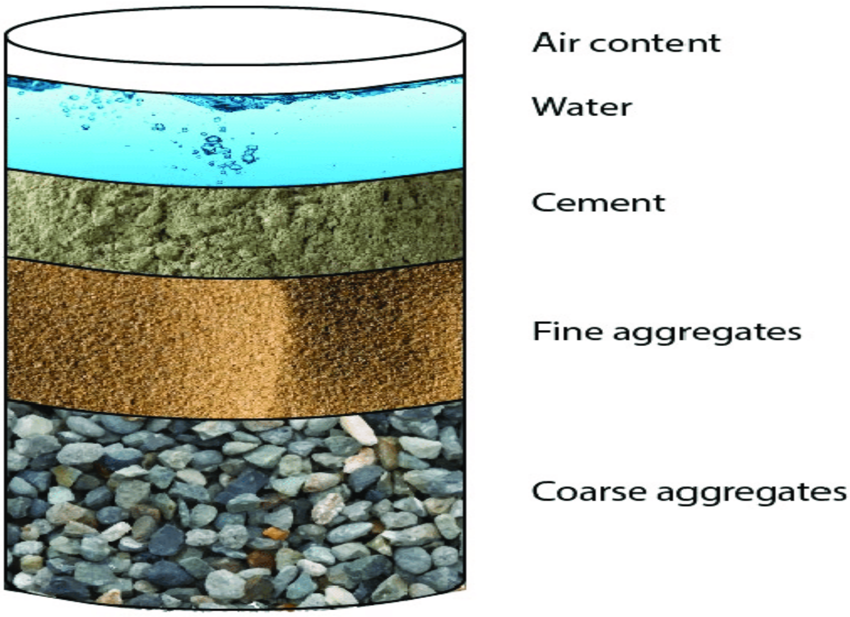


Figure 2.4 Constituent of concrete (Kumar, 2019).

- **Concrete Mix Design:**

  - Strength Requirements: Select a concrete mix based on required compressive strength and exposure conditions.
  - Durability: Use additives and admixtures to enhance durability and resistance to environmental conditions.

- **Foundation Design:**

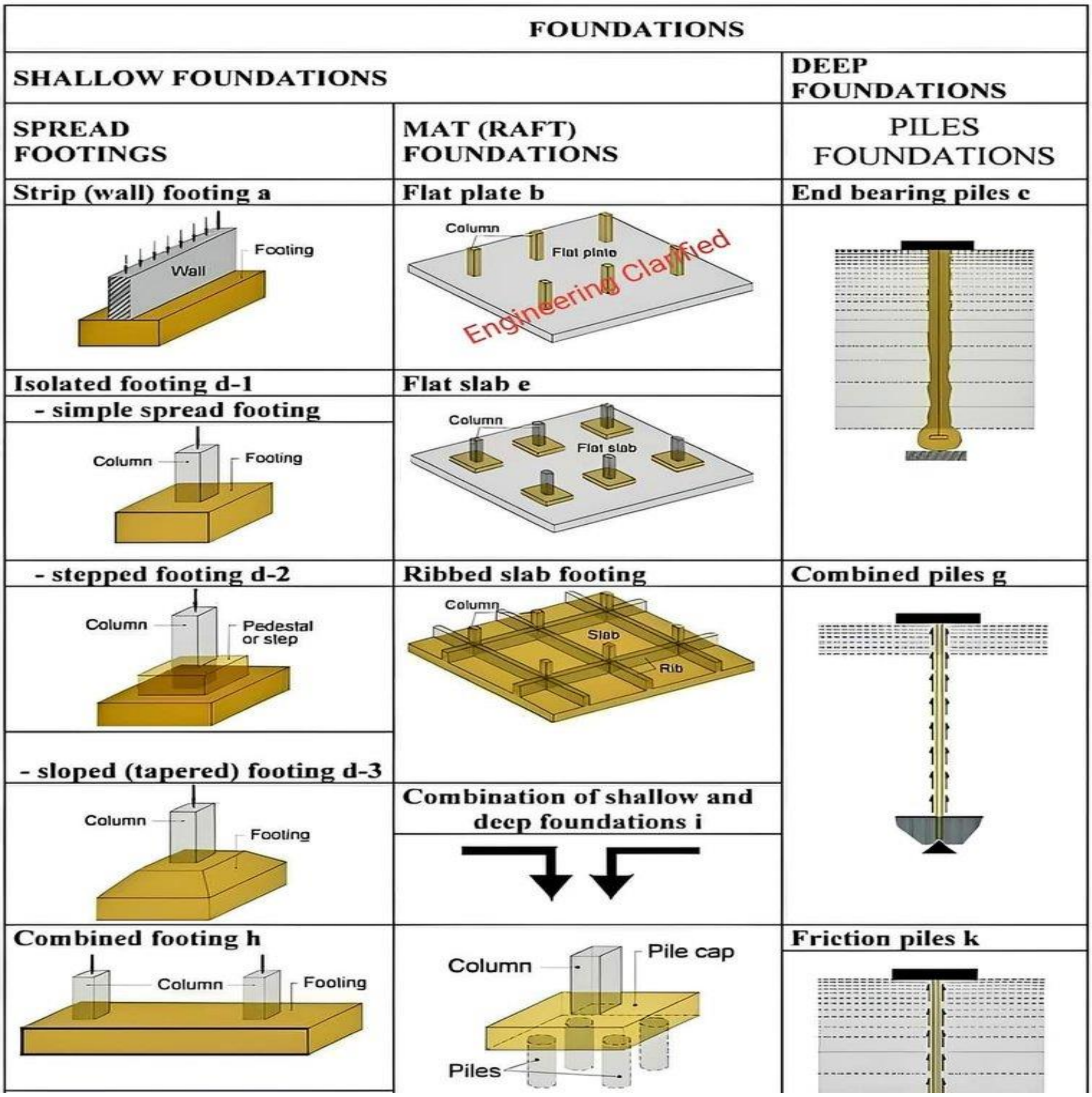


Figure 2.4 Deferent types of foundation

- Type: Choose between shallow foundations (e.g., spread footings) or deep foundations (e.g., piles) based on soil conditions and load requirements.
- Design: Calculate dimensions and reinforcement to safely transfer loads to the soil and accommodate settlement.

- **Column Design:**

- Dimensions: Determine column size based on load-bearing requirements and space constraints.
- Reinforcement: Design the amount and arrangement of steel reinforcement to resist axial loads and bending moments.

- **Beam Design:**
  - Dimensions: Calculate beam dimensions and reinforcement based on span, load, and deflection criteria.
  - Reinforcement: Design reinforcement to handle bending moments, shear forces, and torsion.

- **Slab Design:**

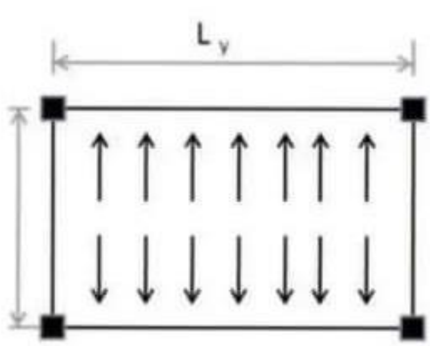


Figure 2.5 one-way slab

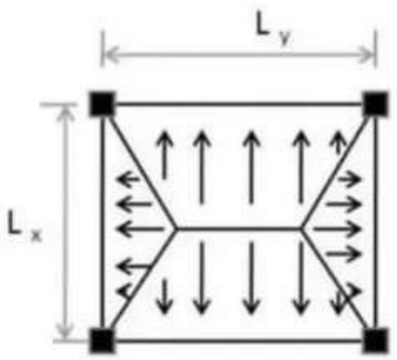


Figure 2.6 two-way slab

  - **Type:** Decide on slab type (e.g., solid slabs, ribbed slabs, or flat slabs) based on span and load requirements.
  - **Thickness and Reinforcement:** Determine slab thickness and reinforcement layout to ensure structural integrity and minimize deflection.

v. Construction Detailing

- **Drawings:**
  - Structural Drawings: Prepare detailed drawings showing the layout of columns, beams, slabs, and reinforcement.
  - Reinforcement Detailing: Include drawings for rebar placement, types, and sizes.

- Specifications:
  - Material Specifications: Provide detailed specifications for concrete mix, reinforcement, and construction practices.
  - Construction Procedures: Outline procedures for concrete pouring, curing, and quality control.

vi. Quality Control and Construction Supervision

- **Material Testing:**
  - Concrete Testing: Perform tests for concrete strength (e.g., compressive strength tests), workability (e.g., slump test), and durability.
  - Reinforcement Testing: Verify the quality of steel reinforcement and its placement.
- **Site Supervision:**
  - **Monitoring:** Ensure that construction follows design specifications and quality standards.
  - **Inspection:** Regularly inspect structural elements during construction to confirm compliance and accuracy.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Project description and localisation

The project is located in Gisozi around ULK University.

Each building has its own purpose and importance. Buildings is constructed based on client requirement, geographical condition of the site, safety, privacy, available facilities, etc. and designed as:

3.2. Planning phase

Planning of building is grouping, arrangement different component of a building to form a homogenous body, which can meet all its function and purposes. Proper orientation, safety, healthy, beautiful and economic construction are the main target of building planning. It is done based on the following criteria:

i. **Functional Planning**

- Client requirement is the main governing factor for the allocation of space required which is based upon its purposes. Thus, demand, economic status and taste of owner features the plan of building.
- Building design should favour with the surrounding structures and weather.
- Building is designed remaining within the periphery of building codes, municipal by laws and guidelines.

ii. **Structural Planning**

The structural arrangement of building is chosen to make it efficient in resisting vertical and horizontal load. The material of the structure for construction should be chosen in such a way that the total weight of structure would be reduced so that the structure will gain less inertial force (caused during earthquake). The regular geometrical shape building is designed as an earthquake resistant structure based on BS code.

3.3. Load assessment

Once the detailed architectural drawing of building is drawn, the building subjected to different loads is found out and the calculation of load is done. The loads on building are categorized as below:

i. **Gravity load**

This consists of imposed load and self-weight of the building such as structural weight, floor finish, partition wall, other household appliances, etc. To assess these loads, the materials to be used are chosen and their weights are determined based on BS code of practice for design loads (other than earthquake) for buildings and structures.

- **Dead Load calculation**

Thickness of the structural member *1.4 unit weight * breath

- **Imposed Load**: we will be using the following table to it value

Table 1. Minimum imposed floor loads

Type of activity for part of the buiding or structure	Examples of specific use		Uniformity distributed load KN/m^2	Concentrated load KN
A domestic and residential activities (also see category C)	All usages within self-contained dwelling units communal areas (including kitchens) in blocks of flats with limited use (see note 1)(for communal areas in other blocks of flats, see C3 and below)		1.5	1.4
	Bedrooms and dormitories except those in hotels and motels		1.5	1.8
	Bedrooms in hotels and motels Hospital wards Toilet areas		2.0	1.8
	Billard rooms		2.0	2.7
	Communal kitchens except in flats covered by note 1		3.0	4.5
	Balconies	Single dwelling units and communal areas in blocks of flats with limited use (see note 1)	1.5	1.4
		Guest houses, residential clubs and communal areas in blocks of flats except as covered by note 1	Same as rooms to which they give access but a minimumof 3.0	1.5/m conncentrated at the outer edge
		Hotels and motels	Same as rooms to which they give access but with a minimum of 4.0	

ii. Lateral load

Lateral load includes wind load and earthquake load. Wind load acts on roof truss while an earthquake act over the entire structure.

3.4 Load Combination

- Dead loads +Imposed loads = 1.4 G k + 1.6 Q k
- Dead loads +Wind loads = 0.9 G k +1.4 W k
- Dead loads +Imposed loads + Wind loads = 1.2 Gk+1.2 Q k +1.2 W k

3.5. Preliminary design

Before proceeding for load calculation, Preliminary size of slabs, beams and columns and the type of material used are decided. Preliminary Design of structural member is based on the IS Code provisions for slab, beam, column, wall, staircase and footing of serviceability criteria for deflection control and failure criteria in critical stresses arising in the sections at ultimate limit state i.e. Axial loads in the columns, Flexural loads in slab and beams, etc.

Appropriate sizing is done with consideration to the fact that the preliminary design based on gravity loads is required to resist the lateral loads acting on the structure. Normally preliminary size will be decided considering following points:

➢Slab: The thickness of the slab is decided based on span/d ratio assuming

Appropriate modification factor.

➢Beam: Generally, width is taken as that of wall i.e. 230 or 300 mm. The depth is generally taken as 1/12 or 1/15 of the span.

➢Column: Size of column depends upon the moments from the both direction and the axial load. Preliminary Column size may be finalized by approximately calculation of axial load and moments.

3.6. Idealization of structure

i. Idealization of support

In structural engineering, idealization of support refers to simplifying the real-world conditions of support in a structure to make analysis and design more manageable. Idealization involves approximating the actual support conditions of a structure to make analytical models more straightforward while still capturing the essential behaviour of the structure. This process is crucial for performing structural analysis efficiently and accurately.

ii. Idealization of load

The load acting on the clear span of a beam should include floor or any types of load acting over the beam on the tributary areas bounded by 450 lines from the corner of the panel i.e. Yield line theory is followed. Thus, a triangular or trapezoidal type of load acts on the beam.

iii. Idealization of structural system

Initially individual structural elements like beam, column, slab, staircase, footing, etc. are idealized. Once the individual members are idealized, the structural system is idealized to behave as theoretical approximation for first order linear analysis and corresponding design. The building is idealized as unbraced space frame. This 3D space framework is modelled in SAP for analysis. Loads are modelled into the structure in several load cases and load combination.

3.7. Modelling and analysis of structure

Structural analysis is the process of calculating the forces, moments and deflections to which the members in a structure are to be subjected. There is a vast range of analysis tools offering speed, precision and economy of 3D design, structural modelling, bespoke such as archicad, prokon software etc. .

Modelling different design of a structures is made easier by the use of full model generating software, with load generating tools enabling frame stability verification along with member checks. The design can be performed to British or European Standards.

It is generally convenient to consider first the form of the building frame in orthogonal directions, and to identify:

- The primary structural elements which form the main frames and transfer both horizontal and vertical load to the foundations
- The secondary structural elements, such as secondary beams which transfer the loads to the primary structural elements
- The other elements, such as partitions, which only transfer loads to the primary or secondary structural elements

3.8. Design and detailing

Detailing translates the engineer's design into a set of clear, actionable drawings and specifications. These documents are used by contractors to understand exactly how to place and secure reinforcement within the concrete. It ensures that all components of the reinforcement are placed correctly according to the design specifications, which helps in achieving the intended structural performance and safety.

i. Components of Detailing:

- **Working Drawings:** These are detailed drawings showing the size, location, and arrangement of reinforcement bars (rebar) within the concrete. They include plans, sections, and elevations of the structure.
- **Reinforcement Layout:** Includes the type, size, spacing, and placement of rebar. This layout is crucial for achieving the desired strength and durability of the concrete.
- **Bar Bending Schedules:** Detailed schedules provide information on how to cut and bend reinforcement bars to meet the design requirements.
- **Connection Details:** Specific drawings showing how different parts of the structure connect, including the interface between reinforcement and other structural elements or systems.

ii. Importance of Good Detailing:

- **Structural Integrity:** Proper detailing ensures that the concrete and reinforcement work together as intended, optimizing the load-carrying capacity and durability of the structure.
- **Compliance:** Good detailing helps in meeting building codes and standards, which is essential for the safety and legality of the construction.
- **Efficiency:** Accurate detailing reduces errors and rework during construction, leading to more efficient use of materials and labour.

CHAPTER 4: RESULT AND DISCUSSION

4.1. Structural drawing

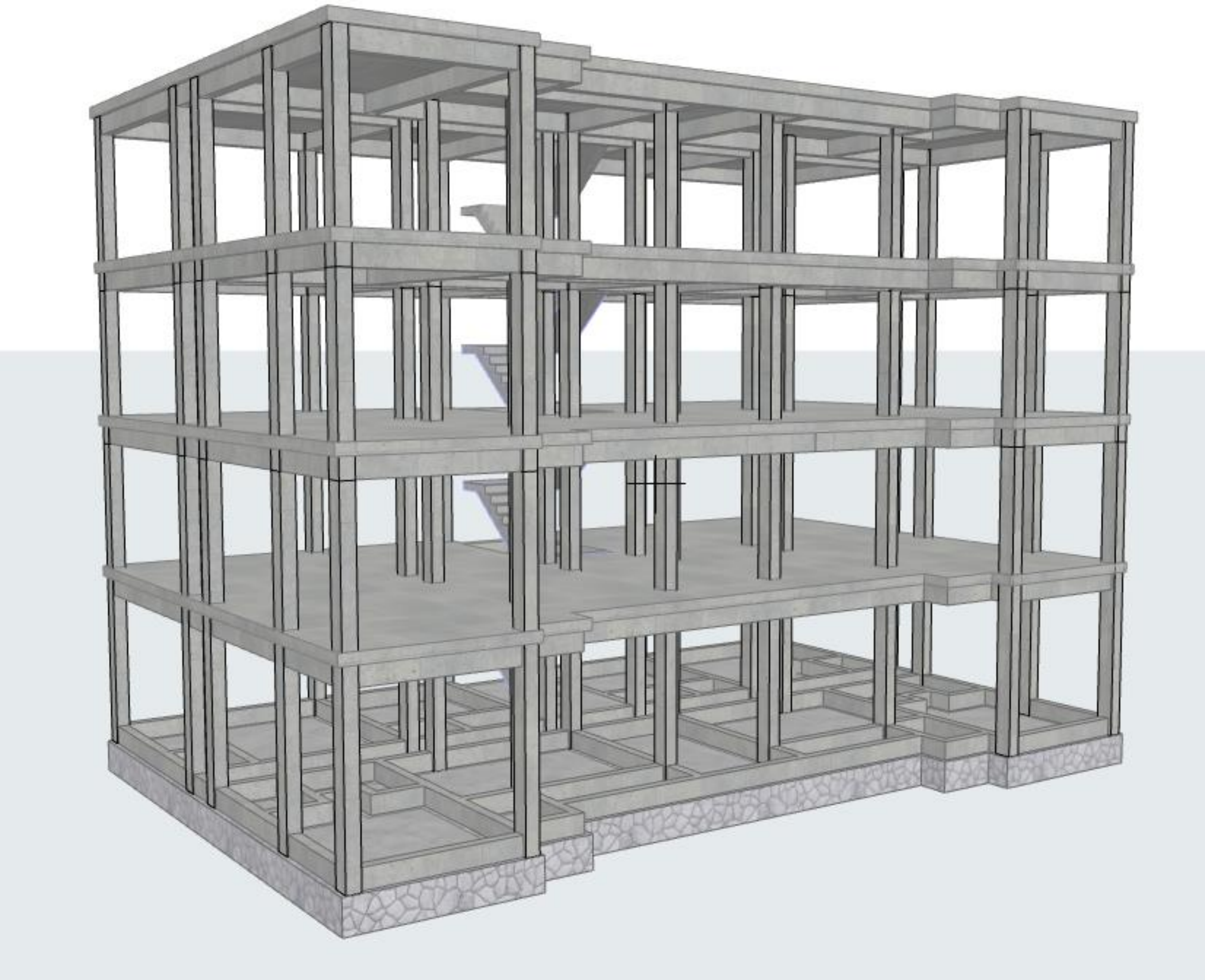
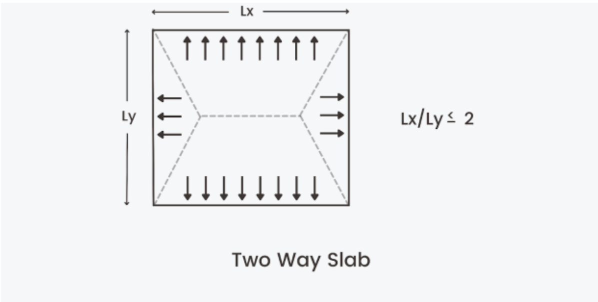


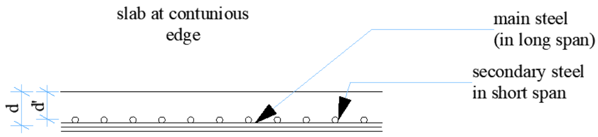
Figure 4.1 structural design

4.2. Design of reinforced concrete solid slab

References	Application and formula	Outcome
	DESIGN OF RC SOLID SLAB Location: Grid 1-1 and A-A, first floor Slab dimensions : $L_x = 4.2m$ $L_y = 4.45m$	$L_x = 4.2m$ $L_y = 4.45m$
	SLAB CLASSIFICATION  Figure 4.2 Two way slab $L_y/L_x = 4.45/4.2 = 1.05$ $L_y/L_x < 2$ is a 2-way slab	2-way slab
Table 3.14	**MOMENT COEFFICIENTS** The slab is tortionally restrained at the corners: Use of top reinforcement is required Slabs supported by RC beams with sufficient stirrups and reinforcement	

	A study of slab panel in relation to others panel shows it's 2 adjacent discontinuous **Short span coefficients for mid span moment** B_{sx} = 0.042 for L_y/L_x = 1.0 B_{sx} = 0.036 for L_y/L_x = 1.1 B_{sx} = (0.036+0.042)/2 = **0.039** for L_y/L_x = 1.05 **Long span coefficients for mid span moment** B_{sy} = 0.034 **Short span coefficients for negative moments at continuous edge** B_{sxt} = 0.047 for L_y/L_x = 1.0 B_{sxt} = 0.056 for L_y/L_x = 1.1 B_{sxt} = (0.047+0.056)/2 = **0.051** for L_y/L_x = 1.05 **Long span coefficient for negative moments at continuous edge** B_{sxt} = 0.045	B_{sx} = 0.039 B_{sxt} = 0.051
	CONCRETE COVER Nominal cover for mild conditions = 20mm Cover of 20 mm gives a maximum fire resistance of 1.5 hours Assume bar diameter of 10mm	

Table 1	**LOADING** self-weight of slab = thickness of slab * unit weight of concrete * breadth of slab Self-weight of slab = 0.15 * 25 * 1= 3.75 KN/m^2 Finishes (ceiling, floor screed and tilling)= 0.06*25*1= 1.5 KN/m^2 Total dead load G_k= 3.75+1.5 =5.25KN/m^2 Live load (residential floor) Q_k= 2KN/m^2 Design load = $1.4G_k + 1.6Q_k$ = 1.4*5.25 + 1.6*2 = 10.55KN/m^2	b = 1m Unit weight of concrete=25KN/m^3 G_k=5.25KN/m^2 Q_k = 2KN/m^2 n = 10.55KN/m^2
3.5.3.4	**CALCULATING THE BENDING MOMENT** Mid span bending moment (short span) Msx = $B_{sx}n(L_x)^2$ = 0.039*10.55*$(4.2)^2$ = 7.257 KNm Mid span bending moment (long span) Msy = $B_{sy}n(L_x)^2$= 0.034*10.55*$(4.2)^2$ = 6.327 KNm Negative moment at continuous edge in the short span Msxt = $B_{sxt}n(L_x)^2$ = 0.051*10.55*$(4.2)^2$ = 9.491 KNm Negative moment at continuous edge in the long span	Msx= 7.257KNm Msy= 6.327 KNm Msxt= 9.491KNm

	$Msyt = B_{syt}n(Lx)^2 = 0.045*10.55*(4.2)^2$ $= 8.374$ KNm	Msyt=8.374
	CALCULATING STEEL REINFORCEMENT  Figure 4.3 Slab at mid span At mid span the slab resists sagging moments in both short span and long span directions, necessitating two layers of reinforcement (main and distribution steel) in the bottom face of the slab. Since Msx > Msy , main steel is placed in short span and distribution steel in long span. **ESTIMATING EFFECTIVE DEPTH** d = h- ⌀/2 – C Where cover C = 20mm, for 1.5 fire resistance **main steel ⌀ = 10 mm** Overall slab depth h = 150mm d = (150 - 10/2- 20) = 125 mm similarly d for **secondary steel**	

	d'=(150- 10- 10/2- 20)= 115mm **REINFORCEMENT**	
Table3.3 Table3.4	**Main steel at mid span, d=125mm, short span direction** K= Msx/fcubd^2= 7.257*10^6/25*1000*125^2 = 0.018 K=0.018< 0.15 , thus no compression reinforcement required Z = d[0.5+√(0.25 - K/0.9)] = d[0.5+√(0.25 - 0.018/0.9)] = 0.979d>0.95d therefore we consider 0.95d Asreq= M/0.95fyZ = 7.257*10^6/0.95*460*0.95*125 = 139.84mm^2/m = 140mm^2/m **Secondary steel at mid span (d=115mm) long span direction** K= Msy/fcubd^2= 6.327*10^6/25*1000*125^2 = 0.019	Main steel d= 125mm Distribution steel d'=115mm Msx = 7.257KNm K= 0.018 Z= 0.95d

	K=0.019< 0.15 , thus no compression reinforcement required Z = d[0.5+√(0.25 - K/0.9)] = d[0.5+√(0.25 - 0.019/0.9)] = 0.97d>0.95d therefore we consider 0.95d Asreq= Msy/0.95fyZ = $6.327*10^6$/0.95*460*0.95*125 = 132mm^2/m **Check minimum steel area** Asmin =0.13%bd = 0.13%*1000*150 = 195mm^2/m As max = 0.4%bd = 0.4%*1000*150 = 600mm^2/m Let's consider As= 195mm^2/m Since Asreq for main and distribution bar < As min Asprov= 314mm2/m From area of steel reinforcement table we can choose Y10@250 centers 314mm2/m Use for both main and distribution reinforcement at the bottom area of the slab	**Z= 0.95d** Asmin = 195mm^2 Asmax = 600mm^2 As'prov = 314mm^2

3.12.5.3;

3.12.6.1

At continuous edge

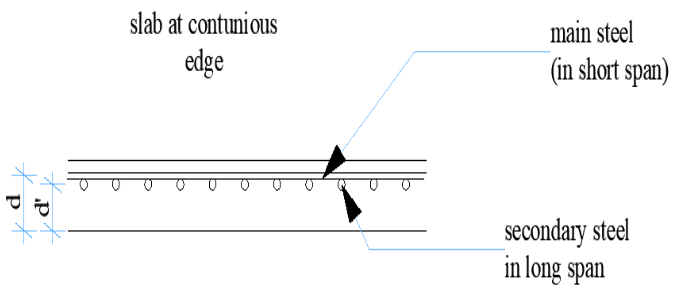


Figure 4.4 Slab at continuous edge

Steel at supports (top steel reinforcement)

At continuous supports the slab resists hogging moment in both short span and long span directions. Therefore two layers of reinforcement will be needed in the top face of the slab.

Comparison of design moments shows that the moment in the short span (9.491KNm) is greater than the moment in the long span (8.374KNm) and it is appropriate therefore that the Steel in short span direction (main steel) be placed at a greater effective depth than the steel in the long span direction (secondary steel).

Calculation of effective depth

Main steel

$d = h - \varnothing/2 - C$

Where cover C = 20mm, for 1.5 fire resistance

main steel ⌀ = 10 mm

Overall slab depth h = 150mm

	d = (150 - 10/2- 20) = 125 mm similarly d for **secondary steel** d'=(150- 10- 10/2- 20)= 115mm **Main steel (d=125mm)** Asreq= Msxt/0.95fyZ = $9.491*10^6/0.95*460*0.95*115$ = $183mm^2/m$ **Secondary steel d=115mm** Asreq= Msyt/0.95fyZ = 8.374*106/0.95*460*0.95*115 = $176mm^2/m$ Use Y10@. 250 Centers, $314mm^2/m$ as main and secondary steel at the top continuous edges.	d = 125mm d'= 115mm Asreq = 183 mm^2 Asprov= $314mm^2$

	CHECK FOR SHEAR	
	Maximum shear load $V = B_{vx}nL_x$	
	Bvx= 0.42	
Table3.15	V = 0.42*10.55*4.2 = 18.61KN/m	**V= 18.61KN/m**
Table3.8	Shear v =V/bd = 18.61*1000/1000*125	
	= 0.148	v = 0.148
	$Vc = 0.79*[(100As/bd)^{1/3}*(400/d)^{1/4}]/\gamma_m$.	
	γ_m= 1.25	
	$(100As/bd)^{1/3}$= 0.538 not > 3 ok	
	$(400/d)^{1/4}$ = 1.337 not < 1 ok	
	Vc = 0.79*0.538*1.33/1.25	
	= 0.455	vc = 0.455
	v< Vc no shear reinforcement required, the slab is safe to shear	

3.4.6 Table 3.9 Table 3.10	**DEFLECTION CHECK** Basic span/effective depth ratio = 26 (continuous slab) Modification factor for tension reinforcement MF = 0.55+ (477-Fs)/[120(Msx/bd^2)+0.9] Msx = 7.257KNm b = 1000m Fs = [2(FyAsreq)/3Asprov] *1/Bb = 2*460*125/3*314= 122.08N/mm2 MF = 0.55+ (477-122.08)/[120(7.257/125^2)+0.9] = 2.71 Since MF > 2 let's take 2 as MF Permissible span/ effective depth= 26* 2 =52 Actual span/d= 4200/125 = 33.6m Actual span/d < permissible/effective depth, deflection requirements are satisfied.	MF = 2.71

4.3 DESIGN OF BEAM

Influence area of a beam

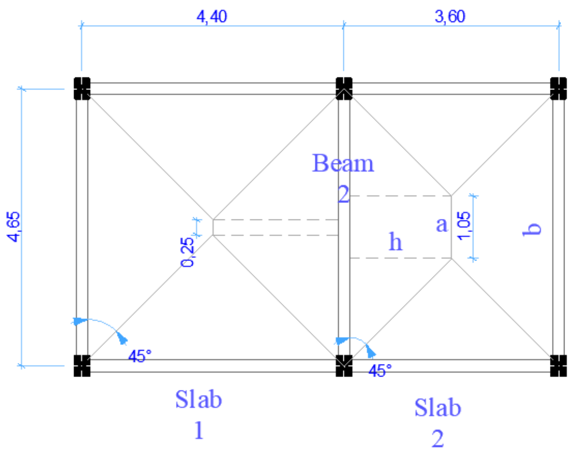


Figure 4.5 Influence area of a beam

Distribution of slab load to beams

Slab 1

b = 4.65m

h = 4.40/2 = 2.20m

a= b - 2x

tan45° = h/x

X = 2.20/ 1 = 2.20 m

a = 4.65 - 2(2.20)

= 0.25 m

Slab surface

= 2(area of triangle) + area of rectangle

= 2[1/2(xh)] + ah

= xh +ah

	= h(x +a) = 2.20(2.20+0.25) = 5.39 m^2 **Slab 2** b = 4.65m h = 3.60/2 = 1.80m a= b - 2x tan45° = h/x X = 1.8/ 1 = 1.8 m a = 4.65 - 2(1.8) = 1.05m Slab surface = h(x+a) = 1.8(1.8+1.05) = 5.13 m^2 Total influence area = area of slab 1 + area of slab 2 = 5.39 + 5.13 = **10.52 m^2** The total load from slab supported by beam =(Influence area * Dead from slab)/Length of span = (10.52 * 10.29)/4.65 = **23.27 KN/m** **Total dead load of beam, wall, finishes combined together**	

	Dead load from slab+ dead load from walls + dead from finishes + self-weight of beam **dead load from wall** =1.4* breadth of wall * height of wall * wall length* unit weight of masonry = 1.4*0.2*2.8*4.65*19 = 69.26KN **dead load from finishes** =1.4* breadth of finishes * height of finishes * finishes length* 2*unit weight of finishes = 1.4 * 0.03*2.8*4.65*2*20 =21KN **dead load from beam** (self-weight) =1.4* breadth of beam * height of beam * beam length* unit weight of concrete = 1.4*0.25*0.45*4.65*25 = 18.30KN **Summation of loads** 69.26+ 21.87+18.30 = 109.43KN Distributed load = 109.43KN/span = 109.43/4.65 =23.5KN/m Total distributed load= 23.27 +23.5	

	= **46.77KN/m**	
	LIVE LOAD Live load on slab = 1.6 * live load from table of BS 6399* influence area = 1.6*3* 10.52 = 66.048KN Distributed live load= 66.048/4.65 = 14.21KN/m Total distributed load along the beam length= 46.77+14.21= **60.98 KN/m** = 61KN/m	
	Computation of moment M = $WLx^2/8$ = 61* $4.65^2/8$ = 165 KNm **Calculating effective depth** Let's assume: h = 450mm , b = 250mm Concrete cover= 20mm Main ⌀ bar = 16mm	

	Links ⌀ = 10 mm Effective depth = h -c - links ⌀ - main ⌀/2 = 450-20- 10- 16/2 =412mm	
	Check whether the section is singly or doubly reinforced beam $K = M/bd^2fcu$ $= 165*10^6/250*412^2*25$ = 0.155 < 0.156 no compression bar is required Z= d[0.5+√(0.25- K/0.9)] = 412[0.5+√(0.25- 0.155/0.9)] = 320.9 mm 0.95d = 0.95*412 = 391.4 Z< 0.95d , use Z As = M/0.95fyZ $= 161*10^6/0.95*460*321$ $= 1148\ mm^2$ Provide 4Y20 = ($1260mm^{2)}$. Asprov = $1260mm^2$ For practical purpose of forming a reinforcement cage , provide a minimum compression reinforcement	Z= 391.4

	as secondary reinforcement which will serve as hanger bars Provide 2T12 ($225mm^2$)	
	Check for shear Maximum design shear load = WL/2 = 61* 4.65/2 = 141.8KN Shear stress v = V/bd v= 141.8 * 1000/250*412 = 1.376 N/mm2 Vc $=0.79/\gamma_m(100As/bd)^{1/3}(400/d)^{1/4}$ $(100As/bd)^{1/3} = 1.03 < 3$ $(400/d)^{1/4} = 0.99$ not < 1 Vc = 0.79/1.25(1.03)(0.99) = 0.64 N/mm2 Vc < v Provide shear links of T10@200mm center to center	

	Deflection check Basic span / effective depth ratio = 4650/412 = 11.28 Basic ratio for simply supported rectangular beam= 20 MF for tension reinforcement $MF = 0.55 + [(477- fs)/120(0.9+M/bd^2)]$ Fs= 2/3[(fyAsreq)/Asprov] *1/B = 276.2 $M/bd^2= 160.68*10^6/250*412^2$ = 3.78 MF = 0.91 <2 Basic ratio = 20* 0.91 = 18.15 Basic span/effective depth ratio < 18.15 ok	

4.4. COLUMN DESIGN

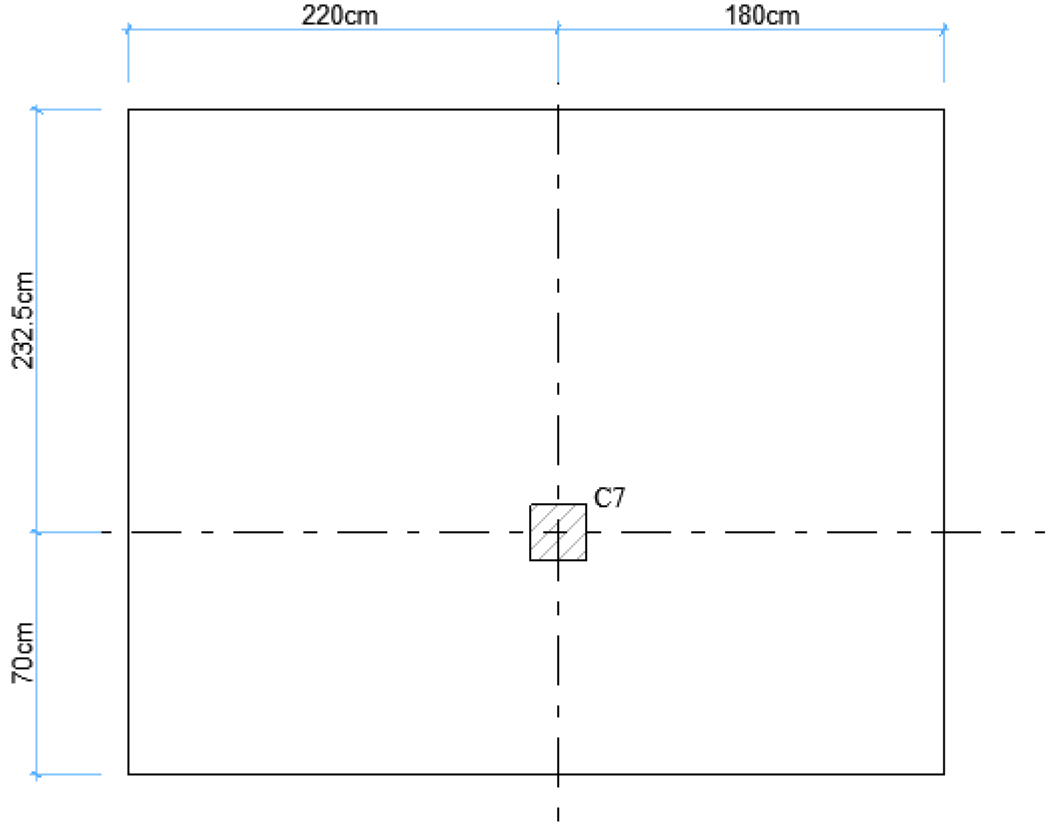


Figure 4.6 Influence area of a column

Given data

Size of column = 25*35 cm

Thickness of beam = 25cm

Design load of slab= 10.55KN/m^2

Live load =3 KN/m^2

Unite weight of masonry= 19KN/m^3

Unite area of finishes= 20KN/m^2

Height of column/floor= 3.5m

Influence area

Influence area = (2.2 + 1.8)*(0.7+2.325)

= 12.1m²

Beam length= 2.325+0.70+2.20+1.80 = 7.025 m

Wall length= (2.325-0.35) + (2.20+1.80-0.25) =5.725m

Wall height= height of column -height of beam=3.5m - 0.35m = 3.15m

Height of finishes= height of column - thickness of slab= 3.5-0.16 =3.34m

Calculation of loads

Dead loads

Self-weight of the column

= 1.4* width of column*breadth of column* height of column*unit weight of concrete

= 1.4*0.25*0.35*3.5*25KN/m^3

= 10.72KN

Load from slab = design load of slab per unit area * influence area

= 10.55KN/m^2 * 12.1m2 = 127.655KN

Load from beam

= 1.4* breadth of beam * thickness of beam * beam length * unit weight of concrete

= 1.4*0.25*7.025*25= 61.46 KN

Load from wall masonry

= 1.4* breadth of wall * high of wall * wall length * unit weight of wall

= 1.4*0.20*3.15*5.725*19

= 95.93KN

Load from wall finishes

=1.4*thickness of finishes*height of wall*wall length*2*unit weight of finishes

= 1.4*0.03*3.15*5.725*20*2

= 30.29KN

Live load

Live load = 1.6*live load from table of BS6399 * influence area

= 1.6*3*12.1 = 58.08 KN

Loads on column of ground floor

N1= (loads from slab + loads from beam + loads from wall + loads from finishes+ live load)*3 + (self-weight of column) *4

= (127.655 +61.46+95.93+30.29+ 58.08)*3 + 10.72*4

= 1163.125 KN

Determine whether the column is braced or unbraced

From the structure, columns are gaining lateral support from walls and beam to increase its stability and load carrying capacity, therefore columns are considered to be braced.

Short or slender column

Column size = 25*35cm

L_{ox}= 3000mm. L_{ox} = floor to floor height

L_{oy}= 3000-350. L_{oy} = floor to beam height

= 2650mm

From clause 3.8.16 of BS 8110

In y -direction

Top end condition of column= 1,

Bottom end condition of column= 1, hence $B_x = 0.75$

$L_{ex}/h = B_x L_{ox}/h$

= 0.75*3000/350

= 6.42

In X-direction

Top end condition of column= 1

Bottom end condition of column= 1, hence By= 0.75

L_{ey}/b = ByLoy/b

= 0.75* 2500/250

= 7.5

Since both L_{ex}/h and $L_{ey}/b < 15$ the column is considered to a short column

From the following figure we can see how the column is resisting an axial load and biaxial moment

Characteristic dead load = 78.164KN

Characteristic live load = 41.28 KN

Axial load= 1163.125KN

Calculate fixed end moment

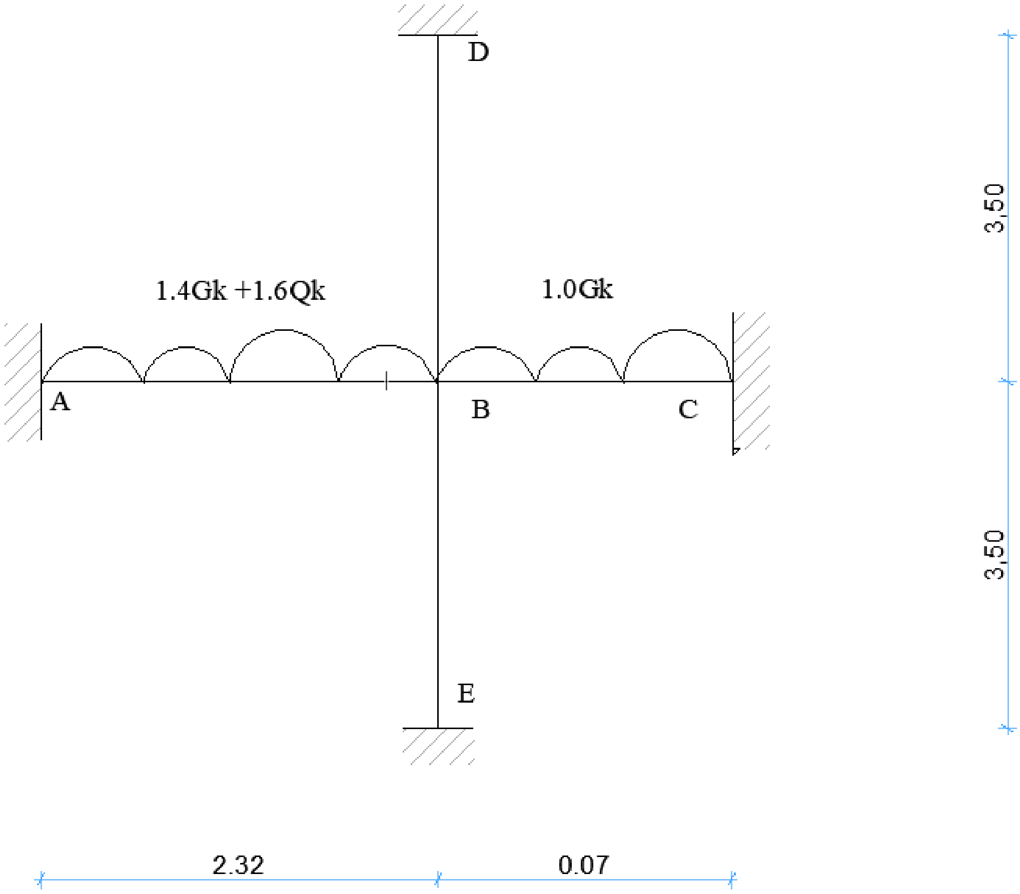


Figure 4.7 Fixed end moment in y direction

Y-direction

K of beam

$K_{AB} = 0.5*bh^3/12L_{AB}$

$K_{AB} = 0.5*0.25*0.35^3/12*2.325$

$= 0.00019$

$K_{BC} = 0.5*bh^3/12L_{BC}$

$= 0.5*0.25*0.35^3/12*0.07$

$= 0.0063$

K of column

$K_{BD}= bh^3/12L_{BD}$

$=0.25*0.35^3/12*3.5$

$= 0.00025$

$\Sigma K = K_{AB}+K_{BC}+K_{col}$

$= 0.0019+0.0063+0.00025$

$= 0.00845$

Distribution factor = Kcol/ΣK

= 0.00025/0.00846

= 0.029

Fixed end moment at point B

FEMBA = $ql^2/12$

$= (1.4*78.164+ 1.6*41.28)* 2.325^2/12$

= 79.05KNm

FEMBC = $ql^2/12$

$= (1.0*78.164)*0.07^2/12$

= 0.031KNm

Difference of moment= FEMBA -FEMBC

= 79.019 - 0.031

= 79.019KNm

Design moment = difference of moment * distributed factor

= 79.019* 0.029

My = 2.29KNm

X direction

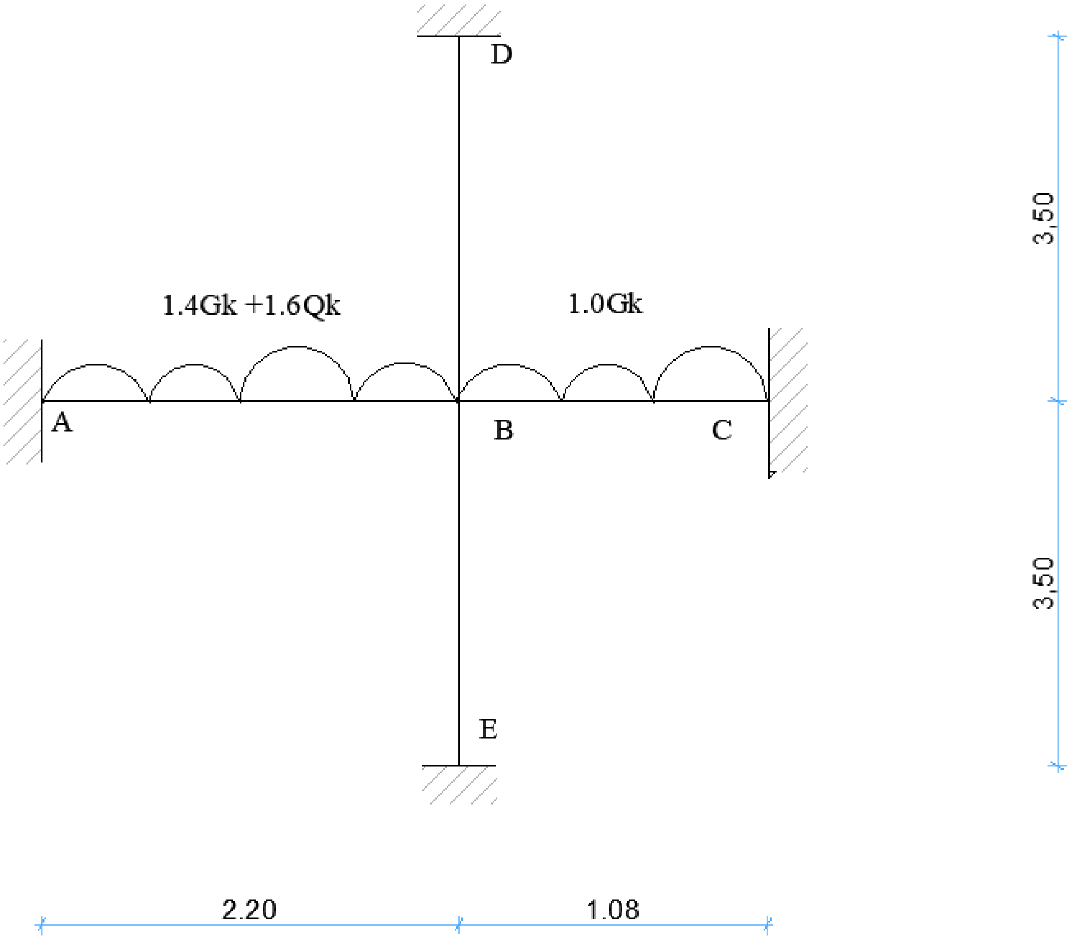


Figure 4.8 Fixed end moment in x direction

K of beam

$K_{AB} = 0.5*bh^3/12L_{AB}$

$K_{AB} = 0.5*0.25*0.35^3/12*2.2$

$= 0.0002$

$K_{BC} = 0.5*bh^3/12L_{BC}$

$= 0.5*0.25*0.35^3/12*1.8$

$= 0.00024$

K of column

K_{BD}= $bh^3/12L_{BD}$

=0.25*0.353/12*3.5

= 0.00025

ΣK = K_{AB}+K_{BC}+ K_{col}

= 0.0002+0.00024+0.00025

= 0.00069

Distribution factor = K_{col} /ΣK

= 0.00025/0.00069

= 0.36

Fixed end moment at point B

FEMBA = $ql^2/12$. Let's assume 1.4Gk + 1.6Qk = 150KN/m and 1.0Gk = 115KN/m

= 150* 2.2^2/12

= 60.5 KNm

FEMBC = $ql^2/12$

= (115)*1.8^2/12

= 31.05KNm

Difference of moment= FEMBA -FEMBC

= 60.5 - 31.05

= 29.45KNm

Design moment = difference of moment * distributed factor

= 79.019* 0.36

Mx = 10.602KNm

Let's consider 25 mm as concrete cover, ⌀ main bar = 16 mm, ⌀. Links= 8mm

h'= 350 - 25 - 16/2 - 8 = 309mm

b' = 250 -25 -16/2 - 8 = 209mm

fcu = 25N/mm2 , fy= 460K/mm2

Ultimate axial load N= 1163.125KN

In x- direction Mx= 10.602KNm

In y- direction My= 2.29KNm

Mx/h'= 10.602/0.309. My/ b' = 2.29/0.209

= 34.31KN. = 10.95 KN

Mx/h' > My/b'. Design moment is about x-x axis

N/bhfcu= $1163.125*10^3/350*250*25$ = 0.53

B= 0.42 from table 3.28

M'_x =Mx + (Bh'/b')My

= 10.602 + (0.42*309/209)2.29

= 12KNm

$M'x/bh^2 = 12* 10^6/350*250^2$

= $0.54N/mm^2$

N/bh= $1163.125*10^3/350*250$

= $13.29N/mm^2$

d/h = 309/350 = 0.90

From chart of BS8110 part 3

$100A_{sc}/bh = 1.2$

A_{sc}= 1.2bh/100 = 1.2*350*250/100 = 1050mm^2

Provide 6T16 (1210mm^2)

4.5 DESIGN OF FOUNDATION/FOOTING

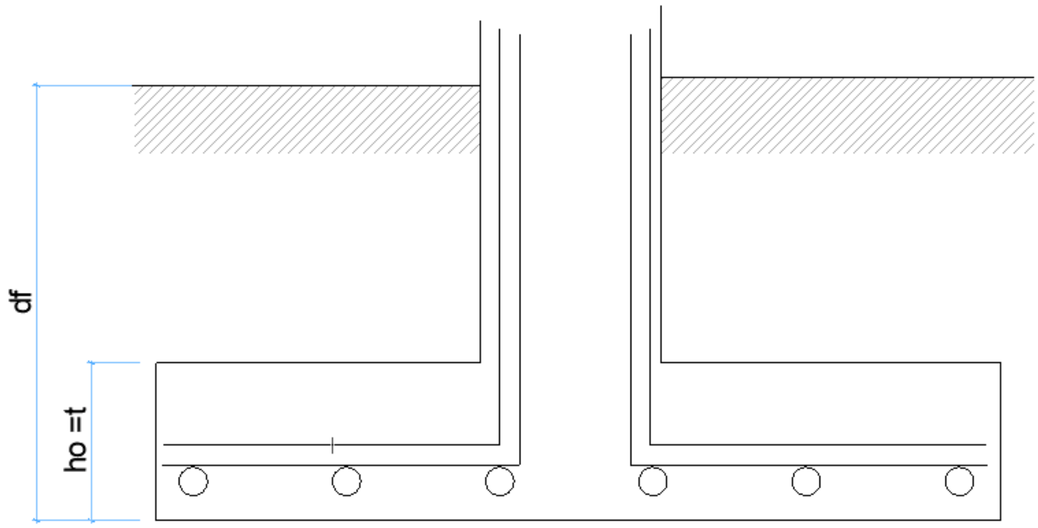


Figure 4.9 Shallow foundation

Classification of foundation

The project is a residential house located on a stable terrain, whereby df/B < Or equal to 2 therefore the foundation is classified as shallow foundation

Gk = 312.656KN,   Qk = 165.12KN

Bearing capacity= 350KN/m^2

1.0Gk + 1.0Qk = 1.0(312.656) + 1.0(165.12)

= 477.776 KN

Load on footing

N = 1.0Gk + 1.0Gk + W

W = 10% (1.0Gk + 1.0Gk)

= 477.776*0.10

= 47.8KN

N = 477.776+ 47.8

= 525.6 KN

Area of footing= N/bearing capacity

Bearing capacity calculation

For square footing the ultimate bearing capacity is given as:

$q_u = 1.2\, c'N_c + \gamma\, D_f\, N_q + 0.4\gamma B\, N_y$

Where = ɣ unit weight of soil, **Df** = depth of foundation, B= width of footing, C' = Cohesion of soil

according to values of soil friction angle ϕ, bearing capacity factors under general shear failure are arranged in the below table.

ϕ	**Nc**	**Nq**	**Ny**
0	5.7	1	0
5	7.3	1.6	0.5
10	9.6	2.7	1.2
15	12.9	4.4	2.5
20	17.7	7.4	5
25	25.1	12.7	9.7
30	37.2	22.5	19.7
35	57.8	41.4	42.4
40	95.7	81.3	100.4
45	172.3	173.3	297.5
50	347.5	415.1	1153.2

Given data:

B = 1.2m Nc= 25.1, Nq= 12.7, Ny= 9.7

Df = 1.5m Fs= 3 C' = 30 KN/m^2

ϕ= 25 degree ɣ = 18.2KN/m^3

$q_u = 1.2\ c'N_c + ɣ\ D_f\ N_q + 0.4ɣB\ N_y$

= 1.2*30*25.1+18.2*1.5*12.7+0.4*18.2*1.2*9.7

= 1335 KN/m^2

q_{all} = qu/Fs

= 1335/3 = 445 KN/m

Area of footing = N/bearing capacity

= 525.6/445

= 1.2 m^2

For square footing= √1.52 =1.1*1.1m

For rectangular footing = a*b

Assume a = 1m, b= area/a

b = 1.2/1 = 1.2m

Design stress = design load/area of footing

= 525.6/1.52 = 345.78KN/m^2

Design stress < bearing capacity, the foundation is safe

Check for vertical shear

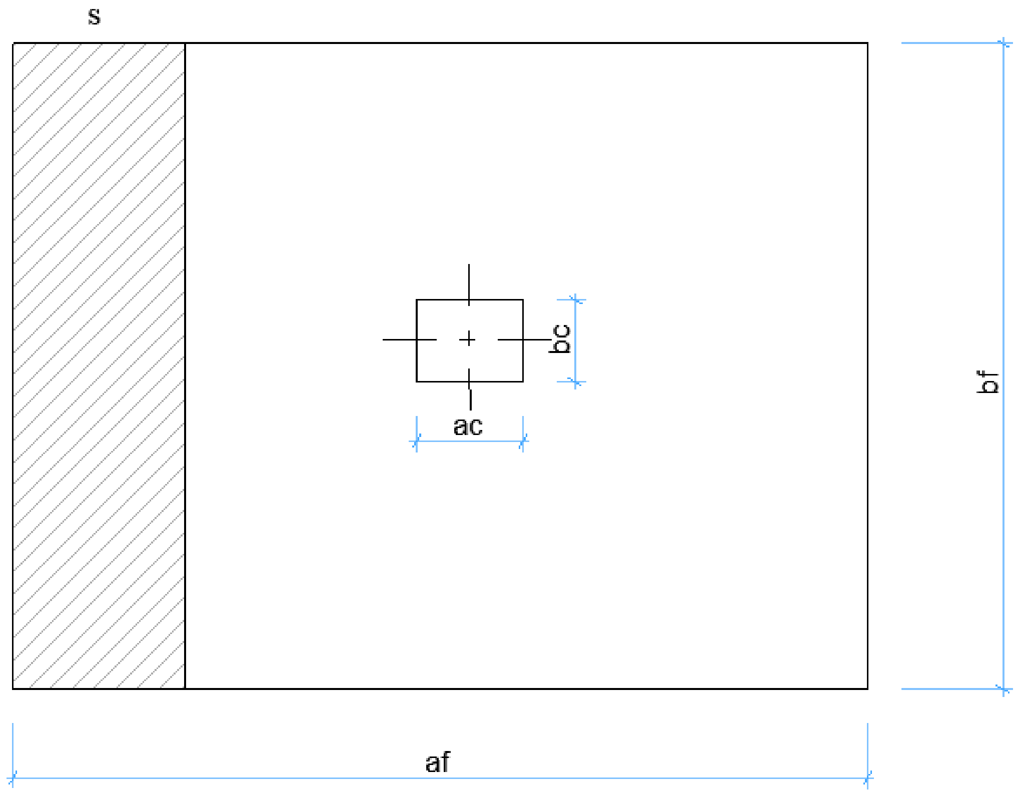


Figure 4.10 footing

af = 1m ac = 35 cm

bf = 1.2m bc = 25 cm

s = 100 mm P = N/ area

P = 525.6KN/1.2

= 438 KN/m^2

= 0.0438KN/cm^2

Rb = 0.09

Assuming thickness of footing = 30 cm

t= depth of footing

= thickness of footing - cover – Ø bar /2

= 30 – 3 – 16/2

= 19 cm

0.45Rb*af*t = 0.54*0.09*100*19

= 92.34 KN

Q= P*bf*S

= 0.0438*1.2*10

= 0.53 KN

Q < 0.45Rb*af*t the condition is verified

4.6 DESIGN OF STAIR

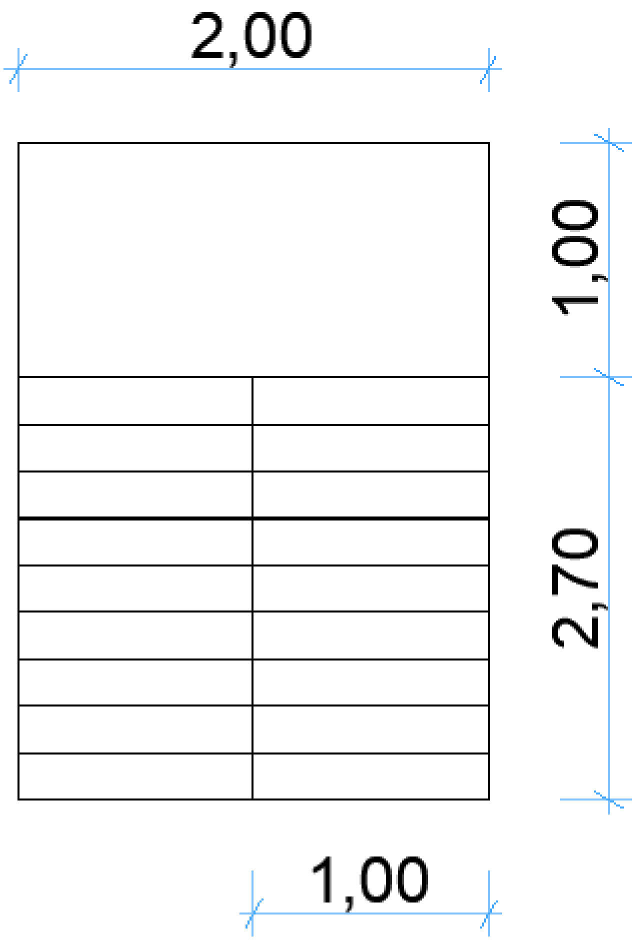


Figure 4.11 Staircase

Preliminary dimensioning of the stairs

Floor to floor height = 3200mm

Horizontal flight span = 2700mm

Landing length= 1m = 1000mm

Total horizontal span =2700+1000

= 3700mm

First flight and landing

15cm < R <25cm

25cm <G< 35cm

Number of going G = 9

Number of risers R = G+1 =10

size of going= 2700/9 = 300mm

Size of riser= 1600/10 = 160mm

effective horizontal length

= Flight horizontal span + landing span

= 2700+ 1000 = 3700mm

Slab waist thickness

Span/ d = 20

d =span/20 = 2700/20 = 135

h = d + bar diameter/2 + cover

= 135 + 10/2 + 20

= 150mmm

Load on waist slab

Load of waist slab = unit weight of concrete* thickness of waist slab

= 25 * 0.150= 3.75 KN/m^2 = 3750N/m^2

The above load obtain in inclined , it must be converted into a horizontal load (W) by multiplying it with $[\sqrt{(R^2+G^2)}]/G$ factor.

W = 3.75 * $[\sqrt{(150^2+200^2)}]200$

= 4.69 KN/m^2

Dead load of steps= 1/2* R* concrete unit weight

= 0.5*0.160*24

= 1.92KN/m^2

Finishes=1.2 KN/m^2

Live load= 1.5KN/m^2

Total dead load stair = 4.69 +1.92+ 1.2

= 7.81KN/m^2

Ultimate design load on staircase

= 1.4Gk+ 1.6Qk

= 1.4(7.81) + 1.6(1.5)

= 13.33 KN/m^2

Compute the bending moment and shear force

$M = WL^2/8$

$=13.33*3.7^2/8.$

= 22.81KNm

V = WL/2

= 13.33*3.7/2

= 24.66KN/m

Design flexural strength design

Cover = 20 mm

main reinforcement bar = 10 mm

d = 140 mm.   h = 165mm.   fcu= 25N/mm2

$K = M/bd^2fcu$

$= 22810* 1000/1000*135^2*25$

= 0.05 < 0.156 no compression steel is required

Z = d [0.5 + √(0.25 - k/0.9)]

= d [0.5 + √(0.25 - 0.05/0.9)]

Z = 0.94d <0.95 d , use Z

Z = 0.94* 135

= 126.9 mm

Asreq= M/0.95fyZ

$= 22.81*10^6/0.95*460*126.9$

$= 412mm^2$

Provide 6T10 ($471mm^2$) , with 160mm center to centre spacing bars

Asmin = 0.0013bd

= 0.0013* 1000*135

= 176mm^2

As min < Asprov ,the condition is satisfied

Asmax = 0.04bh

= 0.04* 1000*150

= 6000mm^2 > As provide ok

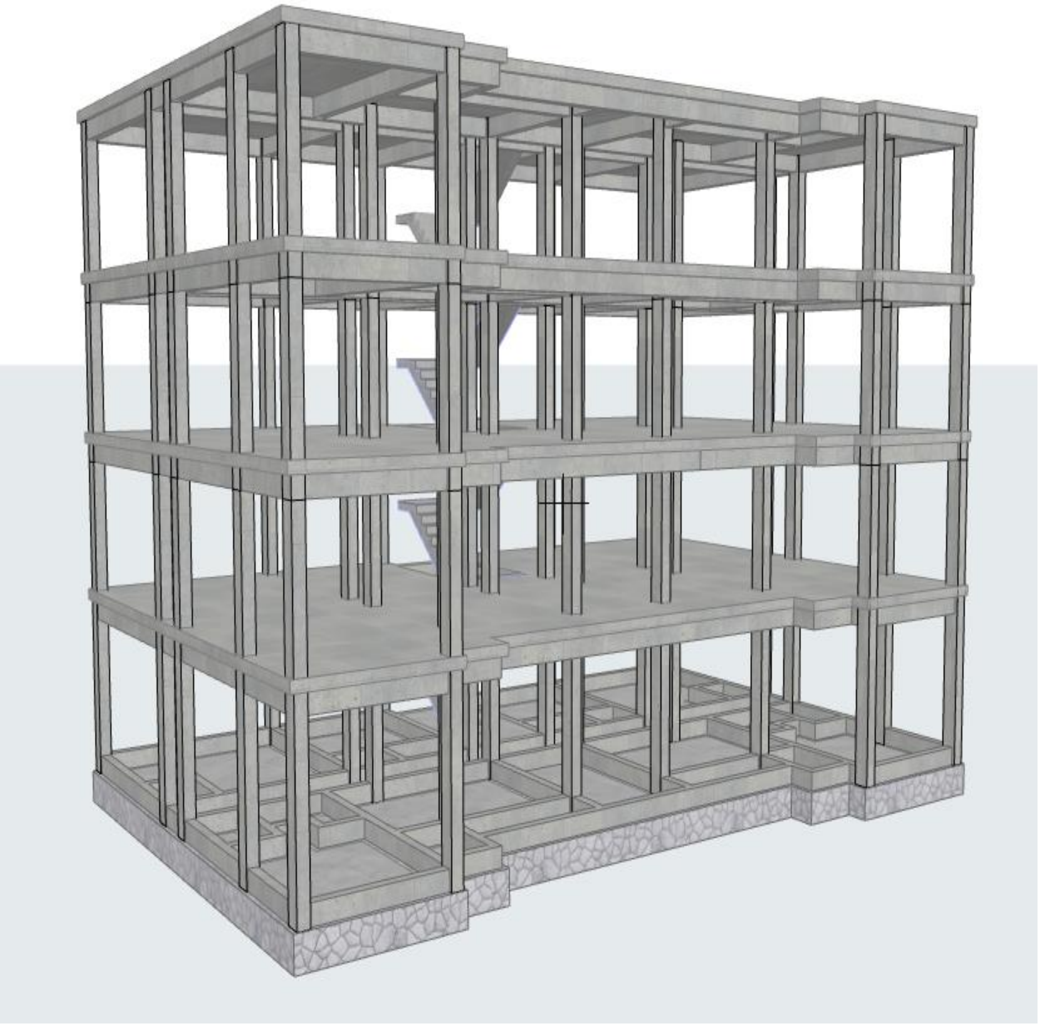
Second flight and first flight have the same outcome

Shear strength design and deflection check are done in the same way of solid slab design

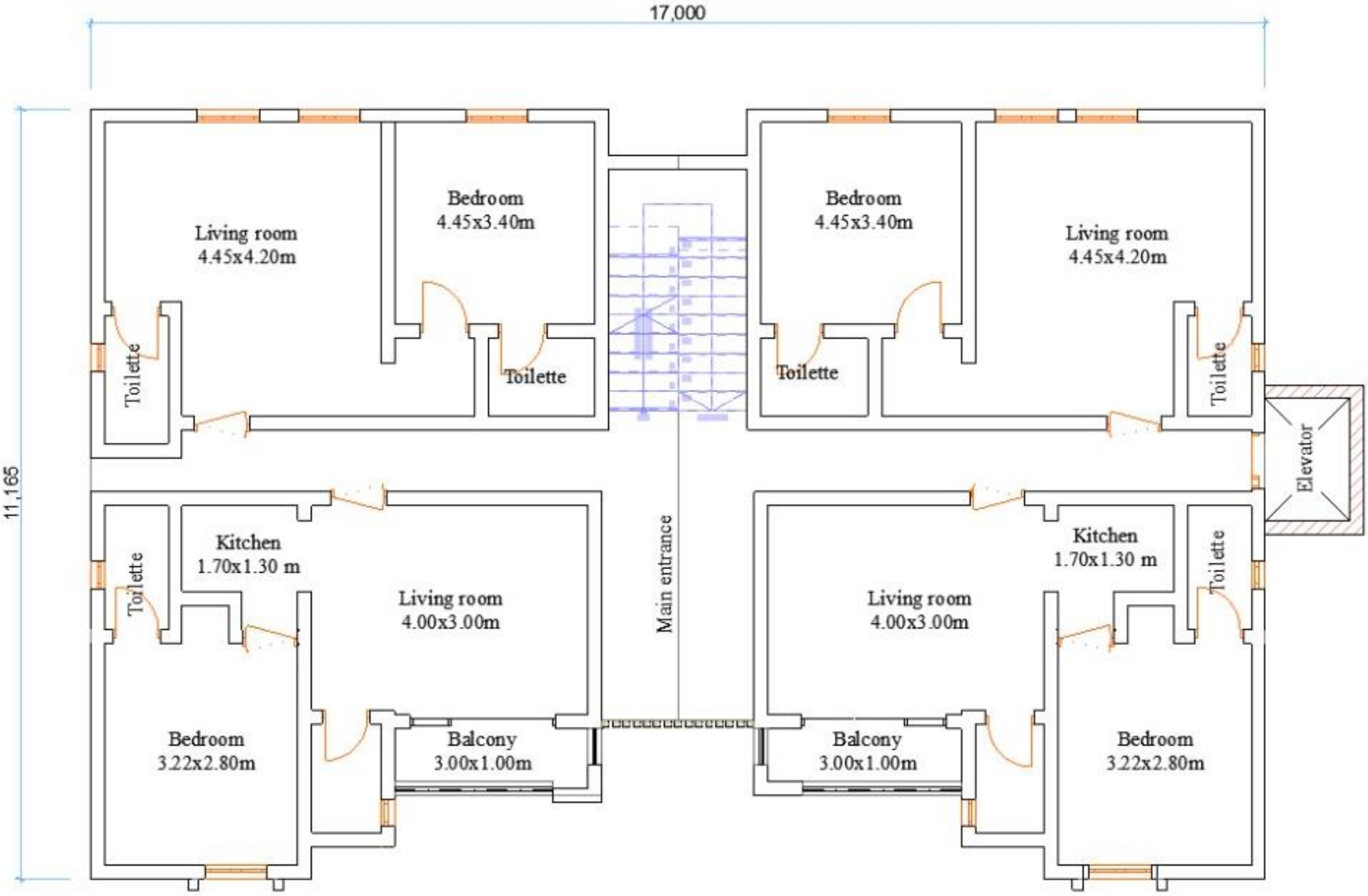
4.7 DRAWINGS

1. Architectural drawing

2. Structural drawing



3.Floor Plan drawings



CHAPTER 5: CONCLUSION AND RECOMMENDATION

The reinforced concrete project has successfully met its objectives, providing a comprehensive analysis of both material performance and structural integrity. Through a series of tests and evaluations, several key conclusions have emerged:

5.1. Performance and strength

The reinforced concrete specimens demonstrated robust performance under various loading conditions, consistently achieving the desired strength and stability. The results validated the effectiveness of the reinforcement in enhancing the tensile and flexural strength of the concrete.

5.2. Material properties

The concrete mix used exhibited excellent workability and setting characteristics, while the reinforcement bars contributed to the improved load-bearing capacity. The interaction between the concrete matrix and the steel reinforcement was effective, ensuring that the composite material behaved as expected under stress.

5.3. Design validation

The project confirmed that the design parameters and construction practices adhered to the relevant codes and standards. The structural components performed well, with minimal cracking and deformation, reflecting the accuracy of the design and quality of construction.

5.4. Challenges and solutions

Several challenges, including variations in material quality and environmental factors, were encountered. These challenges were addressed through rigorous testing and adjustments in material specifications, which ensured the reliability of the reinforced concrete.

5.5. Recommendations for future work

Future research should focus on exploring advanced reinforcement techniques and alternative materials to enhance the performance and sustainability of reinforced concrete. Additionally, investigating the long-term durability of reinforced concrete in diverse environmental conditions could provide further insights.

In summary, the project has provided a clear understanding of reinforced concrete behavior and performance. The findings validate the effectiveness of current practices while highlighting areas for further investigation and improvement. This work contributes valuable knowledge to the field of structural engineering, supporting the ongoing development of more resilient and efficient concrete structures.

BILL OF QUANTITY AND COST ESTIMATION

S/N	DESCRIPTION	UNITS	QUANTITY	RATE (Rwf)	TOTAL AMOUNT(Rwf)
			A. GROUND LEVEL		
	PRELIMINARY WORKS				
1	Site cleaning	Ls	1	150,000	150,000
2	site installation	Ls	1	150,000	150,000
	Subtotal 1				**300,000**
	FOUNDATION				
3	Excavation for foundation	m^3	97	1,500	145,500
4	Base concrete	m^3	106	82,000	8,692,000
5	Concrete Bed	m^3	62	120,000	7,440,000
6	Stone foundation with mortar	m^3	82	50,000	4,100,000
	Subtotal 2				**20,377,500**
	Elevations				
7	Walls of bricks with cement mortar	m^3	56	59,000	3,304,000
8	Columns in concrete	m^3	14	380,000	5,320,000
9	slabs, stairs and elevator support concrete	m^3	82	350,000	28,700,000
10	Beams and tie beams	m^3	40	210,000	8,400,000
	Subtotal 3				**45,724,000**
11	**Doors and windows**				
12	Doors of 90cmx280cm	Items	8	100,000	800,000
13	Doors of 80cmx200cm	Items	8	80,000	640,000
14	Windows 0f 100cmx195cm	Items	12	96,000	1,152,000
	Subtotal 4				**2,592,000**
	FINISHES				
15	Plastering int & ext.	m^2	156	6,480	1,010,880
16	Wall tiles	m^2	36	36,000	1,296,000
17	Pavement with tiles	m^2	260	25,000	6,500,000
18	Latex paints	m^2	468	5,760	2,695,680
19	Email paints	m^2	468	7,200	3,369,600
	Subtotal 5				**14,872,160**

	PLUMBING AND DRAINAGE INSTLATION				
19	Water reticulation to the existing network	Ls	1	284,000	284,000
20	Supply and installation of WC of good quality complete with all accessories and all requirements	Items	8	250,000	2,000,000
21	Supply and installation of ceramic wash hands basin complete with accessories and all requirements.	Items	8	80,000	640,000
	Subtotal 6				**2,924,000**
	ELECTRICAL INSTALLATION WORKS				
22	Provide for general attendance on specialists installing mains connection. and main switchboards, distribution boards and circuits, power and lighting installations and lightning conductors.	LS	1	200,000	200,000
23	Extinctic of 9kgs	Items	4	81,000	324,000
24	Main switchboards, distribution boards (cabin)	Items	1	180,000	180,000
25	Single switch	Items	25	1800	45,000
26	Double switch	Items	8	3150	25,200
27	Power distribution boards	Items	2	1125	2,250
	Subtotal 7				**776,450**
	TOTAL OF GROUND FLOOR				**87,186,110**
B. FIRST FLOOR					
28	**Elevations**				
29	Walls of bricks with cement mortar	m^3	56	36,000	3,304,000
30	Columns in concrete	m^3	14	249,000	5,320,000
31	slabs and stairs, elevator support concrete	m^3	82	210,000	28,700,000
32	Beams and tie beams	m^3	40	210,000	8,400,000
	Subtotal 1				**45,724,000**
33	**Doors and windows**				
34	Doors of 90cmx280cm	Items	8	100,000	800,000
35	Doors of 80cmx200cm	Items	8	80,000	640,000
36	Windows 0f 50cmx195cm	Items	12	96,000	1,152,000
	Subtotal 2				**2,592,000**

	FINISHES				
37	Plastering int & ext.	m^2	156	6,480	1,010,880
38	Wall tiles	m^2	36	36,000	1,296,000
39	Pavement with tiles	m^2	260	25,000	6,500,000
40	Latex paints	m^2	468	5,760	2,695,680
41	Email paints	m^2	468	7,200	3,369,600
	Subtotal 3				**14,872,160**
	PLUMBING AND DRAINAGE INSTALLATION				
42	Piping works to include water supply and drainage	Ls	1	700,000	700,000
43	Drainage works to include the provision of drainage facility such as manholes, septic tanks, soak way pits	Ls	1	900,000	900,000
44	Water reticulation to the existing network	Ls	1	280,000	280,000
45	Supply and installation of WC of good quality complete with all accessories and all requirements	Items	8	250,000	2,000,000
46	Supply and installation of ceramic wash hands basin complete with accessories and all requirements.	Items	8	80,000	640,000
	Subtotal 4				**4,520,000**
	ELECTRICAL INSTALLATION WORKS				
47	Provide for general attendance on specialists installing mains connection and main switchboards, distribution boards and circuits, power and lighting installations and lightning conductors.	LS	1	200,000	200,000
48	Extinctic of 9kgs	Items	4	81,000	324,000
49	Main switchboards, distribution boards (cabin)	Items	1	180,000	180,000
50	Single switch	Items	25	1800	45,000
51	Double switch	Items	8	3150	25,200
52	Power distribution boards	Items	2	1125	2,250
	Subtotal 5				**776,450**
	TOTAL OF FIRST FLOW				**68,484,610**

C. SECOND FLOOR					
	Elevations				
53	Walls of bricks with cement mortar	m^3	56	36,000	3,304,000
54	Columns in concrete	m^3	14	249,000	5,320,000
55	slab, stairs and ramp	m^3	82	210,000	28,700,000
56	Beams and tie beams	m^3	40	210,000	8,400,000
	Subtotal 1				**45,724,000**
57	**Doors and windows**				
58	Doors of 90cmx280cm	Items	8	100,000	800,000
59	Doors of 80cmx200cm	Items	8	80,000	640,000
60	Windows 0f 50cmx195cm	Items	12	96,000	1,152,000
	Subtotal 2				**5,300,000**
	FINISHES				
61	Plastering int & ext.	m^2	468	6,480	3,032,640
62	Wall tiles	m^2	36	36,000	1,296,000
63	Pavement with tiles	m^2	940.5	36,000	33,858,000
64	Latex paints	m^2	468	5,760	2,695,680
65	Email paints	m^2	468	7,200	3,369,600
	Subtotal 3				**44,251,920**
	PLUMBING AND DRAINAGE INSTALLATION				
66	Piping works to include water supply and drainage	Ls	1	700,000	700,000
67	Drainage works to include the provision of drainage facility such as manholes, septic tanks, soak way pits	Ls	1	900,000	900,000
68	Water reticulation to the existing network	Ls	1	280,000	280,000
69	Supply and installation of WC of good quality complete with all accessories and all requirements	Items	8	250,000	2,000,000
70	Supply and installation of ceramic wash hands basin complete with accessories and all requirements.	Items	8	80,000	640,000
	Subtotal 4				**4,520,000**
	ELECTRICAL INSTALLATION WORKS				

71	Provide for general attendance on specialist installing mains connection and main switchboards, distribution boards and circuits, power and lighting installations and lightning conductors.	LS	10	81,000	810,000
72	Extencticher of 9kgs	Items	16	81,000	1,296,000
73	Main switchboards, distribution boards (cabin)	Items	1	180,000	180,000
74	Single switch	Items	29	1800	52,200
75	Double switch	Items	8	3150	25,200
76	Power distribution boards	Items	5	1125	5,625
	Subtotal 5				2,369,025
	TOTAL OF SECOND FLOOR				**68,484,610**
	D. THIRD FLOOR				
78	**Elevations**				
79	Walls of bricks with cement mortar	m^3	56	36,000	3,304,000
80	Columns in concrete	m^3	14	249,000	5,320,000
81	slabs, stairs and ramp	m^3	82	210,000	28,700,000
82	Beams and tie beams	m^3	40	210,000	8,400,000
	Subtotal 1				**45,724,000**
	Doors and windows				
83	Doors of 200cmx300cm	Items	8	100,000	800,000
84	Doors of 80cmx200cm	Items	8	80,000	640,000
85	Windows 0f 50cmx75cm	Items	12	96,000	1,152,000
	Subtotal 2				**5,300,000**
	FINISHES				
86	Plastering int & ext.	m^2	468	6,480	3,032,640
87	Wall tiles	m^2	36	36,000	1,296,000
88	Pavement with tiles	m^2	940.5	36,000	33,858,000
89	Latex paints	m^2	468	5,760	2,695,680
90	Email paints	m^2	468	7,200	3,369,600
	Subtotal 3				**44,251,920**
	PLUMBING AND DRAINAGE INSTALLATION				
91	Piping works to include water supply and drainage	Ls	1	700,000	700,000
92	Drainage works to include the provision of drainage	Ls	1	900,000	900,000

	facility such as manholes, septic tanks, soak way pits				
93	Water reticulation to the existing network	Ls	1	280,000	280,000
94	Supply and installation of WC of good quality complete with all accessories and all requirements	Items	8	250,000	2,000,000
95	Supply and installation of ceramic wash hands basin complete with accessories and all requirements.	Items	8	80,000	640,000
	Subtotal 4				**4,520,000**
	ELECTRICAL INSTALLATION WORKS				
96	Provide for general attendance on specialist installing mains connection and main switchboards, distribution boards and circuits, power and lighting installations and lightning conductors.	LS	10	81,000	810,000
97	Extencticher of 9kgs	Items	16	81,000	1,296,000
98	Main switchboards, distribution boards (cabin)	Items	1	180,000	180,000
99	Single switch	Items	29	1800	52,200
100	Double switch	Items	8	3150	25,200
101	Power distribution boards	Items	5	1125	5,625
	Subtotal 5				2,369,025
	TOTAL OF THIRD FLOOR				**68,484,610**

ELEVATOR

SN	**Deception**	**Unit**	**Quantity**	**Rate (Rwf)**	**Total amount**
1	**Lift and installation**	Ls	1	27354000	27354000
	OVERALL TOTAL				**347,347,940**

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