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**DEPARTMENT OF CIVIL ENGINEERING**

**CONSTRUCTION TECHNOLOGY**

# FINAL YEAR PROJECT.

# STRUCTURAL DESIGN OF G+2 APARTMENT BUILDING.

# CASE STUDY: GASABO DISTRICT/ GISOZI SECTOR

*Dissertation submitted in partial fulfilment of the requirements for the Award of advanced diploma in construction technology.*

***Presented by:***

**Ayen Racheal Deng: 202150007**

***Under the guidance of:***

**Eng. MUNYANEZA J. Pierre**

**Kigali, October 2024**

# DECLARATION

I, **Ayen Racheal Deng** do hereby declare that the work presented in this dissertation is my own contribution to the best of my knowledge. The same work has never been submitted to any other University or Institution. I, therefore declare that this work is my own for the partial fulfilment of the award ofthe advanced diploma in civil engineering department, construction technology option at ULK Polytechnic Institute.

**Name: Ayen Racheal Deng**

**Roll Number: 202150007**

Date of submission: …………………….....

Signature……………………………….

## CERTIFICATION

This is to certify that this dissertation work, entitled “Structural design of G+2 apartment building " is an original study conducted by Ayen Racheal Deng under my supervision and guidance.

The supervisor’s names: **Eng. MUNYANEZA Jean Pierre**

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

Submission date: ……………………………...

**DEDICATION**

This research project is dedicated to:

My parents

My sisters

My brothers

## ACKNOWLEDGMENTS

All praises are addressed to Almighty God who has given me the ability to carry out this research in a timely manner and which has made i strong and healthy when it was written. Glory to you Lord.

My deep sense of gratitude and appreciation also goes to my supervisor, **Eng. MUNYANEZA Jean Pierre** for his encouragement and support throughout this research. Your professional experience and your practical comments from reviews and critics have made our research fruitful.

I wish to express my sincere thanks to the authorities of ULK Polytechnic Institute, in particular the Department of Civil engineering, construction technology option, for their support in terms of knowledge that leads us to the success of the university struggle.

Thanks also to all my classmates and friends for their moral support and invaluable prayers.

**May God bless you all!!!**

Ayen Racheal Deng

# ABSTRACT

The main objective of this research was to work out the structural design of a G+2 apartment building and a bill of quantity. To achieve these objectives, ArchiCAD software was used for the work out of the architectural design of the building, analytical method was done for the computation of the structural design (slab, beam, column, stairs, ramp and foundation), Prokon software was used for beam analysis, lumion was used for the generation of perspectives and the reinforcements were computed using European Standards (EUROCODE 2). The building consists of each floor rooms, stair and ramp for vertical circulation. The structural result obtained showed that slab has 150mm of thickness the required steel reinforcements should be laid in two-way direction at the top and at the bottom were ϕ10@150mm andϕ8@200mm, beams has 600mm height and 300mm breath of web, the required main steel reinforcements at the top and at the bottom were 4ϕ20mm and 4ϕ25mm, the columns has 400x450mm cross section, the required steel reinforcements were of 8ϕ20mm. Stairs steel reinforcements were 7ϕ12mm/m and 4ϕ12mm/m, for ramp beam the steel reinforcement found were 3ϕ12mm and 3ϕ12mm, ramp slab the steel reinforcement found were 5ϕ12mm and footing of 3.2x3.2x0.6m has been calculated according to the bearing capacity of 240KN/$m^2$, steel reinforcement found were 8ϕ25mm and the cost of construction of proposed building was estimated (631,595,556Rwf).

**Keywords:** Architectural, structural design, Apartment

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## LIST OF ABBREVIATIONS

**a**: width of column

**Ab**: Cross section area of the column

**Ab**: is average lateral area of the punching pyramid

**Ab**: The area of the column cross section

**ac**: width of column

**af**: width of footing

**As**: Total cross section of steel reinforcement

**$As_{max}$**: Maximum bending moment (at the top and bottom)

**b**: The width of the compressive area

**bc** :breadth of the column

**bf**: breadth of footing

**bf**: flange of the beam

**bw**: web of the beam

**d**: short distance of The beam

**Def max**: Defection maximum

**F**: fixed support

**Fcu**: the characteristic concrete cube strength.

**$F_u$**: The ultimate deflection

**Fy**: is the characteristic strength of reinforcements

**Fy**: vertical force acts on the support of ramp

**Fyv**: is the characteristic strength of link reinforcements

**G :**(Going or tread)

**GK**: Permanent loads

**h**: height of the beam

**H**: Height of column

**H**: Rise

**he**: Effective height

**Hf**: Height of footing

**hf**: Thickness of the slab

**ho**: Effective height

**lc**: Difference of the distance between half of breadth and half of breadth of the column

**lx**: Length of the short side of the panel

**ly**: Length of the long side of the panel

**$Mx^-$, $My^-$**: Bending moment at the top

**$Mx^+$, $My^+$**: Bending moment at the bottom

**N**: Total loads of slab

**Nc**: loads from the column

**Nf**: Load transmited by the column to the foundation

**No**: numeric number

**P**: Design pressure

**Q**: shear force acting on the cross section

**Qf**: Punching shear force

**QK**: Live loads

**Rb**: Design concrete compression strength

**Rbt**: Concrete design tensile strength

**Rs**: Design steel tensile stress

**Rsc**: Area of steel compressive strength

**s**: Distance between stirrup

**Um**: average perimeter

**Vmax**: Maximum shear force

**αm, η** : coefficient related to the design of members subjected to bending moment

**αsx :** Long side of the panel

**αsy**: short side of the panel

**Δl**: Difference between long span and short span of the beam

**Δq:**balancing shear force

Φ: Diameter of steel reinforcement expressed in (mm)

**γ**: unite weigth

**λ:** Ratio chooses the type of pannel

**λ**: Slenderness ratio

**ξ**: The ratio between the effective depth of concrete compressive zone and the effective depth of the cross section.

**ξR**: the maximum value of ξ

**φ**: Coefficient used to take into account the column slenderness and the construction inaccuracies.

# CHAPTER I: GENERAL INTRODUCTION

## 1.1.Introduction

In general, the introduction will introduce the topic to the reader by stating what the topic is and giving some general background information. This will help the reader to understand what you are writing about, and show why the topic is important. The introduction should also give the overall plan of the essay. This chapter highlights the background of the study, problem statement, purpose of the study, objective of the study, research questions/ hypothesis, scope of the study, significance of the study and organisation of the research.

## 1.2.Background of the study

The process of designing a structure to be both safe and useful under any load is known as structural design. The structural engineer will ascertain the stability, strength, and stiffness (rigidity) of the structure during this process (Khan & Sahay, 2020). The design of a sturdy and practical structure is the focus of the civil engineering sub discipline of structural design. Depending on the objectives of the construction project, they could also collaborate with architects to produce a distinctive, eye-catching design. Before moving a single shovel of earth, structural engineers make sure the structure will be structurally sound through the use of "structural analysis" and other computations. The framework, usability, and essential structural elements and details that support the architect's design are the main topics of structural sketches (MacGinley, 2018).

A full construction project's structural design process is broken down into three stages: planning, designing, and building. The planning stage will take into account all of the variables that impact the structure's dimensions and configuration. In this case, the choice is determined by the building's role (Khode, 2019). The sociology, economics, ecology, and aesthetics will be the next factors examined. Prokon is used for the structural analysis of the structure, and scientific computations using empirical formulas were employed in the calculations. To verify the building's structural stability and safety, the structural members—such as beams, columns, and slabs—are estimated (Pathak & Rastogi, 2015).

Every building member's structural design details are decided upon throughout the design phase. The acquisition of supplies and machinery, labor migration, and the erection process are all part of the construction phase of a structural design project. Realistic challenges may necessitate the redesign of certain tasks. A thrilling phase in the construction management process' lifetime is the design development stage. Even while you won't start building on your project right away, the design development phase is when schematics are completed, building materials are picked, and the project's final interior and exterior designs are decided (Baiburin, 2017).

The planning and designing of buildings with an emphasis on both beauty and usefulness is known as architectural design. In addition to meeting the needs of the client and/or project criteria, the design must be appropriate for the user's experience. According to Nirit and Yehuda (2017), architectural design is a field that focuses on covering and meeting needs and requests, as well as creating living places utilizing certain tools and, most importantly, creativity. Consequently, despite the widespread misconception that architecture is solely a technological endeavor, the goal is to integrate the technological and the artistic. An architect should constantly consider the technical and aesthetic aspects of a project, as well as the fundamentals of construction, while conducting an analysis and designing and building in accordance with the needs and available resources (A, 2006). Because of this, the process that is able to recognize all of these factors must take into account the requirement to represent the demands on paper (or software) spaces that integrate the project in both an artistic and technological manner (Rani et al., 2020). Here, the lines serve as the primary component of the architectural design, defining a number of factors including the size, form, and placement of the many spaces that integrate the project (Rani et al., 2020).

Over the past ten years, Rwanda's population has grown at a 2.3% yearly pace. As of August 2022, the country's population was 13,246,394; by 2052, it is expected to reach 23.6 million. The 2.3% yearly growth rate in Rwanda's population is giving the country's building industry a significant boost. Rwanda is heavily experiencing the rising demand in the real estate and construction industries. Kigali experiences an annual demand for between 28,000 and 35,000 residential and commercial units; developers are finding it difficult to supply this demand. The building industry, which accounts for a sizeable portion of GDP, has had tremendous growth in a number of areas, including offices, infrastructure, and developments (Maina & Jagongo, 2022).

Many people in Rwanda have realized that we must develop vertically due to the country's growing population, limited resources, and pressing need to protect as much of our natural and agricultural land as possible. We can address the pressing ecological problems we confront by growing denser and focusing our society into concentrated areas with fewer, taller buildings. But the necessity to construct higher is not just a new custom. Building up has always made sense for a number of reasons, including prestige, resource preservation, defense, and the advantages of residing in a center of culture and commerce (Dolacek-Alduk et al., 2020).

In North America, the word "apartment" is preferred (but in certain places, "flat" refers to a portion of a house with two or three flats, usually one per level). In the UK, an apartment on a single level is generally, but not entirely, referred to as a "flat" apartment. The term "apartment" is more prevalent in professional real estate and architecture circles. According to Studart and Costa (2019), apartment buildings are multi-story structures that house three or more homes. An apartment building, apartment complex, flat complex, block of flats, tower block, high-rise, or, on occasion, mansion block (in British English) can be used to describe such a structure, particularly if it has numerous rental apartments. In Australia, a high-rise apartment structure is often called a residential tower, apartment tower, or block of flats.

The real estate market in Rwanda is still highly demanded, according to Patrick Sebatigita, CEO of Ujenge Group and Young Presidents' Association member. According to Sebatigita, excessive mortgage interest rates might make investment in real estate projects burdensome. "People think to focus on reducing the construction cost but it could be a bit complex than that if we want to address demand" Sebatigita explains. Additionally, he stated that over 50% of the building materials used in the region are imported, and the East African bloc is attempting to make up for this by eliminating costs (Nama et al., 2015). Due to Rwanda's fast population growth, the city of Kigali is experiencing a surge in employment and educational institutions, particularly in the Gisozi sector, making it challenging for residents to build new homes in new neighborhoods. Researchers believe that the architectural and structural layout of the G+2 apartment complex can effectively address these issues by optimizing land use and offering Gisozi sector inhabitants cheaper dwelling options. In Gisozi sector, this kind of building design will provide a number of advantages, including lessening the negative effects on the environment, encouraging social inclusion, and enhancing the standard of living for locals (Ahmad & Bajwa, 2023).

The Gisozi sector is expanding quickly in terms of both population and socioeconomic activity. In order to accommodate this increase, housing infrastructures must be developed. Examples of these infrastructures include apartment buildings for Kigali Independent University ULK students, as well as items that are used both within and outside of this sector. In order to combat this circumstance, the researcher plans to design the architecture and construction of a G+2 apartment building and have it constructed in order to promote the availability of lodging options in the study area.

### 1.3.Problem statement

A major obstacle to accomplishing the goals of Rwanda Vision 2050 and the National Strategy for Transformation (NST) 1 is the growing population in Rwanda's urban areas, particularly in Kigali city. This has resulted in a shortage of decent, reasonably priced housing (Nirit & Yehuda, 2017). Homelessness, informal settlements, and inadequate and subpar housing are the results of the fast population growth's strain on the system of housing (Zhu, 2000). The lack of reasonably priced and decent housing in Rwanda's urban areas, particularly in Kigali, has resulted in an increase in population density. This presents a serious obstacle to accomplishing the goals of Rwanda Vision 2050 and the National Strategy for Transformation (NST) 1 (Nirit & Yehuda, 2017). The current housing infrastructure has been strained by the quick population development, leading to poor and inadequate housing, homeless people, and informal settlements (Zhu, 2000).

The purpose of this project is to fulfil NST 1's objectives and assist Kigali, particularly the Gisozi sector, in providing adequately affordable housing and living spaces that meet all human needs. As a result, residents should be given advice on how to live in a compact apartment building.

### 1.4. Purpose of the study

The purpose of this study is to conduct the Structural design of G+2 apartment building in the line of the aim of Rwanda country of providing modern infrastructures. In addition, this project come out in order fulfil the goals of NST 1 and to support the city of Kigali especially Gisozi sector in providing living spaces that are well equipped with all the human needs, with enough affordable dwelling units, therefore citizens need to be advised on the way they can live in a space saving apartment building.

## 1.5. Objective of the Study

### 1.5.1. Main objective

The general objective of this project was to do the structural design of G+2 apartment building in Gasabo district Gisozi sector.

### 1.5.2. Specific objectives

This project's specific objectives were as follows:

a) To make structural design of the proposed G+2 apartment building
b) To make the bill of quantity for the proposed G+2 apartment building

## 1.6. Research questions

Based on the project's serviceability and functionality, answers to the following research questions will be offered in order to fulfil the above particular objectives.

a) How structural design of the proposed G+2 apartment building can be produced?
b) How the bill of quantity for the proposed project of G+2 apartment can be estimated?

## 1.7. Scope of study

The project of providing the structural designs of (G+2) apartments building in Gisozi sector is the main point of interest. Due to time constraints, it was limited to some geotechnical work, such as soil testing, and the bearing capacity of the soil which will be used will be derived from secondary data. Electrical design, like electricity installation, plumbing, septic tanks, drainage systems and cost estimation, was also delimited. This final project will cover structural elements design such as slab, beam, column, and foundation. The calculations will be demonstrated in details and focus on area reinforcements in this project. It will also covered the preparation of B.Q.

## 1.8. Significance of the study

This study helps to shift from theory to practice; Above all, it contributed to the successful completion of advanced diploma in construction technology. Thereafter improving the knowledge and skills of research about structural design, it will also help to master some engineering soft wares like AutoCAD, Archi CAD 22 and protostructure. It will cover the most important course of engineering like RCD I and II, and structural analysis I and II. This project study academically this will be used as a reference for students and other individuals who want to conduct any study about design of multistory building. Thus, the region where the infrastructure is built the surrounding population would enjoy the healthy and safe life due to house of high standard.

## 1.9.Research methodology

This project gave a general description of different structural design elements such as Slab, stair, beam, column and foundations. To achieve the intended goals, the standard which will be used in design BS 8110 and EC2 will be used with doing research about the different of two codes by reads books from library. Vision like (Euro code: Design of concrete structures (EC2/1992) and the design will be based on BS8110, with its application.

In addition, the general purpose of this section is to describe the various materials, techniques, and process employed to achieve the goals of the study. The structural design and cost-estimating processes which will be used in this study will be detailed. Arch CAD 22 software will be utilized to create architectural drawings such as Foundation layout, floor plan layout, Elevation, Section. The 3D model will be exported from the Arch CAD 22 and integrated into Lumion, which will be generated photorealistic photos of the planned flat. The building's intended structural plan will include reinforced concrete columns, beams, and slabs. Etab and Prokon structural design software will be utilized. In this research some software will be used to achieve intended goal, that software include protostructure for designing structural frame (beam, column and slab), Microsoft office (MS word) for writing and MS Excel for tables and figures.

### 1.10. Structure of the research

This work consists of five chapters, where chapter one will be the general introduction, which comprises the introduction of the study, background of the study, problem statement, purpose of the study, the objectives of the study, research questions, scope of the study, significance of the study and the organisation of the study. The second chapter will be the literature review, which will be about the general understanding of the reviews of other researchers with the related studies. The third chapter will be the research methodology and it will focus on the methods and materials to be used to achieve the objectives of the study. The fourth chapter will be the results and discussions and it will be the most important one because it will show the presentation of the results acquired. The fifth one, which will be the last chapter, will cover the conclusion and recommendations with respect to the predefined objectives.

# CHAPTER 2: LITERATURE REVIEW

## 2.1.Introduction

Structure analysis deals with the study of ways or methods, which are aimed to obtain safe and economical engineering structure for human us. Civil engineers design and construct major structure and facilitate that essential in day to day lives civil engineering is perhaps the broadest of the engineering field for its deals with the creation, improvement and protection of the community environment or this particular project, we shall mainly base on architectural drawing and building structure of museum building (Nassen, 2006)

## 2.2.Schematic Design

The first step of the design phase is the schematic design. The schematic design is where the architect gathers information on the needs, style, and wants for the project and from there the he will create two to three design options for the client to review (Elvin, 2007).

### 2.2.1. Design Development

In the design development, the architect will take the schematic designs and develop them to an approved design concept. Any changes the client wants to make to the design should be communicated to the architect during this phase.

### 2.2.2. Construction Documents

Construction documents are given to a contractor for the construction of your project. An architect will put together drawings with a lot of detail on them for the contractors to follow when building.

### 2.2.3. Bidding

Bidding is when the architect or client seeks a contractor for their project. They bid the job to the contractor by giving them bid documents which display details of the project. These documents include construction documents and technical specifications.

### 2.2.4. Construction

Construction begins once you've found a contractor you like, and you've settled on a design concept that fits your needs. Your architect will be in contact with your contractor throughout the duration of the construction phase to ensure that your project is being built according to the plans.

## 2.3. Structure design

Structural analysis is a very important part of a design of buildings and other built assets such as bridges and tunnels. The building regulations require that structures must be designed and built to be able to withstand all load types that they are likely to face during their lifecycle. As structural loads can cause stress, deformation and displacement that may result in structural problems or even failure (Bakis et al.,2002).

There are a number of different types of load that can act upon a structure, the nature of which will vary according to the design, use, location and materials being used. Design requirem ents are generally specified in terms of the maximum loads that a structure must be able to withstand (Park, 1975).

### 2.3.1. Structural design elements

Structural design being the branch of Structural Engineering, deals with the selection of proper material, proper sizes, proportion and shape of each member and its connecting details. The selection is such that it is economical and safe. It satisfies all the stress requirements imposed by the most severe combination of loads to which the structure is required to transmit or resist including its self-weight (Darwin, 2016).

#### 2.3.1.1. Slab

Horizontal plate elements carrying lateral loads. They may be simply supported or continuous over one or more supports and are classified according to the method of support as follows: Spanning one way between beams or walls, Spanning two ways between the support beams or walls, and Flat slabs carried on columns and edge beams or wall (Darwin, 2016).

Slabs are plate elements forming floors and roofs in buildings which normally carry uniformly distributed loads. The depth of the slab is usually very small relatively to length and width

#### 2.3.1.1.1. Types of slab

Type of supports: simply supported, continuous slab over two or more support slab and restrained slabs. Direction of supports: spanning one way (between walls and support), spanning two-way (between support and walls) and flat slabs which are carried on column or walls no interior beams. Type of section: solid slabs and ribbed slabs (Neyfert, 1996)

**1) One way slab**

One-way slabs transfer the imposed loads in one direction only, they may be supported on two opposite sides only in which the structural action is essentially one-way, the loads being carried in direction perpendicular to the supporting beams or walls and the ratio of longer span (ly) to shorter span (lx) which is in other words length over width, is equal or greater than 2 (Park, 1964)

$$\frac{\boldsymbol{Long\ span\ (ly)}}{\boldsymbol{Short\ Span\ (lx)}} \geq \mathbf{2}$$

**2) Two-way slab**

Two-way slab when it is supported by beams on all the four sides and the loads are carried by the supports along with both directions. In two-way slab, the ratio of longer span (ly) to shorter span (lx) is less than 2. (Pachpor, 2020)

$$\frac{\boldsymbol{Long\ span}}{\boldsymbol{Short\ Span}} = \frac{\boldsymbol{l}}{\boldsymbol{b}} < \mathbf{2}$$

The main reinforcement here is provided in both directions because the load is meant to be carried off course in both directions. The bending moments and deflections in these kinds of slabs are known to be less than those in one-way slabs; hence, the same slab is able to carry more loads when supported on four sides.

### 2.3.1.2. Beams

Horizontal members carrying lateral loads transmit to the column. They are singly reinforced concrete beams; these are rectangular beams which should be reinforced in the tension zone, doubly reinforced concrete beams, if the concrete alone cannot resist the applied moment in compression, can be provided in the compression zone and the design flanged beams, these flanged beams occur where beams are cast integral with and support a continuous floor slab and they are divided into two types: T-beam and L-beam (Ngo & Scordelis, 1967).

Beams are horizontal members carrying lateral loads transmit to the column, they are singly reinforced concrete beams; these are rectangular beams which should be reinforced in the tension zone, doubly reinforced concrete beams, if the concrete alone cannot resist the applied moment in compression, can be provided in the compression zone and the design flanged beams, these flanged beams occur where beams are cast integral with and support a continuous floor slab and they are divided into two types: T-beam and L-beam.
(Choo,2002)

#### 2.3.1.2.1. Classification of beams

#### 2.3.1.2.1.1.Classifications of beam based its section

The beam may be classified depending on section this may interfere in its structure design typically in the determination of its flange and the load to be carried.

**1. Rectangular Beams**

The rectangular beams have a cross-section rectangular shape. These kinds of beams commonly encounter tension at the bottom and compression at the top. Rectangular beams are the most popular types of beams utilized in constructing buildings.

**2. I-Beam**

I – Beam is shaped like an alphabet “I”.  Also, it is a structural element in the form of an “I”, implying a central tangle with a crossbar at the top and bottom.

**3. T-Beam**

The beam is constructed in the shape of a "T" cross-section. This beam is normally shaped with the slab. As a result, the slab works as an essential part of the beam and twists in the longitudinal direction of the beam.

**4. L-Beam**

L – Beam placed at the corner or around the perimeter of the slab. Also, we can determine the end beams including slabs only on one side.

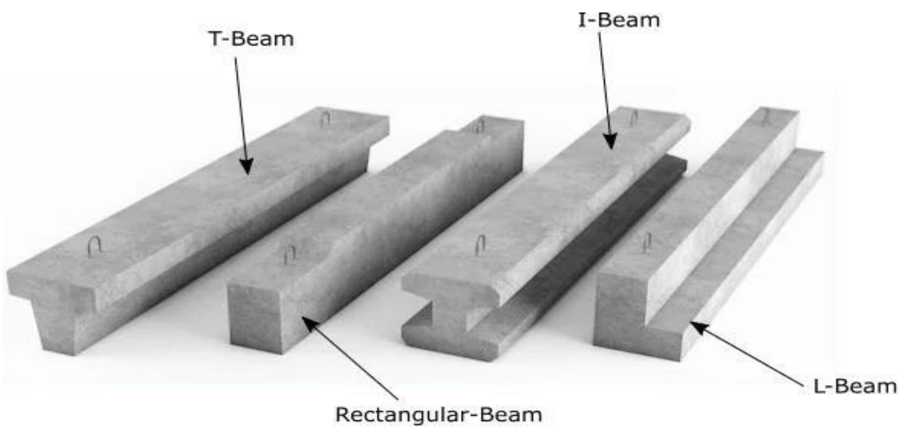



Figure 2. 1**:** The different types of beams based on section

**2.3.1.2.1.2. Classification of beam based on support**

- Beam can be also classified according on the condition support as follows:
- Simply supported beam: it is a beam support on the ends which are free to rotate and have non-moment resistance.
- Over hanging beam: is a simple extending beyond its support on one end.
- Fixed beam: is a beam supported on both ends and restrained from rotation.
- Continuous beam: is a beam extending over more than two supports.
- Double over hanging beam: is beam with both ends extending beyond its support on both ends.
- Trussed beam: is a beam strengthened by adding a rod or cable to form a truss

Cantilever beam: is beam projecting beam fixed only at on ends (Pike, 2006).

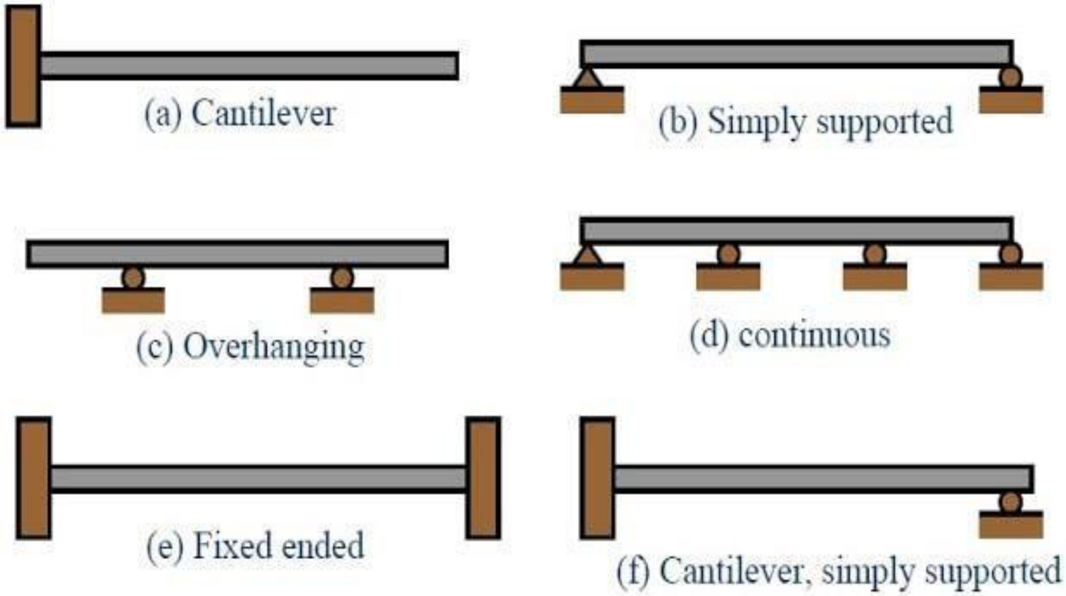



Figure 2. 2. Shows the different types of beams based on support

**2.4.1.3. Columns**

Columns are vertical or inclined compression members used for transferring superstructure load to the foundation. The structural design of reinforced concrete columns involves the provision of adequate compression reinforcement and member size to guaranty the stability of the structure. In typical cases, columns are usually rectangular, square, or circular in shape. Other sections such as elliptical, octagonal are also possible (Arya C. , 2009).

**2.4.1.3.1. Types of columns**

The columns are classified into two types; short column and long column

**2.4.1.3.1.1.Short column**

When the ratio of effective length of column to it is least lateral dimension does not exceed: 14.3: for rectangular shapes, 12.4: for circular shapes and 12.7: for octagonal shapes is termed short column.

**2.4.1.3.1.2.Long column**

When the ratio of effective length to its lateral dimension exceeds: 14.3: for rectangular shapes, 12.4: for circular shapes, 12.7: for octagonal shapes is termed long column

#### 2.4.1.3.2. Failure of column

Crushing: is the mode of failure for the short column and this increase cracks

Buckling: is the mode of failure of long column (bending)

The buckling capacity is the capacity of the element to withstand the propensity to buckle. Its capacity depends upon its geometry, material, and the effective length of the column, which depends upon the restraint conditions at the top and bottom of the column.

### 2.3.1.4. Wall

A wall is a structure that defines an area, carries a load; provides security, shelter, or soundproofing; or is decorative or vertical plate elements resisting vertical, lateral or in plane loads. Walls can be classified as internal non-load bearing walls: they may be of hallow block or light movable partitions that divide space only, external curtain walls: these carry self-weight and lateral wind loads, external and internal infill walls in framed structures: these may be designed to provide stability to the building but do not carry vertical building loads; the external walls would also carry lateral wind loads (Hendry, 2001).

All buildings contain walls the function of which is to carry loads, Walls are the most basic component of a structure; they are vertical plate elements that resist lateral or plane loads. The fundamental function of a wall is to surround or divide a building's space; it provides privacy, security, and protection from elements such as cold, heat, sun, and rain (Chudley & Greeno, 2013).

#### 2.3.1.4.1. Walls may classify into the following types

- Internal non-load bearing walls of block work or light movable partitions that divide space only
- External curtain walls that carry self-weight and lateral wind loads

- External and internal infill walls in framed structures that may be designed to provide stability to the building but do not carry vertical building loads; the external walls would also carry lateral wind loads
- Load bearing walls designed to carry vertical building loads and horizontal lateral and in-plane wind loads and provides stability (Ginley, 1990).

### 2.3.1.5. Stair

Stairs must be provided in almost all buildings, either low-rise or high-rise buildings, even if adequate numbers of elevators are provided. Stairs consist of rises, runs (or treads), and landings. The total steps and landings are called a staircase. The rise is defined as the vertical distance between two steps, and the run is the depth of the step. The landing is the horizontal part of the staircase without rise. There are several types of stairs in construction design to provide access to different floor levels of the building. Building has stairs so that people can gain access to the upper floors. Stairs should be designed so that they are convenient for the majority of people use (Archea et al., 1979).

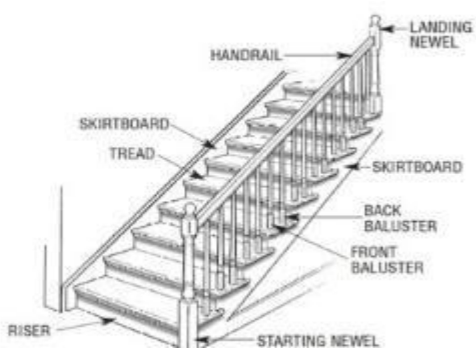



Figure 2. 3**.** Stair terminologies

The phrase "stair" refers to a whole flight of steps between two floors, including newel posts, landings, handrails, balustrades, and other components. Because young and old people find it difficult to move up and down stairs, solid handrails that are supported by balustrades on the open sides of the structure should be installed to prevent accidents (Bartlette, 1911).

Even if an adequate number of elevators are supplied, practically all low-rise or high-rise buildings must have stairs. A stair consists of the rise, which is defined as the vertical distance between two steps, and the run, which is defined as the depth of the steps. (Blanc, 1996)

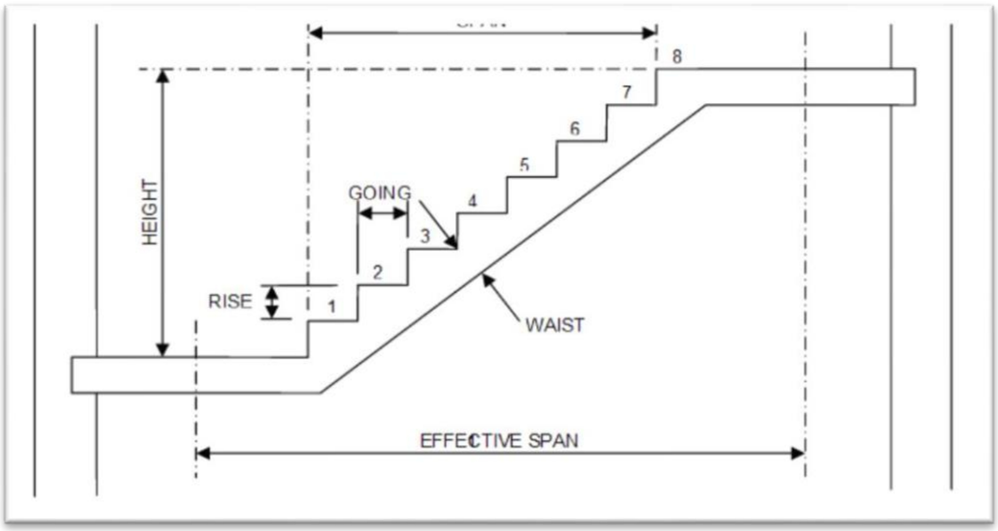



Figure 2. 4. Different component of a stairs

**2.3.1.5.1. The usual form of stairs can be classified into two types:**

**2.3.1.5.1.1.Stair spanning horizontal**

Stair of this type may be supported on one side by a wall and on the both side s or they may be cantilever from a supporting wall.

**2.3.1.5.2. Stair spanning longitudinally**

The landing that is at a straight angle to the stairs may be covered by the stair slab. The major reinforcement needs to be positioned at the top of the stairs and secured into the support. The effective depth of the member is determined by taking the mean effective depth of the section. To prevent shrinkage cracking, a thin reinforcing mesh is positioned in the lower face (Murty et al., 2002).

#### 2.3.1.5.3. Types of stairs

Although there are many different types of staircases, the most popular ones are the follows: straight staircases, L-shaped or 900 staircases, switchback staircases or U-shaped staircases with curves and spiral staircases.

### 2.3.1.6. Ramp design

Access to steps and other elevated landings is made easier for individuals in wheelchairs, pushing strollers for their kids, pushing carts, and using other wheeled devices. For those with disabilities who can't use stairs but still need to access the building, a ramp is suitable. Thus, having ramps and steps at the same location is not only required in our nation, but it is also unavoidable. Providing both stairs and a ramp at changes in level will allow people to choose the option that best suits their needs, resulting in a flexible and more universally accessible design.

### 2.3.1.7. Footing

Footing is structural members used to support columns and walls and transmit their loads to the underlying soils. Reinforced concrete is a material admirably suited for footings and is used structures as such for both reinforced concrete and structural, the permissible pressure on a soil beneath a footing is normally a few tons per square foot. The compressive stresses in the walls and columns of an ordinary structure may run as high as a few hundred tons per square foot. It is necessary to spread these loads over sufficient soil areas to permit the soil to support the loads safely. Not only is it desired to transfer the superstructure loads to the soil beneath in a manner that will prevent excessive or uneven settlements and rotations, but it is also necessary to provide sufficient resistance to sliding and overturning. (Wilbur & Mead, 1993)

#### 2.3.1.7.1. Types of footing

Due to factors like as soil type, many types of footings can be employed in foundations. Wall footing, isolated footing, combined footing, strip footing, strap footing, raft footing, and pile footing are the most prevalent**.**

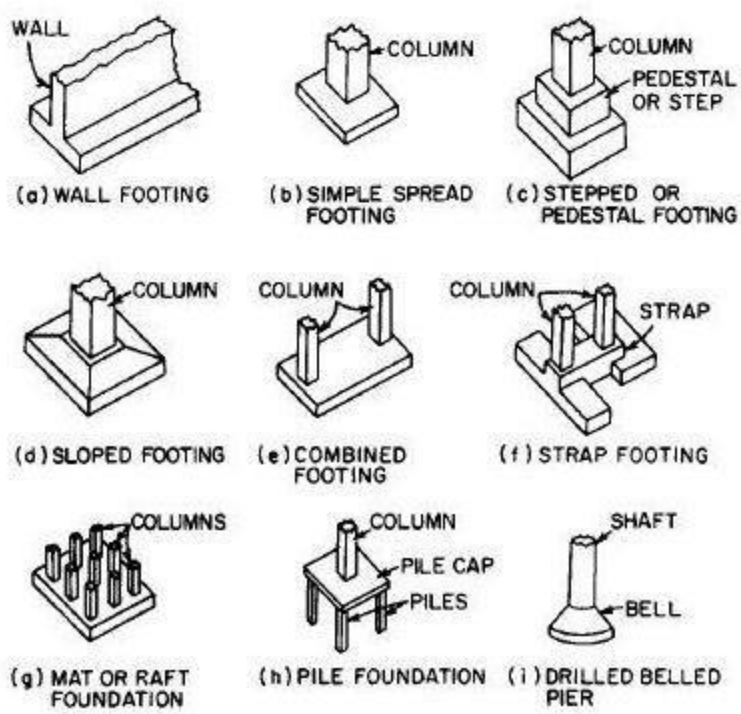



Figure 2. 5.The different types footings

### 2.3.1.8. Foundation

Foundation failure may arise as a result of (a) allowable bearing capacity of the soil being exceeded, or (b) bending and/or shear failure of the base. The first condition allows the plan-area of the base to be calculated, being equal to the design load divided by the bearing capacity of the soil, i.e. Ground pressure = design load /plan area < bearing capacity of soil

Since the settlement of the structure occurs during its working life, the design loadings to be considered when calculating the size of the base should be taken as those for the serviceability limit state (i.e. 1.0Gk + 1.0Qk). The calculations to determine the thickness of the base and the bending and shear reinforcement should, however, be based on ultimate loads (i.e. l.4Gk + 1.6Qk) (Meyerhof, 2010).

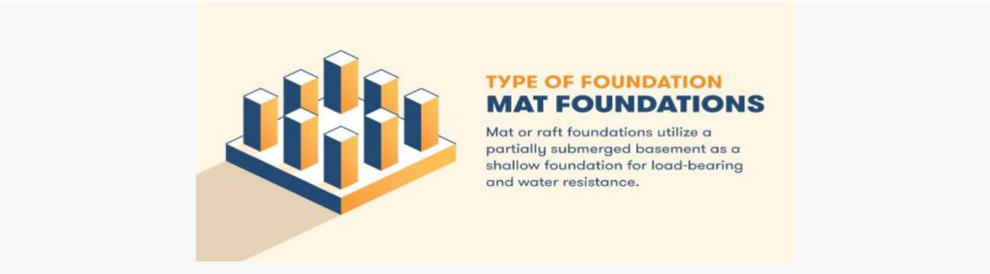
The types of foundation in construction structure case depend on the capacity of soil existing on site: Examples of Shallow Foundations (Das, 2017).

There are four examples of shallow foundations that we'll cover mat, individual footing, combined footing and stem wall. Each has a unique structure and various use cases but according to weight of this building project. Mat foundation was used.

**2.3.1.8.1. Mat Foundation**

A mat foundation takes full advantage of the surface area where the building will be erected, essentially using the basement as the entire load-bearing foundation. Mat foundations are often used when the soil is loose, weak, and requires the weight to be distributed evenly.

Mat foundations are also used when a basement is feasible and the pillars or columns are spaced close together. It is often referred to as a raft foundation because the basement foundation is submerged in the soil like the hull of a raft in water (Meyerhof, 2010).




Mat foundation

Figure 2. 6**. Mat foundation**

**2.3.1.8.1.1. Choosing the Right Type of Foundation**

Depending on the size, location, and geotechnical challenges facing your project, the decision to build shallow or deep foundations may be clear, but the exact type of foundation may be more nuanced. Given the importance of a building's foundation to its overall structural integrity, getting this decision right is essential (Day, 2010).

**2.3.1.9. Roof**

A roof is the top covering of a building, including all materials and constructions necessary to support it on the walls of the building or on uprights; it provides protection against rain, snow, sunlight, extreme of temperature, and wind. So, a roof is a part of the building envelope. The characteristics of a roof are dependent upon the purpose of the building that it covers the available roofing materials and the local traditions of construction and wider concepts of architectural design and practice and may also be governed by local or national legislation. Roof can either be flat or sloped based on the location and weather conditions or the purpose of the building (Brotrück, 2017).

#### 2.3.1.10. Swimming poor

A swimming pool, swimming bath, wading pool, paddling pool, or simply pool, is a structure designed to hold water to enable swimming or other leisure activities. Pools can be built into the ground (in-ground pools) or built above ground (as a freestanding construction or as part of a building or other larger structure), and may be found as a feature aboard ocean-liners and cruise ships. In-ground pools are most commonly constructed from materials such as concrete, natural stone, metal, plastic, or fiberglass, and can be of a custom size and shape or built to a standardized size, the largest of which is the Olympicsize swimming pool (Gabrielsen, 1969).

Many health clubs, fitness centers, and private clubs have pools used mostly for exercise or recreation. It is common for municipalities of every size to provide pools for public use. Many of these municipal pools are outdoor pools but indoor pools can also be found in buildings such as natatoriums and leisure centers. Hotels may have pools available for their guests to use at their own leisure. Pools as a feature in hotels are more common in tourist areas or near convention centers (Day, 2010).

Educational facilities such as high schools and universities sometimes have pools for physical education classes, recreational activities, leisure, and competitive athletics such as swimming teams. Hot tubs and spas are pools filled with water that is heated and then used for relaxation or hydrotherapy. Specially designed swimming pools are also used for diving, water sports, and physical therapy, as well as for the training of lifeguards and astronauts. Swimming pools most commonly use chlorinated water or salt water and may be heated or unheated (Shen et al., 2019).

### 2.3.2. Limit state design

Limit state design Also known as Load and Resistance Factor Design (LRFD), refers to a design method used in structural engineering. A limit state is a condition of a structure beyond which it no longer fulfills the relevant design criteria. The condition may refer to a degree of loading or other actions on the structure, while the criteria refer to structural integrity, fitness for use, durability or other design requirements. Limit state design requires the structure to satisfy two principal criteria: the ultimate limit state (ULS) and the serviceability limit state (SLS) (Punmia et al., 2007).

#### 2.3.2.1. The ultimate limit state (ULS)

The ULS is a physical situation that involves either excessive deformations leading and approaching collapse of the component under consideration or the structure as a whole, as relevant, or deformations exceeding pre-agreed values. It involves, of course, considerable inelastic (plastic) behavior of the structural scheme and residual deformations. In contrast, the ULS is not a physical situation but rather an agreed computational condition that must be fulfilled, among other additional criteria, in order to comply with the engineering demands for strength and stability under design loads. A structure is deemed to satisfy the ultimate limit state criterion if all factored bending, shear and tensile or compressive stresses are below the factored resistances calculated for the section under consideration (Kotsovos & Pavlovic, 1999).

#### 2.3.2.2. The serviceability limit state (SLS)

To satisfy the serviceability limit state criterion, a structure must remain functional for its intended use subject to routine (everyday) loading, and as such the structure must not cause occupant discomfort under routine conditions. As for the ULS, the SLS is not a physical situation but rather a computational check. The aim is to prove that under the action of Characteristic design loads (un-factored), and/or whilst applying certain (un-factored) magnitudes of imposed deformations, settlements, or vibrations, or temperature gradients etc. the structural behavior complies with, and does not exceed, the SLS design criteria values, specified in the relevant standard in force(Kotsovos & Pavlovic, 1999).

The main serviceability limit state are Deflection, Cracking and Vibration

### 2.4. Characteristics and Design load

#### 2.4.1. Characteristic load

The load that has a 95% chance of not being exceeded over the structure's lifetime is known as the characteristic load. The loads specified in different standards will be taken to be the characteristic loads in the absence of any data. However, overloading can also affect structures. Therefore, based on the types of loads or their combinations and the limit state under consideration, structures should be constructed with loads that are produced by multiplying the characteristic loads with appropriate safety factors. Partial safety factors (γf) for loads are the name given to these load safety factors (Shen et al., 2019).

##### 2.4.1.1. Partial factors of safety for loads

Possible variation such as construction tolerances are allowed for by partial safety applied to the strength of the material and the load.  Partial factors of safety for material (Baikie, 1985).

It is obtained by this equation:

$$\text{Design strength } = \frac{\text{characteristic strength (fk)}}{\text{partial factor of safety }(\gamma\text{m})}$$

Errors and accuracies may be due to a number of causes: design assumptions and an accuracy of calculation, possible unusual increases in magnitude of the actions, unforeseen stress, redistributions and construction inaccuracies

#### 2.4.2. Design Loads

##### 2.4.2.1.Definition

The forces that act on a structure are called loads.

Architecture and engineering, design load is the maximum amount of stress that can be put on a structure. Weight is one of the key factors that has to be considered to calculate, but it is not the only one.

#### 2.4.2.2.Categories

##### 2.4.2.2.1. Dead loads

Permanent loads including the weight of the structure itself

##### 2.4.2.2.2. Live loads

Non-permanent loads (the placement might not be set).

For example, furnishings, machinery, and building inhabitants.

Without any lateral loads, the design load is equal to 1.4Gk + 1.6Qk.

It should be acknowledged, therefore, that the design dead loads may, in theory, differ from the characteristic and final values, or 1.0Gk and 1.4Gk. In a similar vein, the loads imposed by the design can range from zero to the maximum value, or between 0.0 and 1.6 Qk.

There are various types of loads that affect a structure, including wind, earthquake, snow, dead, and live loads. There will be characteristic and design values for every kind of loading, and these need to be evaluated. Furthermore, the load combination that is most likely to have the worst possible impact on the structure in terms of bending moments, shear forces, and deflections must be identified by the designer.

Structural loads that remain constant in size throughout time are known as dead loads. They consist of the structural elements' self-weight, which includes the floors, walls, ceilings, plasters, beams, columns, and roofs. The loads of fixtures that are affixed to the structure permanently are also considered dead loads (Takabatake, 1990). Live loads, which are sometimes referred to as applied, imposed, or variable actions, can change over time and are frequently caused by a structure's occupancy. People, the movement of wind on an elevation, furniture, cars, the weight of books in a library, and other objects are examples of typical live loads (Chalk & Corotis, 1980).

Wind loads: Apply pressure to a building's façade; this type of loading is distinct and significant for tall buildings (Dyrbye & Hansen, 1997).

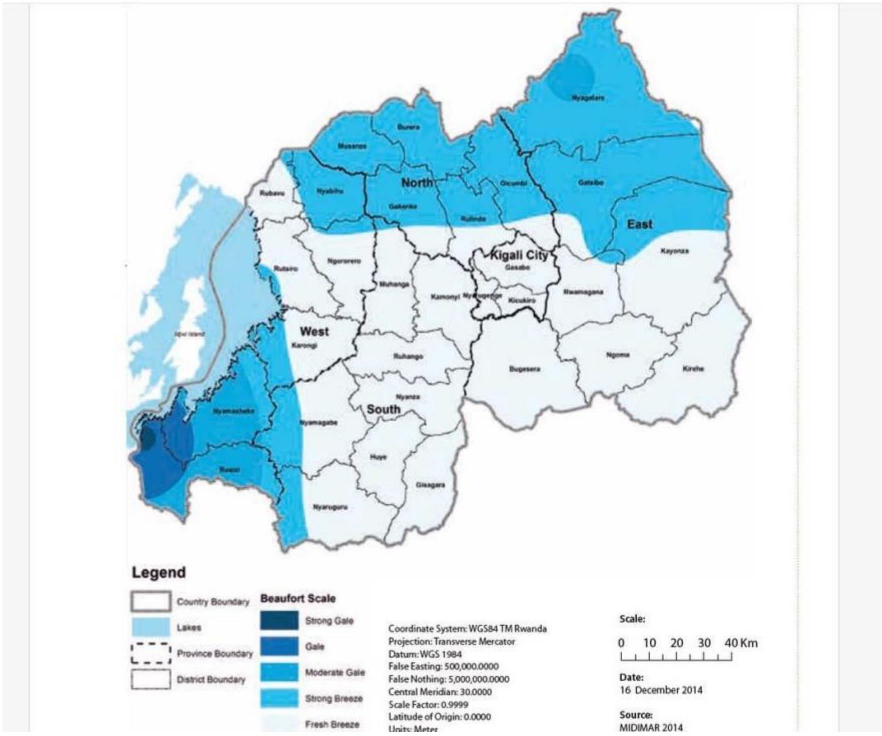



Figure 2. 7**.** Wind zone in Rwanda

Figure 1**:** Beaufort windstorm scale

Table 36. Beaufort Windstorm Scale

| Beaufort | Description of the windstorm | Observation | Wind speed (m/s) |
|---|---|---|---|
| 0 | Calm | Smoke rises vertically. The sea is mirror smooth. | 0 - 0.15 |
| 1 | Light Air | Direction of wind shown by smoke drift but not by vanes. Scale-like ripples on sea, no foam on wave crests. | 0.15 - 2.7 |
| 2 | Light Breeze | Wind felt on face, leaves rustle, ordinary vanes moved by wind. Short wavelets, glassy wave crests. | 2.7 - 3.6 |
| 3 | Gentle Breeze | Leaves and small twigs in constant motion, wind extends light flag | 3.6 - 7.2 |
| 4 | Moderate Breeze | Raises dust and loose paper, small branches moved. Fairy frequent whitecaps occur. | 7.2 - 8.9 |
| 5 | Fresh Breeze | Small trees in leaf begin to sway. Moderate waves, many white foam crests. | 8.9 - 12.5 |
| 6 | Strong Breeze | Large branches in motion, whistling heard in telegraph wires. Some spray on the sea surface. | 12.5 - 14.5 |
| 7 | Moderate gale | Whole trees in motion, inconvenience felt when walking into wind. Foam on waves blows on streaks. | 14.5 - 20 |
| 8 | Gale | Twigs broken of trees, generally impeded progress. Long streaks on foam appear on sea. | 20 – 22 |
| 9 | Strong gale | Straight structural damage, e.g. slates and chimney pots removed from the roofs. High waves, crest start to roll over. | 22 – 28 |
| 10 | Storm | Trees uprooted, considerable structural damage. Exceptionally high waves, visibility affected. | 28 – 31 |
| 11 | Violent Storm | Widespread damage | 31 – 37 |
| 12 | Hurricane | Air is filled with spray and foam. | > 37 |

Source: (NOAA , 2008)

Earthquake loads: Need to be considered in geographic locations where there is a reasonable probability of occurrence (Salajegheh et al., 2008).

Seismology and measuring of earthquakes As we've seen, tectonic stresses—which are produced at the borders of the Earth's tectonic plates—are the primary cause of most earthquakes. Seismic waves, which are shock waves that can be felt and measured, are the result of the released energy. Seismology is the study of seismic waves; the word comes from a Greek verb that means "to shake." Shearer (2019).

The devices used to record earthquakes are called seismographs. These devices are the main tool used by scientists to investigate seismic waves. During an earthquake, these highly sensitive devices can identify, gauge, and document the intensity of ground vibrations.

A basic pendulum is used as a seismograph. The base and frame tremble with the ground's vibrations, while the pendulum bob remains stationary due to inertia. In relation to the vibrating ground, it moves. A seismogram is a tool used to trace out the record of an event by measuring variations in the pendulum's displacement over time (Shearer, 2019).

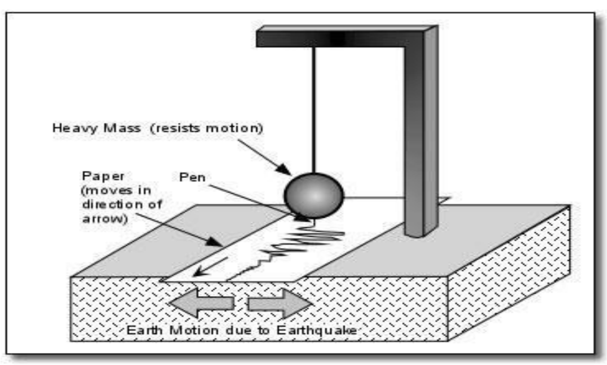



Figure 2. 8**.** A seismograph

The seismograph at the visitor center at Sunset Crater Volcano National Monument is depicted in the above image. Every time an earthquake is detected, a pen at the top of the instrument records a zigzag line on the moving, paper-covered cylinder. Every day, the paper record, or seismogram, is taken out and replaced. Scientists then examine the seismogram's earthquake data. Seismographs can assist in estimating the amount of energy released during an earthquake as well as its duration, epicenter, focus, and kind of faulting (Shearer, 2019).

#### 2.4.2.2.3. Magnitude and other units of measurement

The severity of an earthquake can vary from events which are barely detectable even using the most sophisticated devices, to devastating events which can level cities and trigger Tsunamis and sometimes even volcanic activity. The severity of an earthquake is called its magnitude. Various scales were proposed to measure the magnitude of earthquakes until 1935, when the Richter Scale was developed by a seismologist named Conrad Richter to measure the intensity of the seismic waves (Dahlen & Tromp, 2021).

The amplitude (height) of the largest recorded wave of an earthquake at a specific distance is called the Richter magnitude. Under the Richter scale, each order of magnitude is 10 times more intensive than the last one, which means that a two is 10 times more intense than a one and a three is one hundred times greater. But it is to point out that, while it is correct to say that for each increase in 1 in the Richter magnitude there is a tenfold increase in amplitude of the wave, it is incorrect to say that each increase of 1 in Richter magnitude represents a tenfold increase in the size of the earthquake (as is commonly incorrectly stated by the press). A better measure of the size of an earthquake is the amount of energy released by the earthquake, which is related to the Richter scale by the following equation: $\log E = 11.8 + 1.5 M$ (Richter, 2010). Where Log refers to the logarithm to the base 10, E is the energy released in ergs and M the Richter magnitude.

Table 2. 1. Earthquake Severity - Richter scale

| Richter Magnitude | Earthquake effects |
|---|---|
| 0-2 | Not felt by people |
| 2-3 | Felt little by people |
| 3-4 | Ceiling lights swing |
| 4-5 | Walls crack |
| 5-6 | Furniture moves |
| 6-7 | Some buildings collapse |
| 7-8 | Many buildings destroyed |
| 8-Up | Total destruction of buildings, bridges and roads |

Tectonic earthquakes can range in size from magnitudes less than zero, resulting from fault slippage of a few centimeters, to the largest events (magnitude greater than 9), where fault displacements are on the order of many meters. Earthquake size is determined not only by amount of displacement but also area of the ruptured fault plane. Hence the larger the rupture area, the larger is the earthquake. A magnitude 7 earthquake ruptures a fault area of about 1000 $km^2$ or about 50 km long and 20 km wide (Adushkin, 2016).

Also depth is an important factor influencing earthquake severity. We know that earthquakes can originate at various depths within the Earth's solid core. The deeper the earthquake, the more powerful it is, but it is also far less likely to reach the surface. That's why shallow earthquakes are more common and more dangerous, because the shallower an earthquake, the more damage to surface structures it can cause (Adushkin, 2016).

There is no limit to the possible magnitude of an earthquake but historically just over magnitude 9 is the record. The earthquake of most recent history to reach 9 on the Richter scale was the Japan quake of March 2011. This was also the largest recorded Japanese earthquake of all time.

Figure 2. 9**.** Earthquake in Japan, March 2011

#### 2.4.2.2.4. Earthquakes in Rwanda since 1950

The biggest earthquake to ever strike Rwanda occurred on July 8, 2015, in the Bukavu region, with a Richter scale magnitude of 5.8. Three people lost their lives as a result of the tectonic plate moving at a depth of 54 km (Oluwafemi et al., 2018).

Table 2. 2**.** The National Geophysical Data Center earthquake statistics in Rwanda.

| Date | Region | Depth | Magnitude | Deaths | Total damage |
|---|---|---|---|---|---|
| 05/25/2021 | Rubavu; Congo | 10 km | 4.7 | 0 | |
| 09/23/2016 | Risuzi; Congo (Ukavu) | 1 km | 4.8 | 8 | |
| 08/07/2015 | Bukavu | 54 km | 5.8 | 3 | |
| 02/14/2008 | Gisenyi | 46 km | 4.9 | 1 | |
| 01/17/2002 | Gisenyi | 29 km | 4.7 | 0 | |

These statistics are based on data's from the National Geophysical Data Center / World Data Service (NGDC/WDS): Significant Earthquake Database.

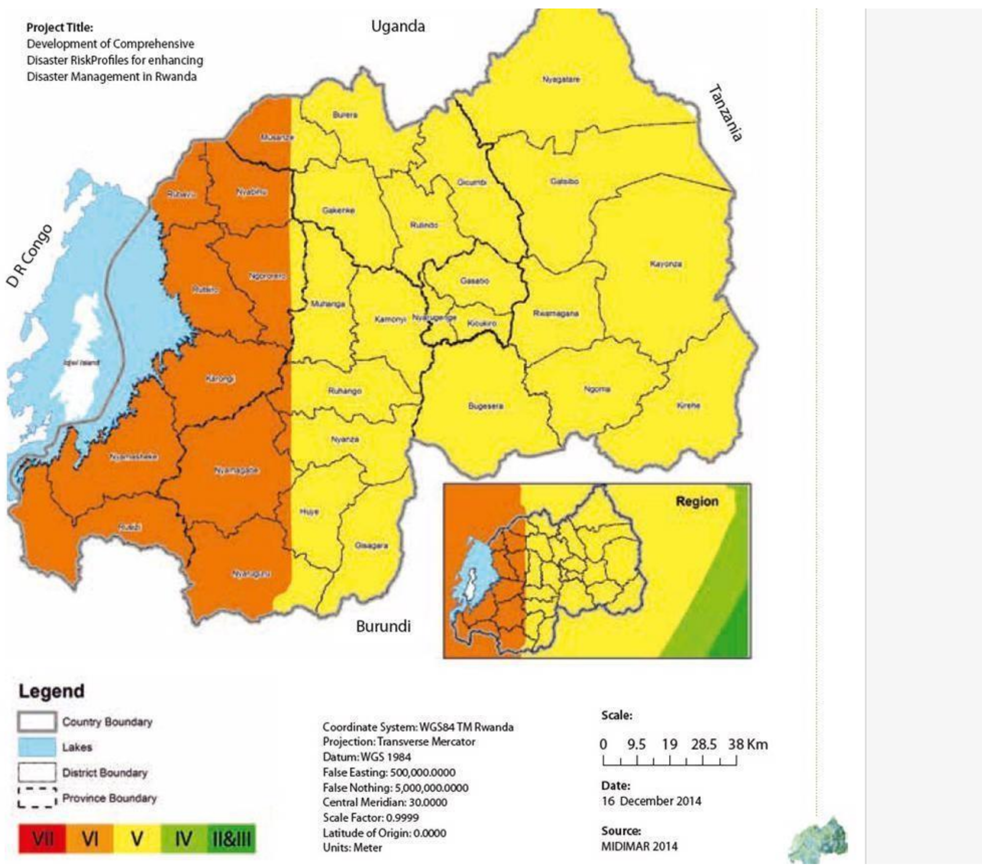



Figure 2. 10**.** Significant Earthquake Database

Table 2. 3**.** Earthquake hazard zonation map at 10% probability of exceedance in 50 years

CHAPTER IV: HAZARD ASSESSMENT AND MAPPING

Table 32. Earthquake hazard zone scale

| Zone | MMI Range | PGA (g) correspondent | Shaking | Description |
|---|---|---|---|---|
| Very high | VII | 0.18 -0.34 | Very strong | Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. |
| High | VI | 0.092 – 0.18 | Strong | Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. |
| Moderate | V | 0.039-0.092 | Moderate | Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop. |

Source of Description: (USGS) http://earthquake.usgs.gov/learn/topics/mercalli.php

Figure 42. Earthquake hazard zonation map at 10% probability of exceedance in 50 years

### 2.4.3. Load combinations and patterns for the ultimate limit state

When loading a structure, it is necessary to take into account different combinations of the characteristic values of the wind load Wk, variable load Qk, and permanent load GK, as well as their partial factors of safety. Chapter 2 discusses the code's partial factors of safety. The loading combinations for the ultimate limit state for the same chapter's table are as follows:

1) Permanent and Live load

1.35 Gk + 1.5Qk

2) Permanent and wind load

1.0 Gk + 1.5Wk

3) Permanent, Live and wind load

1.3 Gk +1.35Qk + 1.35W

4) Permanent, Live, wind load and earthquake load

1.2Gk +1.2Qk + 1.2W+1.2E (Ellingwood & Culver, 1977).

**Allowable load and allowable stress, factor of safety**

The maximum load that structural member will be allowed to carry under normal condition of utilization is considerably smaller than ultimate load. This smaller load is referred to as the allowable load and sometimes as working load or design load. The ratio of the ultimate load to the allowable load is used to define the factor of safety (Blume, 1977).

$Fs = \frac{\text{Ultimate load}}{\text{Allowable stress}}$ Where FS is factor of safety.

## 2.5. Criteria for safe design

The design of an engineering structure must ensure that under the most loading the structure is safe, and during normal working condition the deformation of the member does not detract from the appearance, durability or performance of the structure, the purpose of design is to achieve acceptable profanities that a structure will not became unfit for its intended use, that is that it will not reach a limit state thus, any way in which a structure may cease to be fit for use will constitute a limit state and the design aim is to avoid any such condition being reached during the expected life of the structure (Mosley,1999).

### 2.5.1. Ultimate limit state

Ultimate limit state (ULS) require that the structure must be able to withstand, with an adequate factor of safety against collapse, the load for which it is designed, the possibility of buckling or over turning must also be taken into account, as must the possibility of accidental damage for example by an internal explosion

### 2.5.2. Serviceability limit state

Serviceability limit state (SLS) are those which correspond to conditions beyond which specified service conditions of a structure or structural member are no longer met. They generally include issues like deformation, cracking and vibration which can damage structure and cause discomfort to the occupants of buildings.

### 2.5.3. Bill of quantity

Estimating is the technique of calculating or computing the various quantities and expected expenditure to be incurred on a particular work or project. A cost estimate is a compilation of many elements, an approximation of the probable quantity and unit cost of each of the elements. Estimating is the technique of calculating or computing the various quantities and expected expenditure to be incurred on a particular work or project. A cost estimate is a compilation of many elements, an approximation of the probable quantity and unit cost of each of the elements (Stewart et al., 1995).

#### 2.5.3.1. Roles of estimating and costing

Estimating and costing play a great role in designing and implementation of the proposed project and the following are the main roles of estimating and costing: It gives an idea of time required for the completion of the work Programming, It is a basis for projecting fund, It is used in making financial decisions; It is used to avoid project cost overrun and also avoid excessive cost underrun. Cost underrun leads to shortage of funding to deliver the project, while cost overrun leaves unused funds that could have been used to deliver other important projects. It gives an idea of the cost of the work and hence its feasibility can be determined. It is required to invite the tenders and the quotations (prices) and to arrange contract; It is required to control the expenditure during the execution of work (basis for cash flow requirements over time)

#### 2.5.3.2. Methods of cost estimation

##### 2.5.3.2.1. Center line method

This method is only if the offsets are symmetrical and the building is more or less rectangle in shape, the center line of the building is determined carefully after doing deduction for repeated measurement, it acts as length for the complete calculation of the estimate, if the deduction is not cared for the result of result of estimates may be wrong, all the walls should have the same section

#### 2.5.3.2.2. Crossing method

This method length and breadth of the masonry walls at plinth level are taken (internal dimension of the room +thickness of the walls) for calculating quantities. The symmetrical offsets are must as in the case of centerline method

#### 2.5.3.2.3. Out to out & in to in method

This method is most practicable under all circumstance and it is general

## 2.6. Reinforced concrete material

### 2.6.1. Introduction

Combining steel reinforcement with concrete to give the concrete the tensile strength it lacks is known as reinforced concrete. In addition to being utilized in columns, steel reinforcement can withstand compression stresses and is employed in a different scenario that will be discussed subsequently (Mosley, 2012).

### 2.6.2. Composition of reinforced concrete

#### 2.6.2.1. Portland cement

Cements are general senses are adhesive and cohesive materials which are capable of bonding together particles of solid matter into a compact durable mass. For civil engineering works, they are restricted to calcareous cements containing compounds of lime as their chief constituent, its primary function being to bind the fine (sand) and coarse (grits) aggregates particles together. Cements used in construction industry may be classified as hydraulic (include Portland cement which is the most common type of cement in use) and non-hydraulic (Gonçalves, 2015)

#### 2.6.2.2. Aggregates

Aggregates are the materials basically used as filler with binding material in the production of mortar and concrete. They are derived from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag, etc. Aggregates form the body of the concrete, reduce the shrinkage and effect economy. They occupy 70-80 per cent of the volume and have considerable influence on the properties of the concrete. It is therefore significantly important to obtain right type and quality of aggregates at site. They should be clean, hard, strong, and durable and graded in size to achieve utmost economy from the paste

#### 2.6.2.3. Water

The water causes the hardening of concrete through a process called hydration. Concrete derives its strength by the hydration of cement particles where they are absorbing water. And of course, the rate of hydration is fast to start with, but continues over a very long time at a decreasing rate. But amount of water must be limited to produce concrete of the quality required for job `plus the fact that water can also be used for washing aggregates (Walker, 2006).

## CHAPTER 3. RESEARCH METHODOLOGY

### 3.1. Introduction

This section outlines the field of research as well as the various materials, techniques, and processes which will be employed to accomplish the study's objectives. Where the case study will be detailed, as well as structural design, and cost-estimating processes which will be used.

### 3.2. Case study description

The research is being conducted in Gasabo District, Gisozi Sector. Gasabo as well as Gisozi sector has a tropical climate. The winters have significantly more rainfall than the summers. The average annual temperature of Gasabo is 20.9 °C (69.6 °F). Annual precipitation totals 908 mm (35.7 inches). The structure is a G+2 structure, and the location is easily accessible from the road, with connection to water and electricity. Gisozi sector has two cells; Ruhango and Musezero.

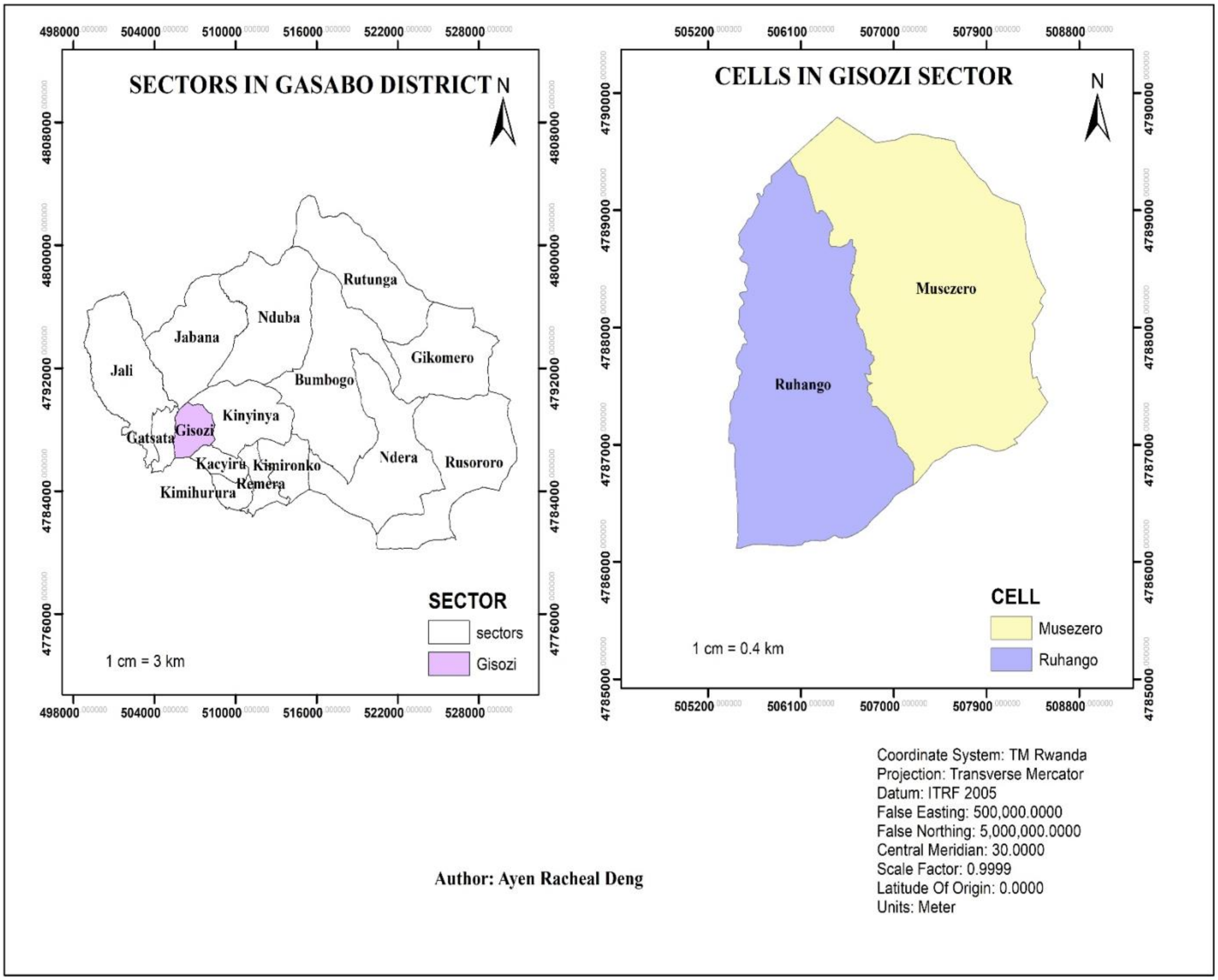



Figure 3. 1**:** Map shows the site location.

### 3.3. Structural design

After the completion of architectural drawings, structural plans will be created. The building's intended structural plan included reinforced concrete columns, beams, and slabs. Etab and Prokon structural design software will be utilized.

#### 3.3.1. Design assumptions

When designing a reinforced concrete structure, different assumptions will be made. The following assumptions will be considered in the design of the planned building: Concrete has no tensile strength. Bond between the interfaces of the two materials steel and concrete is perfect with in elastic limit of steel.

- The concrete does not resist any tensile forces; all tensile stress is taken by reinforcement and none by concrete.
- The stresses in steel and concrete are related only by the factor known as modular ratio.
- The stress-strain relationship of steel and concrete is straight line under working loads.
- All forces and moments applied to joints are determined according to EN 1993-1.
- Distribution of internal forces is realistic concerning stiffness in joints.
- Concrete is assumed to carry zero tensile stresses.
- At the ultimate limit state, the strain in concrete is 0.0035.
- The strains in concrete and reinforcing steel are directly proportional to the distances from the neutral axis at which the strain is zero.
- Partial safety factors for loads are used.
- The applied loads to the structure multiplied with the design coefficients represent the ultimate loading possible to happen on the structure in the zone of construction.
- Partial safety factors for material strength according to BS 8110 part 1 is 1.15 for steel and 1.5 for concrete.

### 3.3.2. Design Criteria

Table below which was illustrated above shows different information related to the design of building project which was designed to be constructed in Rusororo sector (Kigali city).

Table 3. 1**.** Information related to the structural design of the proposed building.

| | |
|---|---|
| **Building Regulations and**<br><br>**Design Code** | BS 8110-Cl.3.8.4.5: The structural use of concrete. Part 1- 1997,<br><br>BS8110-Cl.3.4.5.2: Shear Check,<br><br>IS 875: Code for practice Design Loads for building and Structures. Part 2 1987<br><br>BS 8666_2000: Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete.<br><br>BS 8004:1986 Code of Practice for Foundations.<br><br>Rwanda Building Control Regulations 2020 |
| **General loading condition** | Roof live load: 1.5 kN/m2<br><br>Toilet area: 2 kN/m2<br><br>Bed rooms live loads: 2 kN/m2 36<br><br>Stair slabs live Load : 3.00 kN/m2<br><br>Slabs and Stair Finishes 1.5 kN/m2<br><br>Live load of hotel: 2 kN/m2 |
| **Exposure conditions** | **Moderate Conditions (Internals and Externals** |
| **Material Characteristics** | Concrete: Grade M25/30 (fcu = 30Mpa) (with 20mm max. Aggregates).<br><br>Reinforcement: Characteristic strength $f$y = 460 N/mm |

| | |
|---|---|
| **Other relevant information** | Self-weight of Reinforced concrete = 24 kN/m3<br><br>Self-weight of masonry = 18 kN/m3<br><br>Self-weight of plaster =20 kN/m3<br><br>Self-weight of soil= 18 kN/m3<br><br>Self-weight of curten wall=2.14 kN/m |
| **Partial safety factor** | Dead load =1.4<br><br>Live load =1.6<br><br>Structure under bending and axial loading=1.56 |
| **Design method** | Design for ultimate limit states and checked for serviceability limit states (cracking and deflection |

**3.3.3. Design of one-way slabs and two-way slab**

**Design of one-way slab**

According to BS 8110, the following procedures were used for the design of slabs: Firstly, determining a suitable depth of slab, and then calculating the main and secondary reinforcement areas, checking critical shear stresses, therefore check detailing requirements.

**Determining a suitable depth of the slab**

The deflection requirements for slabs will often control the depth of slab needed. The minimum effective depth of slab, d, can be calculated using Eq. 1. Table 3 shows the basic span to effective depth ratio.

$$\mathrm{d} = \frac{\text{longest span}}{\text{modification factor} \times \text{span/effective depth ratio}} \qquad (3.1)$$

Table 3. 2**.** Basic span/effective depth ratios (BS 8110)

| **Support conditions** | **Span/depth ratio** |
|---|---|
| Cantilever | 7 |
| Simply supported | 20 |
| Continuous | 26 |

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

**Calculating the main and secondary steel reinforcements**

Where M = Maximum applied moment on the slab

fy = Tensile strength of steel

$$Z = d[0.5 + \sqrt{(0.25 - K/0.9)}] \quad (3.7)$$

The self-weight of the slab together with the dead and live loads were used to calculate the design moment, M. The ultimate moment of resistance of the slab, Mu was calculated using equation 3.2 and the area of steel required was calculated using Eq.3. 3 provided that Mu ≥M.

$$Mu = 0.156 \times bd^2 \times fcu \quad (3.2)$$

Where b = width which is taken as 1m for slabs d= effective depth of main steel fcu = compressive strength of concrete

$$A_s = \frac{M}{0.87 \times f_y \times Z} \quad (3.\ 3)$$

$$K = \frac{M}{f_{cu} \times b \times d^2} \quad (3.4)$$

### 3.3.4. Design of two-way slabs

The design of two-way spanning restrained slabs supporting uniformly distributed loads is generally similar to that for one-way spanning slabs. The extra complication arises from the fact that it is rather difficult to determine the design bending moments and shear forces in this type of slabs. BS 8110 contains tables of coefficients that may assist in this task. Those coefficients can be found in Table 7 and Table 8 Thus, the maximum design moments per unit width of rectangular slabs of shorter side lx and longer side ly were given by Eq 3.6 and Eq 3.7 respectively.

$$Msx = \beta_{sx} \times n \times l_x^2 \qquad (3.5)$$

$$Msy = \beta_{sy} \times n \times l^2_y \qquad (3.6)$$

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

Msy = maximum design ultimate moments either over supports or at mid-span or on strips of unit width and span ly n = total design ultimate load per unit area Similarly, the design shear forces at supports in the long span direction, Vsy, and short span direction, Vsx, may be obtained from the from Eq 3.8 and Eq 3.9 respectively.

$$Vsy = \beta_{sy} \times n \times l^2_y \qquad (3.8)$$

$$Vsx = \beta_{sx} \times n \times l_x^2 \qquad (3.9)$$

Table 3. 3**:** Bending moment coefficients βsx and βsy, for two-way restrained slabs (BS 8110)

| *Type of panel and moments considered* | *Short span coefficients, $\beta_{sx}$ Values of $\ell_y/\ell_x$* | | | | | | | | *Long span coefficients, $\beta_{sy}$, for all values of $\ell_y/\ell_x$* |
|---|---|---|---|---|---|---|---|---|---|
| | *1.0* | *1.1* | *1.2* | *1.3* | *1.4* | *1.5* | *1.75* | *2.0* | |
| *Interior panels* | | | | | | | | | |
| Negative moment at continuous edge | 0.031 | 0.037 | 0.042 | 0.046 | 0.050 | 0.053 | 0.059 | 0.063 | 0.032 |
| Positive moment at mid-span | 0.024 | 0.028 | 0.032 | 0.035 | 0.037 | 0.040 | 0.044 | 0.048 | 0.024 |
| *One long edge discontinuous* | | | | | | | | | |
| Negative moment at continuous edge | 0.039 | 0.049 | 0.056 | 0.062 | 0.068 | 0.073 | 0.082 | 0.089 | 0.037 |
| Positive moment at mid-span | 0.030 | 0.036 | 0.042 | 0.047 | 0.051 | 0.055 | 0.062 | 0.067 | 0.028 |
| *Two adjacent edges discontinuous* | | | | | | | | | |
| Negative moment at continuous edge | 0.047 | 0.056 | 0.063 | 0.069 | 0.074 | 0.078 | 0.087 | 0.093 | 0.045 |
| Positive moment at mid-span | 0.036 | 0.042 | 0.047 | 0.051 | 0.055 | 0.059 | 0.065 | 0.070 | 0.034 |

Figure 3. 2**:** Shear force coefficients βvx and βvy, for two-way restrained slabs (BS 8110)

| *Type of panel and location* | *$\beta_{vx}$ for values of $\ell_y/\ell_x$* | | | | | | | | $\beta_{vy}$ |
|---|---|---|---|---|---|---|---|---|---|
| | *1.0* | *1.1* | *1.2* | *1.3* | *1.4* | *1.5* | *1.75* | *2.0* | |
| *Four edges continuous* | | | | | | | | | |
| Continuous edge | 0.33 | 0.36 | 0.39 | 0.41 | 0.43 | 0.45 | 0.48 | 0.50 | 0.33 |
| *One long edge discontinuous* | | | | | | | | | |
| Continuous edge | 0.36 | 0.40 | 0.44 | 0.47 | 0.49 | 0.51 | 0.55 | 0.59 | 0.36 |
| Discontinuous edge | 0.24 | 0.27 | 0.29 | 0.31 | 0.32 | 0.34 | 0.36 | 0.38 | – |
| *Two adjacent edges discontinuous* | | | | | | | | | |
| Continuous edge | 0.40 | 0.44 | 0.47 | 0.50 | 0.52 | 0.54 | 0.57 | 0.60 | 0.40 |
| Discontinuous edge | 0.26 | 0.29 | 0.31 | 0.33 | 0.34 | 0.35 | 0.38 | 0.40 | 0.26 |

### 3.3.5. Design of beams

Beams can be designed as singly or doubly reinforced beams. According to BS 8110, the following procedure was followed for the design of singly reinforced beams: From the minimum requirements of span/depth ratio given in Table 3.5 to control deflection estimate a suitable effective depth d, then assuming the bar diameter for the main steel and links and the required cover as determined by exposure conditions, estimate an overall depth h where h is given by d plus bar diameter plus link diameter plus cover, after that assume breadth as about half the overall depth.

Calculate the self-weight, calculate the design live load and dead load moment using appropriate load factors where the load factors are normally 1.4 for dead loads and 1.6 for live loads. Therefore, calculate K using Eq. 3.5 and z using Eq. 3.4. $z/d \leq 0.95$ if $k \geq 0.0428$, then Calculate the required steel as using Eq. 3.3, hence areas of steel were obtained, determine the design concrete shear stress $\upsilon_c$ from Table 10.

Calculate the design shear stress in the beam υ by diving the ultimate shear force in the beam by the cross-sectional area of the beam.

Then, use Table 10 for determining the form and area of links to be used in the beam where Asv is the required area of links and Sv is the spacing of links.

Table 3. 4: Span/effective depth ratios for initial design

| *Support condition* | *Span/effective depth* |
|---|---|
| Cantilever | 6 |
| Simply supported | 12 |
| Continuous | 15 |

Table 3. 5**.** Form and area of links in beams (BS 8110)

| *Values of $\upsilon$ ($N/mm^2$)* | *Area of shear reinforcement to be provided* |
|---|---|
| $\upsilon < 0.5\upsilon_c$ throughout the beam | No links required but normal practice to provide nominal links in members of structural importance |
| $0.5\upsilon_c < \upsilon < (\upsilon_c + 0.4)$ | Nominal (or minimum) links for whole length of beam $A_{sv} \geq \frac{0.4bs_v}{0.87f_{yv}}$ |
| $(\upsilon_c + 0.4) < \upsilon < 0.8\sqrt{f_{cu}}$ or 5 N/mm² | Design links $A_{sv} \geq \frac{bs_v(\upsilon - \upsilon_c)}{0.87f_{yv}}$ |

The design of doubly reinforced beams is done when the design moment M is greater than the ultimate moment capacity $M_u$. Then areas of compression and tension reinforcements must be required and can be calculated using Eq. 3.10 and Eq. 3.11 respectively.

$$A'_s = \frac{M - M_u}{0.87f_y(d - d')} \qquad (3.10)$$

$$A_s = \frac{M_u}{0.87f_y} + A'_s \qquad (3.11)$$

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

$$z = d\{0.5 + \sqrt{(0.25 - K'/0.9)}\}$$

$$K' = 0.156$$

### 3.3.6. Design of columns

Both concrete and longitudinal reinforcements contribute to the load carrying capacity of a column. According to BS 8110, the design load carrying capacity $N_u$ of an axially loaded short column is with a cross-sectional area $A_c$ and steel area $A_{sc}$ is calculated using Eq. 3.12.

$$Nu = 0.4fcuAc + 0.75\ Asc\ fy \qquad (3.12)$$

After determining the design axial load in the column, the area of reinforcements can be calculated using Eq. 10. For short braced columns supporting an approximately symmetrical arrangement of beams. These beams must be designed for uniformly distributed imposed loads and the spans must not differ by more than 15% of the longer span. The ultimate load is given by Eq. 13

$$N = 0.35\ fcu\ Ac + 0.67Asc\ fy \qquad (3.13)$$

### 3.3.7. Design of foundations

Pad foundations were designed in this project. According to BS 8110, the following procedure was used for the design of foundations: Firstly, assume weight of the footing as 10% of the serviceability load (Dead load + Live load from the column). Calculate the total serviceability load by adding the weight of the footing to the total serviceability load from the column.

Secondly, calculate the base area A of the footing by dividing the allowable bearing pressure of the soil by the total serviceability load. Then, assume the overall depth h of the footing and calculate the self-weight of the footing using Eq. 3.14.

$$\text{Self-weight of footing} = A \times h \times \text{density of concrete} \qquad (3.14)$$

Furthermore, calculate the total ultimate load = 1.4 dead load + 1.6 live load, and calculate the earth pressure caused by ultimate loads by dividing the total ultimate load by the plan area of the base.

Calculate the maximum design moment M in the footing which occurs at the face of the column using Eq. 3.15.

$$M = \frac{P_s \times l^2}{2} \qquad (3.15)$$

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

$P_s$= earth pressure

After that, assuming the diameter of reinforcements, calculate the effective depth of the footing d which is equal to total depth minus diameter of the bar minus the cover. Lastly, calculate the area of reinforcements required using Eq. 3.3. The minimum reinforcements in the footing is 0.13%bh according to BS 8110.

**Checking for punching shear**

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

Calculate the critical perimeter $P_{cr}$ using Eq. 3.16

$$P_{cr} = \text{column perimeter} + 8 \times 1.5d \qquad (3.16)$$

Calculate the area within the critical perimeter $A_{cr}$ using Eq. 3.17

$$A_{cr} = \text{Column width} \times 3d^2 \qquad (3.17)$$

Using Eq. 3.18, calculate the ultimate shear force V in the foundation.

$$V = P_s \times (A - A_{cr}) \qquad (3.18)$$

Calculate the design punching shear stress using Eq. 3.19.

$$\upsilon = \frac{V}{Pcr \times d} \qquad (3.19)$$

By using table 3.5, determine the design shear stress in concrete $\upsilon_c$. For the foundation to be safe, $\upsilon c \geq \upsilon$ otherwise the footing depth must be increased.

### 3.3.8. Stair calculation

For calculating stair, it is necessary to compute equivalent thickness, as different stair parts are required, let suppose that story height (h), Stair width (b), story landing width (bSK), Intermediate landing width (bSA), step width (a), Step height (Rise), stair hole width (bK), plate thickness (dK), plate thickness (landing) (dS), and support width (bM)

$\theta=\tan^{-}(\frac{rise}{going})$, $h=\frac{H}{2}+\frac{dl}{\cos\alpha}$, effective height (d) =equivalent thickness- concrete cover, where the loads on stair are dead load, finishes load and live load. Once loads are applied on stair, the bending moment take place.

$M=ql^2/8$

$Am = M/(b.hu^2.Rb)$

**Required steel reinforcement in the stair**

$A_s = \frac{M}{fcu*b*d^2}$ (3. 20)

This formula helps to get value of **η**

$As = M/(\eta.\ hu.\ Rs)$ (3. 21)

Distribution bar $As_2= As_1/5$

Main bar $As_2= As_1/3$

# CHAPTER 4: RESULTS AND DISCUSSION

## 4.0. Introduction

This building consists of a four story commercial building which located in Kigali city Gasabo district Gisozi sector. It has a three stories where from the ground floor to the second floor is for residential apartment purposes.

## 4.1. Structural design

### 4.1.1. Slab design

Slab is horizontal plate elements carrying lateral loads. They may be simply supported or continuous over one or more supports and are classified according to the method of support as follows: Spanning one way between beams or walls, spanning two ways between the support beams or walls, and flat slabs carried on columns and edge beams or walls.

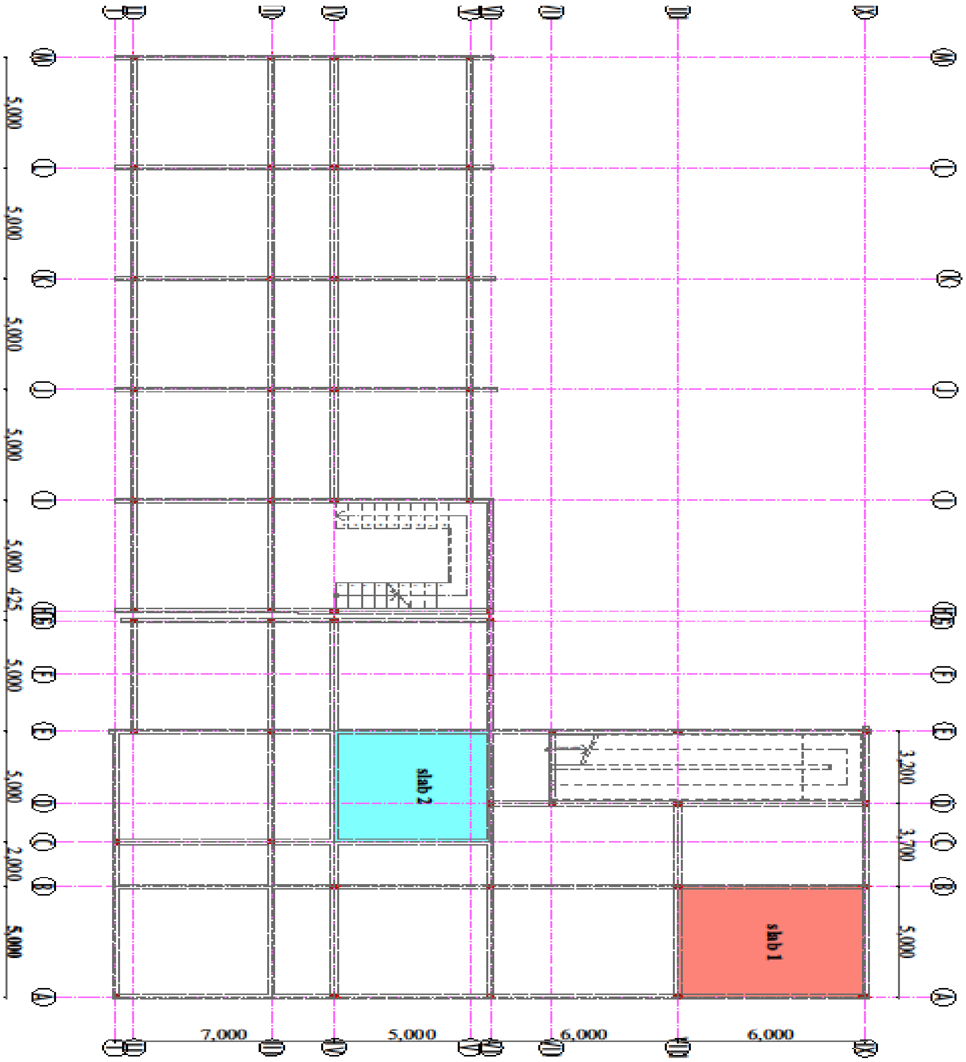



Figure 4. 1**:** Designed slab panels

#### 4.1.1.1. SLAB 1(A, B, VII, IX)

**a) Slab thickness**

Calculation of the depth of slab

The thickness of the slab lies between Lx/25 and Lx/40; where Lx is the short side of the panel. Considering the biggest panel among others; taken (A, B, VIII, IX**)** of 6mx5m.

$(h_f) = \frac{500}{25}$ = 20cm in comparison with $\frac{500}{40}$= 12.5cm

As the thickness of the slab ($h_f$) lies between 20cm and 12.5cm, taken $h_f$ =15cm.

The effective height (ho) = thickness of the slab – the clear cover = 15-2.5= 12.5cm

The effective height of the slab (ho) =12.5cm

**b) Calculation of steel reinforcement in the slab**

Calculation of total load on the slab

Dead load

Self-load= 1.4*1*1*0.15*24KN/m= 5.04KN/$m^2$

Finishes= 1.4*1*1*1.5KN/m= 2.1KN/$m^2$

Total dead load= 5.04KN/$m^2$ + 2.1KN/$m^2$ = 7.14KN/$m^2$

Live load

The weight of live load for house used as commercial apartment is equal to 4KN/$m^2$

Live load= 1.6*1*1*4KN/m= 6.4KN/$m^2$

Total load on the slab = 7.14KN/$m^2$ + 6.4KN/$m^2$ = 13.54KN/$m^2$

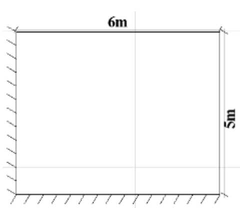



Figure 4. 2**:** Sketch of slab

Ly= 6m, Lx= 5m

$$\frac{\text{ly}}{\text{lx}} = \frac{6}{5} = 1.2 < 2(\text{two way slab})$$

**c) Calculation of bending moment**

$M_{sx} = \alpha_{sx} * n * L_x^2$

$M_{sy} = \alpha_{sy} * n * L_x^2$

$M_x^- = 0.084 * 13.54 * 5^2$ =28.43 KNm

$M_x^+ = 0.037 * 13.54 * 5^2 = 12.52$KNm

$M_y^- = 0.059 * 13.54 * 5^2 = 19.97$KNm

$M_y^+ = 0.026 * 13.54 * 5^2 = 8.81$KNm

**d) Steel bars calculation**

Rb = 1.4KN/cm$^2$

Rs = 40KN/cm$^2$

$M^-_{max} = 28.43$KNm

$M^+_{max} = 19.97$KNm

**e) Required steel reinforcement at the top**

$$\alpha m = \frac{M^-}{Rb * ho^2 * b} = \frac{28.43 * 100}{1.4 * 12.5^2 * 100} = 0.12$$

αm= 0.12 taken 0.122 which corresponds to ξ= 0.13; from the table of coefficients related to the design of members subjected to bending moment.

$\xi = 0.13$; $\xi < \xi_R = 0.393$ (Case of singly reinforcements)

$\eta = 0.935$

$As = \frac{M^-}{\eta * ho * Rs} = \frac{28.43*100}{0.935*12.5*40} = 6.08$cm$^2$/m

With this cross section, we use the minimum steel cross section: 6ϕ12 mm/m**,** with As = 6.79cm$^2$/m

**f) Required steel reinforcement at the bottom**

$$\alpha m = \frac{M^+}{Rb * ho^2 * b} = \frac{19.97 * 100}{1.4 * 12.5^2 * 100} = 0.091$$

αm= 0.091 taken 0.095 corresponds to ξ= 0.1; from the table of coefficients related to the design of members subjected to bending moment.

$\xi = 0.1$; $\xi < \xi_R = 0.393$ (Case of singly reinforcements)

$\eta = 0.95$

$As = \frac{M^+}{\eta * ho * Rs} = \frac{19.97*100}{0.95*12.5*40} = 4.2$cm$^2$/m

With this cross section, we use the minimum steel cross section: 4ϕ12 mm/m**,** with

As = 4.52cm$^2$/m

**g) Steel arrangement in the slab**

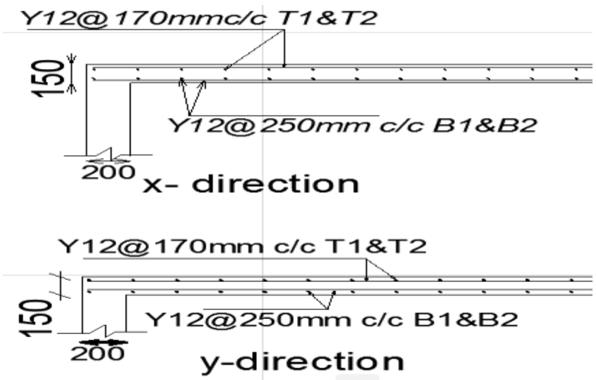



Figure 4. 3**:** Steel reinforcement arrangement

**4.1.1.2. SLAB 2 (C, E, IV, VI)**

**a. Slab thickness**

Calculation of the depth of slab

The thickness of the slab lies between Lx/25 and Lx/40; where Lx is the short side of the panel. Considering the biggest panel among others; taken (C, E, IV, VI**)** of 5mx5m.

$(h_f) = \frac{500}{25}$ = 20cm in comparison with $\frac{500}{40}$= 12.5cm

As the thickness of the slab ($h_f$) lies between 20cm and 12.5cm, taken $h_f$ =15cm.

The effective height (ho) = thickness of the slab – the clear cover = 15-2.5= 12.5cm

The effective height of the slab (ho) =12.5cm

**b. Calculation of steel reinforcement in the slab**

Calculation of total load on the slab

Dead load

Self-load= 1.4*1*1*0.15*24KN/m= 5.04KN/$m^2$

Finishes= 1.4*1*1*1.5KN/m= 2.1KN/$m^2$

Total dead load= 5.04KN/$m^2$ + 2.1KN/$m^2$ = 7.14KN/$m^2$

Live load

The weight of live load for house used as commercial apartment is equal to 4KN/$m^2$

Live load= 1.6*1*1*4KN/m= 6.4KN/$m^2$

Total load on the slab = 7.14KN/$m^2$ + 6.4KN/$m^2$ = 13.54KN/$m^2$

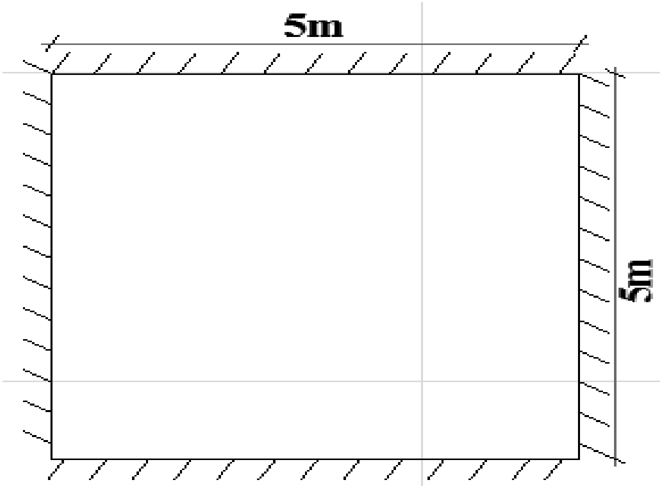



Figure 4. 4**:** Sketch of slab

Ly= 5m, Lx= 5m

$$\frac{ly}{lx} = \frac{5}{5} = 1 < 2(\text{two way slab})$$

**c. Calculation of bending moment**

$M_{sx} = \alpha_{sx} * n * L_x^2$

$M_{sy} = \alpha_{sy} * n * L_x^2$

$M_x^- = 0.042 * 13.54 * 5^2 = 14.217$ KNm

$M_x^+ = 0.018 * 13.54 * 5^2 = 6.093$KNm

$M_y^- = 0.042 * 13.54 * 5^2 = 14.217$KNm

$M_y^+ = 0.018 * 13.54 * 5^2 = 6.093$KNm

**d. Steel bars calculation**

Rb = 1.4KN/cm$^2$

Rs = 40KN/cm$^2$

$M^-_{max} = 14.217$KNm

$M^+_{max} = 6.063$KNm

**e. Required steel reinforcement at the top**

$$\alpha m = \frac{M^-}{Rb * \ ho^2 * b} = \frac{14.217 * 100}{1.4 * \ 12.5^2 * 100} = 0.06$$

αm= 0.06 taken 0.58 which corresponds to ξ= 0.06; from the table of coefficients related to the design of members subjected to bending moment.

$\xi = 0.06$; $\xi < \xi_R = 0.393$ (Case of singly reinforcements)

$\eta = 0.97$

$As = \frac{M^-}{\eta * ho * Rs} = \frac{14.217*100}{0.97*12.5*40} = 2.93 cm^2/m$

With this cross section, we use the minimum steel cross section: 4ϕ10 mm/m**,** with

$As = 314 cm^2/m$

**f. Required steel reinforcement at the bottom**

$$\alpha m = \frac{M^+}{Rb * \ ho^2 * b} = \frac{6.063 * 100}{1.4 * \ 12.5^2 * 100} = 0.027$$

αm= 0.027 taken 0.03 corresponds to ξ= 0.03; from the table of coefficients related to the design of members subjected to bending moment.

$\xi = 0.03$; $\xi < \xi_R = 0.393$ (Case of singly reinforcements)

$\eta = 0.985$

$As = \frac{M^+}{\eta * ho * Rs} = \frac{6.063*100}{0.985*12.5*40} = 1.23 cm^2/m$

With this cross section, we use the minimum steel cross section: 4ϕ8mm/m**,** with

$As = 2.01 cm^2/m$

**g. Steel arrangement in the slab**

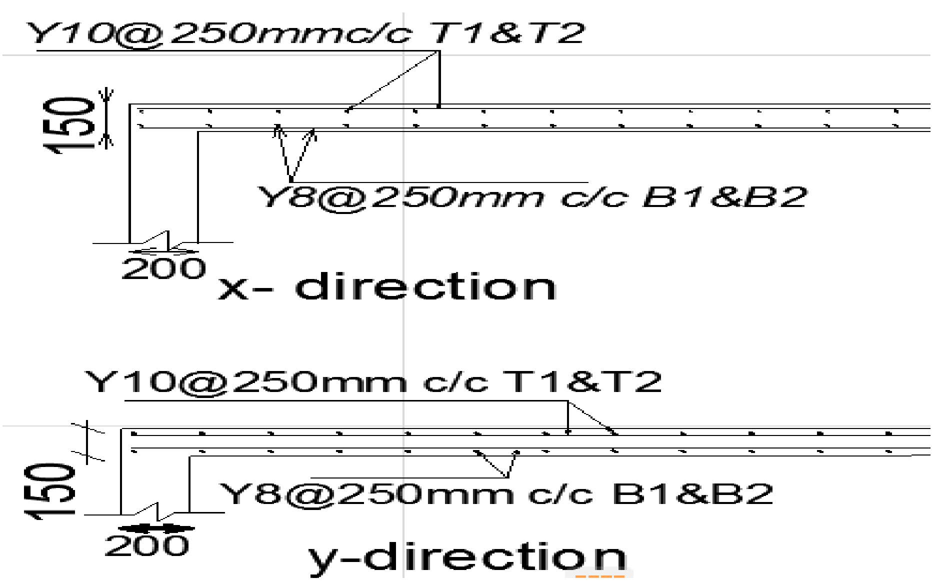



Figure 4. 5: steel reinforcement arrangement

**Discussion**

This Fig.4.7, shows how the steel reinforcement are arranged in the slab and this figure show the section of steel reinforcement sizes and the spacing between bars to be used in the slab. The steel found for slab on top and bottom which has the diameter greater or equal to 8mm the minimum diameter for slab has to be equal or greater than 8mm. All slab panels have the thickness which equal to 150mm which is in the range between 100mm to 500m means the slab thickness are good. To say that, the reinforced concrete design slab for buildings has to be in the range 100 to 500mm. the calculations of steel bars on top and bottom are required for slab in order to resist for the bending moment (Johnson, 2018).

### 4.2.1. Beam design

#### 4.2.1.1. Beam 1(B-B) design

Method of calculation, the beams are analysed and dimensioned to resist the actions and reaction which are applied on it.

With: Lmax –Effective span.

F – Design loads: 1.4 $G_K$+1.6 $Q_K$. (30)

**a) Computation for the depth of the beam (h)**

$\frac{Lmax}{8} \leq h \leq \frac{Lmax}{15}$, W`here Lmax is the largest span of the beam between two supports from the structural plan.

$\frac{700}{8} \leq h \leq \frac{700}{15}$ =87.5 ≤ h ≤ 46.6, Taken h = 60cm

**b) Computation for the breath of the beam (bw)**

$0.5 \leq \frac{bw}{h} \leq 1$, where h= 60cm

$0.5 * 60 \leq bw \leq 1 * 60 => 30 \leq bw \leq 60$,

Taken bw = 30cm, h=60cm

**c) Determination of width of flange**

For the section of T beam

$$\mathbf{bf} \leq \begin{cases} \frac{1}{3}\text{ of the beam span} = \frac{1}{3}(700) = 233.3\text{cm} \\ \frac{1}{2}\text{ of the distance between beams} = \frac{500}{2} = 2520\text{cm} \\ 12.\text{hf} + \text{bw (for T section)} = (12 * 15) + 30 = 210\text{cm} \end{cases}$$

**d) Load calculation**

**Dead load**

Additional dead load:

Floor finish =1KN/ m2, Suspended ceiling: 0.5kN/$m^2$

**Total additional (Unfactored) g=1.5N / $m^2$**

**Live load Vn for commercial building** Vn=4kN/ $m^2$

Wall load appield on slab= 0.2*2.9*1*18=10.44Kn/spm

Wall finishes load applied on slab=0.03*2.9*1*20*2=3.48kN/sqm

Total=10.44+3.48=13.92kN/sqm

**Dead load from secondary beam 1 SPAN 1**

Load from beam = 0.2x0.5x3.5x24=8.4 kN

Unfactored dead load of the slab= 7.14/1.4=5.1 KN/$m^2$

Dead load from slab= 6.025x5.1=30.72kN

Wall load appield on slab= 0.2*2.9*1*18=10.44 Kn/m

Wall finishes load applied on slab=0.03*2.9*1*20*2=3.48Kn/m

Total dead load= 53.04kN

Total live load= 6.025x4kN= 24.1kN

Table 4. 1: Load calculation for beam 1

| Items | span1 | span2 | span3 | span4 |
|---|---|---|---|---|
| Length(m) | 7 | 5 | 6 | 6 |
| Surface($m^2$) | 12.5 | 11.28 | 16.5 | 16.5 |
| g | 23.02kN/m | 25.42kN/m | 28kN/m | 28kn/m |
| v | 7.14kN/m | 9.024kN/m | 11KN/m | 11kn/m |

NB: g= (dead load from the slab*influence area + load from wall)/length of the beam

v=slab live load*influence area/length of the span

Table 4. 2: inputs of design parameter of the beam

| | |
|---|---|
| Fcu (MPa) | 25 |
| Fy (MPa) | 450 |
| Fyv (MPa) | 250 |
| % Redistribution | 0 |
| Downward/Optimized redistr. | D |
| Cover to centre top steel(mm) | 25 |
| Cover to centre bot.steel(mm) | 25 |
| Dead Load Factor | 1.4 |
| Live Load Factor | 1.6 |
| Density of concrete (kN/m3) | 24 |
| % Live load permanent | 25 |
| Ø (Creep coefficient) | 2 |
| Ecs (Free shrinkage strain) | 300E-6 |

The table 4.2 shows the paremeter to be used when you get total load which can applied on the beam. The parameter help toget the size and the number of steel contain in the beam

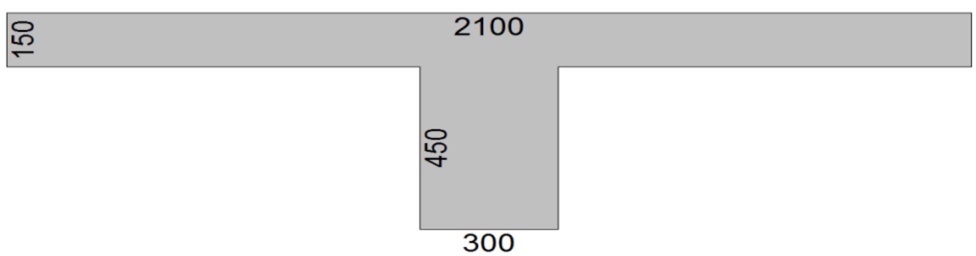



Figure 4. 6**:** The cross section of the beam

Fig.4.8 shows the cross section of the beam and all dimension of our beam, height of beam 600mm, flange width 2100mm and breath of web 300mm.

e) **Beam supports**

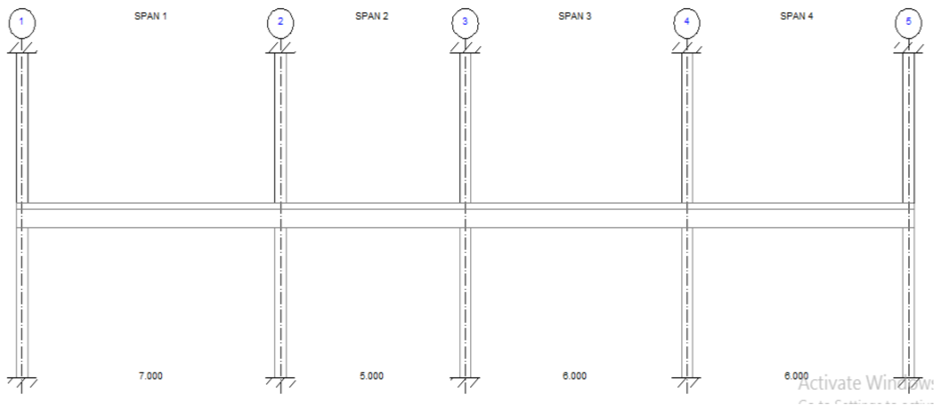



Figure 4. 7**:** Beam supports of the beam

Fig.4.9 shows the distance between the beam with their support and each distance between the spans show contain on the floor plan, these dimensions shown on this figure are the same as the dimension of floor plan.

**f) Beam loading**

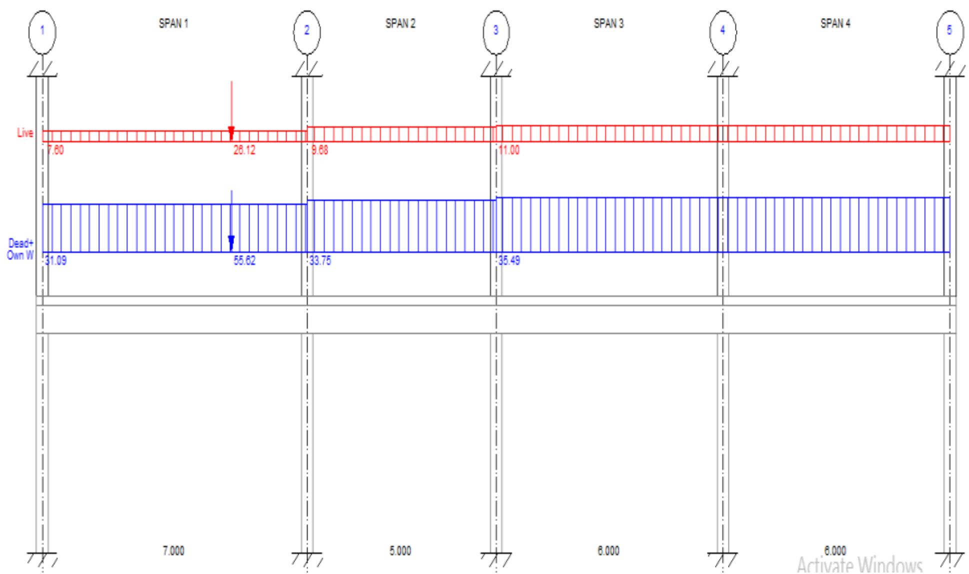



Figure 4. 8**:** Beam loads of the beam

Fig.4.10, this figure shows how the load are distributed to the structure, the load divided into two party, First party o is dead load which is self weight of structure and other load is live load which is the load come from tomporary structure,Furnitures and uses.

**g) Deflection**

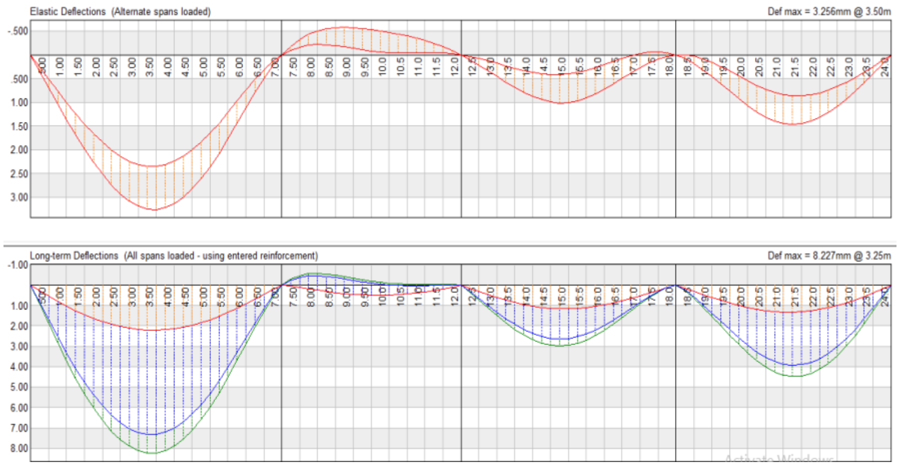



Figure 4. 9**:** Deflection of the beam

Fig.4.11, this figure shows long term deflection which has the long-term deflection of 8.22mm@3.25mm, and elastic deflections which has the maximun deflections of 3.25mm@3.5m

Ultimate deflection checking: Lmax/500 =7000/500=14mm

Max. long-term deflection = 8.22mm < 14mm………………...Ok (h= 60mm OK.)

### h) Shear and bending moment

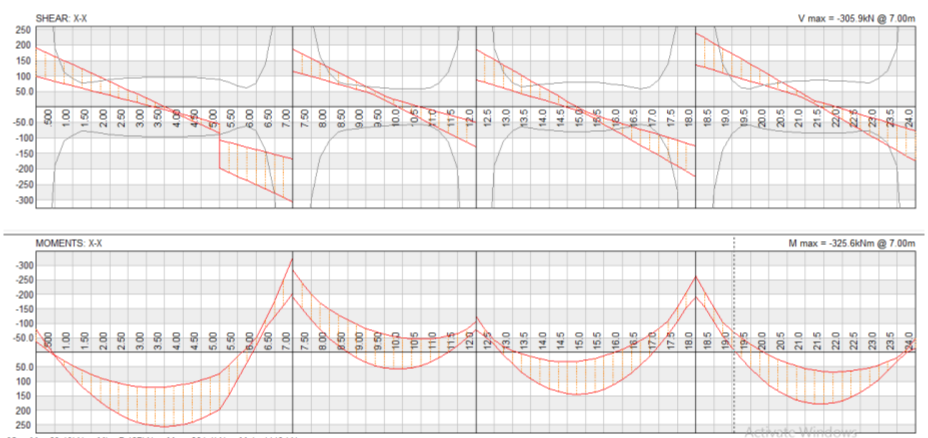



Figure 4. 10**:** Shear and bending moment of the beam

Fig 4.12, this figure shows the beam Shear and bending moment of the beam, this beam has Vmax=-305KN@7m and Mmax=-325KNm@6.86m

### i) Steel reinforcements

Table 4. 3**:** Beam reinforcement of the beam

| Bars | Mark | SC | Span | Offset | Length | Hook | Layer |
|---|---|---|---|---|---|---|---|
| 3Y12 | A | 34 | 1 | -0.205 | 0.825 | L | T |
| 4Y20 | B | 34 | 1 | -0.125 | 11.985 | L | T |
| 4Y25 | C | 34 | 1 | -0.055 | 12.675 | L | B |
| 3Y25 | D | 20 | 2 | -1.350 | 2.700 | L | T |
| 1Y25 | E | 20 | 2 | 4.000 | 2.000 | L | T |
| 4Y20 | F | 34 | 2 | 4.160 | 12.875 | R | T |
| 4Y25 | G | 34 | 2 | 4.460 | 12.455 | R | B |
| 2Y25 | H | 20 | 4 | -1.350 | 2.700 | L | T |
| 2Y12 | I | 34 | 4 | 5.050 | 0.925 | R | T |
| 2Y25 | J | 20 | 1 | 1.310 | 4.500 | L | B |

Table 4.3, this table shows length of steel reinforcements which are shown in the following figure 4.13, this figure shows steel arrangement in beam with 4 ϕ 20mm on the top, 4 ϕ 25mm at the bottom,2 ϕ 20mm at the side , stirrups of ϕ 8mm.

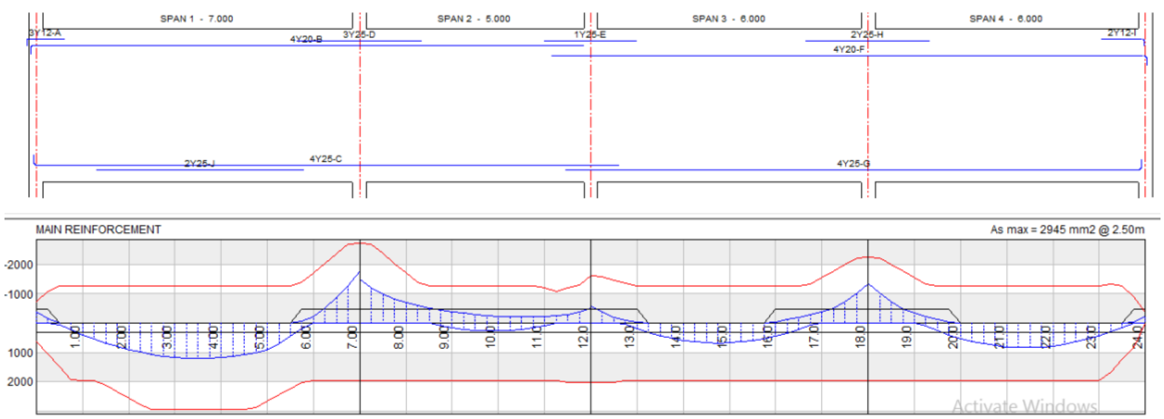



Figure 4. 11**:** Main reinforcement of the beam

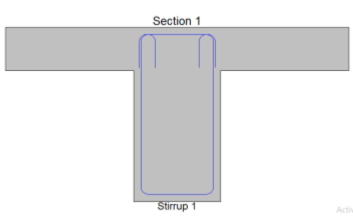



Figure 4. 12**:** Stirrups cross section.

Fig 4.14, this figure shows haw the stirrup are fixed to the main bars beam and this stirrup are needed in order to help the main bars of the beam in their position .

Table 4. 4**:** Stirrups of the beam

| Stirrup Number | Spacing | Span | Offset | Length (m) |
|---|---|---|---|---|
| 1 | 200 | 1 | 0.250 | 4.490 |
| 1 | 100 | 1 | 4.880 | 1.870 |
| 1 | 200 | 2 | 0.250 | 16.785 |

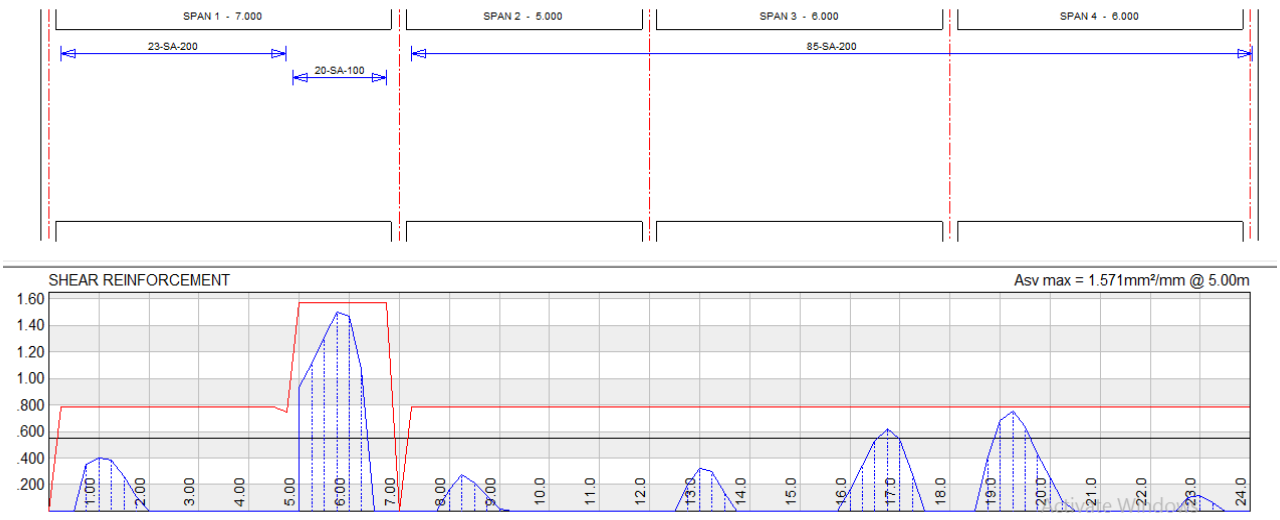



Figure 4. 13: Shear reinforcement of the beam

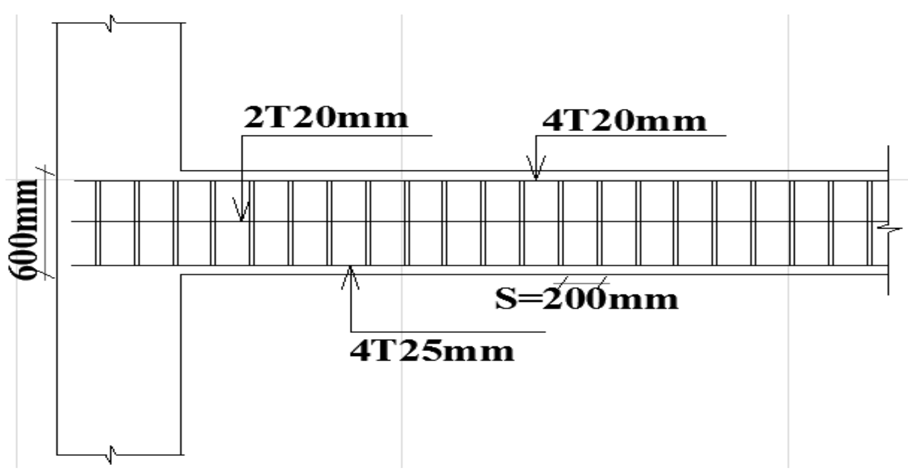



Figure 4. 14**:** Longitudinal section of the steel reinforcement of the beam

**Discussion**

According to Park & Paulay, (1975), beam is a horizontal structural element that is capable of withstanding loads primarily by resisting bending. The design steel bars calculations on top and bottom the aim was to know the number and diameter of steel which would resist on the applied load.

#### 4.2.2.2. Beam (ii-ii) design

Method of calculation

The beams are analysed and dimensioned to resist the actions and reaction which are applied.

With: Lmax –Effective span.

F – Design loads: 1.4 $G_K$+1.6 $Q_K$.

**a. Computation for the depth of the beam (h)**

$\frac{\text{Lmax}}{8} \leq \text{h} \leq \frac{\text{Lmax}}{15}$, Where Lmax is the largest span between two consecutive beams from the structural plan.

$\frac{500}{8} \leq \text{h} \leq \frac{500}{15}$ =62.5 ≤ h ≤ 33.3, Taken h = 60cm

**b. Computation for the breath of the beam (bw)**

$0.5 \leq \frac{\text{bw}}{\text{h}} \leq 1$, where h= 60cm

$0.5 * 60 \leq \text{bw} \leq 1 * 60 => 30 \leq \text{bw} \leq 60$,

Taken bw = 30cm, h=60cm

**c. Determination of width of flange**

For the section of T beam:

$$\textbf{bf} \leq \begin{cases} \frac{1}{3} \text{of the beam span} = \frac{1}{3}(500) = 166.6\text{cm} \\ \frac{1}{2} \text{ of the distance between beams} = \frac{440}{2} = 220\text{cm} \\ 12.\text{hf} + \text{bw (for T section)} = (12 * 15) + 30 = 210\text{cm} \end{cases}$$

For the section of L beam:

$$\textbf{f} \leq \begin{cases} \frac{1}{3} \text{of the beam span} = \frac{1}{3}(500) = 166.6\text{cm} \\ \frac{1}{2} \text{ of the distance between beams} = \frac{440}{2} = 220\text{cm} \\ 6\text{hf} + \text{bw (for L section)} = (6 * 15) + 30 = 120\text{cm} \end{cases}$$

## f. Load calculation

**Dead load**

Additional dead load:

Floor finish =1KN/ m2, Suspended ceiling: 0.5kN/$m^2$

**Total additional (Unfactored) g=1.5N / $m^2$**

**Live load Vn for commercial building** Vn=4kN/ $m^2$

Wall load appield on slab= 0.2*2.9*1*18=10.44Kn/spm

Wall finishes load applied on slab=0.03*2.9*1*20*2=3.48kN/sqm

Table 4. 5**:** loads calculation for beam 2

| Items | span1 | span2 | span3 | span4 | span5 |
|---|---|---|---|---|---|
| Length(m) | 5 | 5 | 5 | 5 | 5 |
| Surface($m^2$) | 9.33 | 6.67 | 9.33 | 6.67 | 9.33 |
| g (KN/m) | 23.43 | 20.72 | 23.43 | 20.72 | 23.43 |
| v (KN/m) | 7.46 | 5.33 | 7.46 | 5.33 | 7.46 |

NB: g= (dead load from the slab*influence area + load from wall)/length of the beam

v=slab live load*influence area/length of the span

Table 4. 6: inputs of design parameter of the beam

| | |
|---|---|
| Fcu (MPa) | 25 |
| Fy (MPa) | 450 |
| Fyv (MPa) | 250 |
| % Redistribution | 0 |
| Downward/Optimized redistr. | D |
| Cover to centre top steel(mm) | 25 |
| Cover to centre bot.steel(mm) | 25 |
| Dead Load Factor | 1.4 |
| Live Load Factor | 1.6 |
| Density of concrete (kN/m3) | 24 |
| % Live load permanent | 25 |
| Ø (Creep coefficient) | 2 |
| Ecs (Free shrinkage strain) | 300E-6 |

Table 4.6 shows the paremeter to be used when you get total load which can applied on the beam. The parameter help toget the size and the number of steel contain in the beam


Figure 4. 15**:** The cross section of the beam

Fig.4.17 this figure shows the cross section of the beam and all dimension of the beam, height of beam 600mm, breath of web 300mm.

**g. Beam supports**

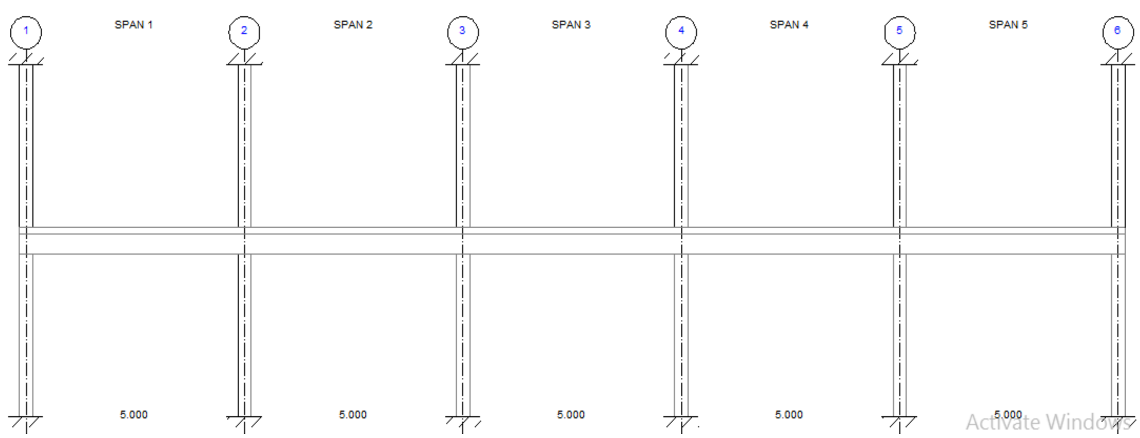



Figure 4. 16**:** Beam supports of the beam

Fig.4.18 shows the distance between the beam with their support and each distance between the spans show contain on the floor plan, these dimensions shown on this figure are the same as the dimension of floor plan.

### h. Beam loading

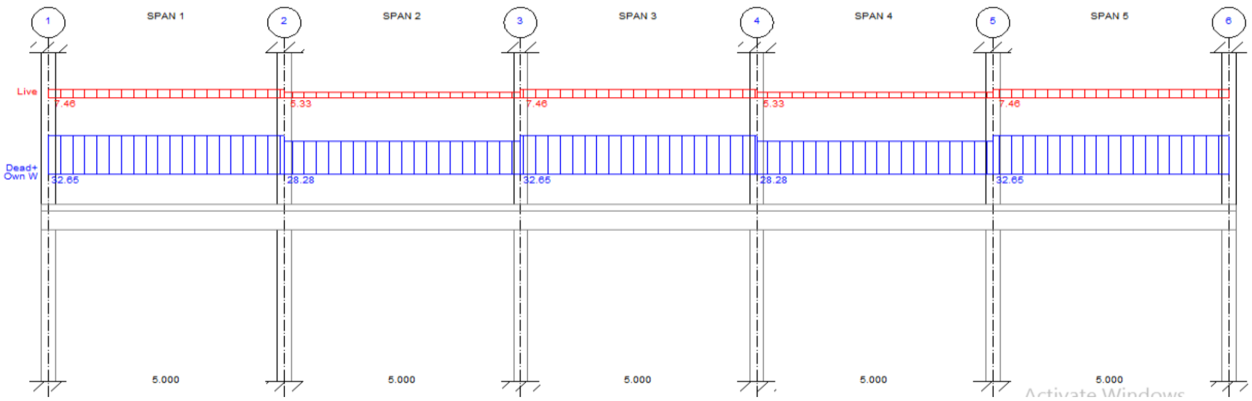



Figure 4. 17**:** Beam loads of the beam

Fig.4.19, this figure shows how the load are distributed to the structure, the load divided into two party, First party o is dead load which is self-weight of structure and other load is live load .

### i. Deflection

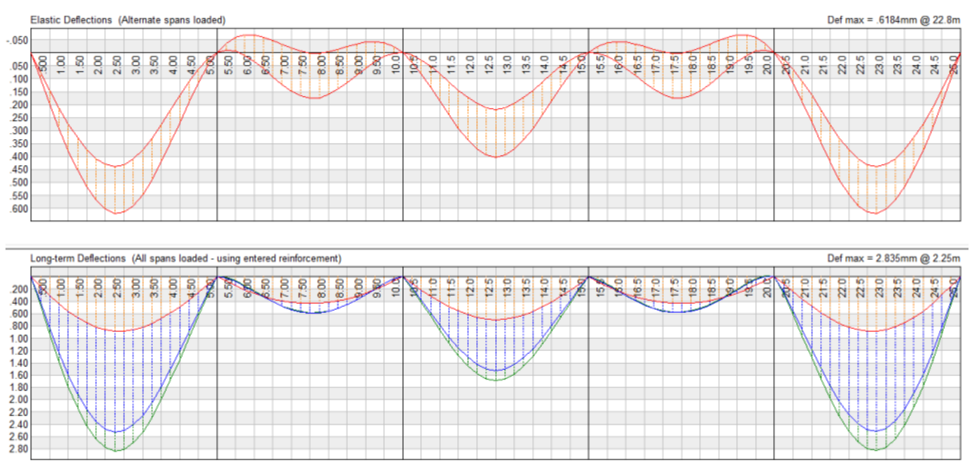



Figure 4. 18**:** Deflection of the beam

Fig.4.20, this figure shows long term deflection which has the long term deflection of 2.5mm@2.25m, and elastic deflections which has the maximun deflections of 6.14mm@2.2m

Ultimate deflection checking: Lmax/500 =5000/500=10mm

Max. long-term deflection = 2.8mm < 10mm………………...Ok (h= 60mm OK.)

### j. Shear and bending moment

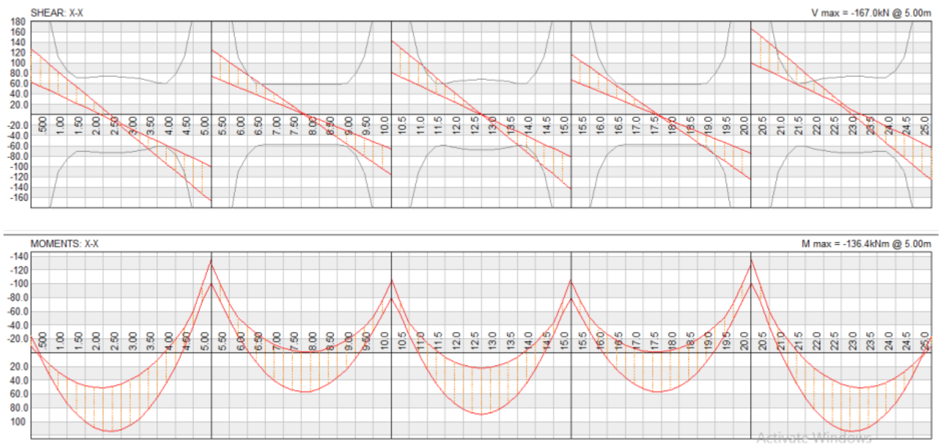



Figure 4. 19: Shear and bending moment of the beam

Fig 4.21, this figure shows the beam Shear and bending moment of the beam, This beam has Vmax=-167KN@5m and Mmax=-136.4KNm@5m.

### k. Steel reinforcements

Table 4. 7**:** Beam reinforcement of the beam

| Bars | Mark | SC | Span | Offset | Length | Hook | Layer |
|---|---|---|---|---|---|---|---|
| 1Y20 | D | 20 | 2 | -1.600 | 2.700 | L | T |
| 2Y12 | E | 20 | 2 | 4.300 | 1.485 | L | T |
| 4Y20 | F | 20 | 3 | -0.200 | 10.400 | L | B |
| 4Y16 | G | 34 | 4 | 4.750 | 5.500 | R | T |
| 2Y12 | H | 20 | 3 | 4.215 | 1.485 | L | T |
| 1Y20 | I | 20 | 4 | 3.900 | 2.350 | L | T |
| 4Y20 | J | 34 | 4 | 4.835 | 5.325 | R | B |
| 2Y12 | K | 34 | 5 | 4.100 | 1.025 | R | T |
| 4Y16 | B | 20 | 2 | 4.620 | 10.630 | L | T |

Table 4.7, this table shows length of steel reinforcements which are shown in the following figure 23, this figure shows steel arrangement in beam with 4 ϕ 16mm on the top, 4 ϕ 20mm at the bottom,2 ϕ 16mm at the side ,stirrups of ϕ 8mm.

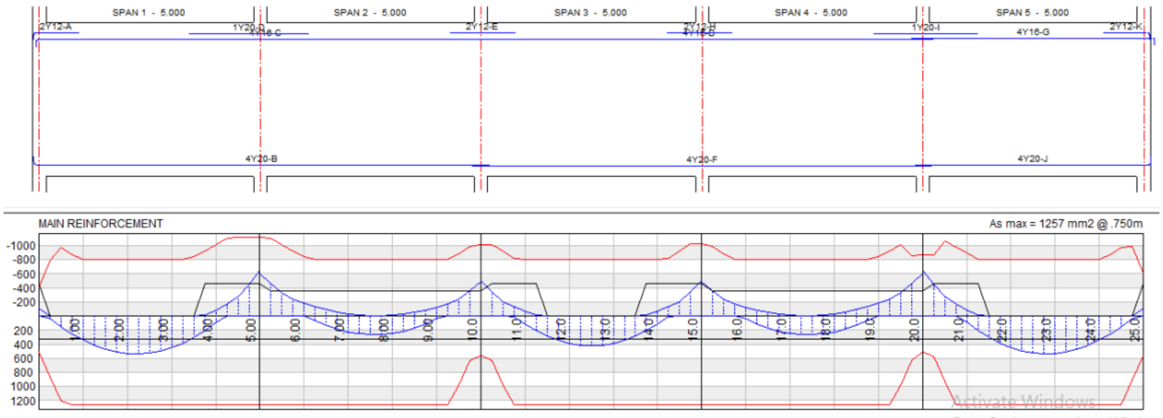



Figure 4. 20: Main reinforcement of the beam


Figure 4. 21**:** Stirrups cross section

Fig 4.23, this figure shows haw the stirrup are fixed to the main bars beam and this stirrup are needed in order to help the main bars of the beam in their position .

Table 4. 8**:** Stirrups of the beam

| Stirrup Number | Spacing | Span | Offset | Length (m) |
|---|---|---|---|---|
| 1 | 200 | 1 | 0.250 | 24.595 |

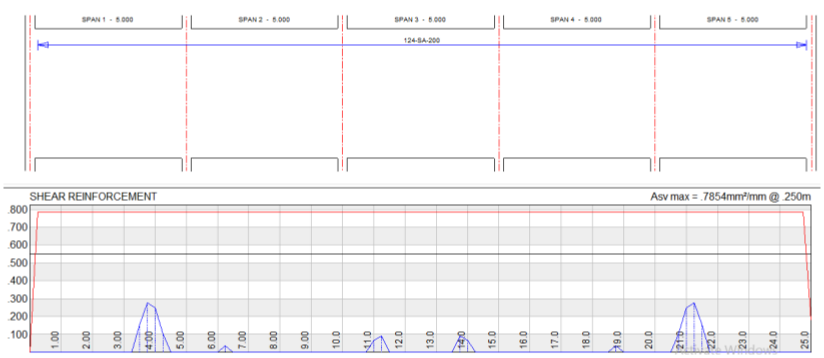



Figure 4. 22: Shear reinforcement of the beam

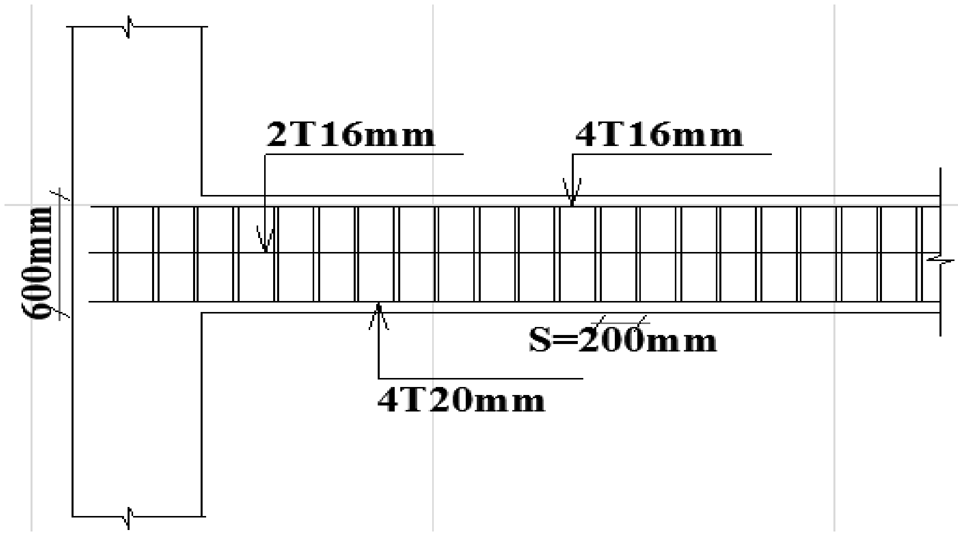



Figure 4. 23: Longitudinal section of the steel reinforcement of the beam

**Discussion**

According to Park & Paulay, (1975), beam is a horizontal structural element that is capable of withstanding loads primarily by resisting bending. The design steel bars calculations on top and bottom the aim was to know the number and diameter of steel which would resist on the applied load.

**4.2.3. Design of columns**

A column is a vertical rigid structure element which carries the axial loads from roof, beams and slabs, it occurs as a compression member which transmits the applied loads acting on the structure down to the foundation.

**a. Columns classification**

Based on the slenderness ratio (λ), columns are categorized as follow:

**Short column:** When slenderness ratio (λ) is less than 14.3

**Long column:** when slenderness ratio (λ) is greater than 14.3

Where: $\lambda = \frac{Lo}{a}$

**Lo:** is the effective height of the column

Lo=0.7H for the interior columns and 0.9H for the exterior columns.

H is the height of the column (one floor).

**a:** is the smallest side of the cross section of the column

**Design of column (E-III)**

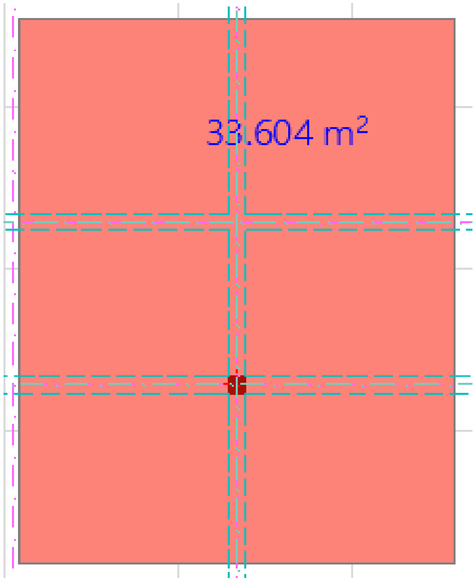



Figure 4. 24: the influence area of the critical column

**b. Loads calculation from TOP FLOOR**

Load calculation is done with area method.

- Cross section of the column 40cm*45cm

- Dead load of column =1.4 x {(0.4x 0.45 x 3.5)} x 24= 16.12kN
- Column finishes =1.4 x(0.4x2+0.45x2) x0.05x3.5x20=7.84kN
- Dead load of the slab = 33.604x7.14 =240kN
- Dead load of the beam = 1.4x0.3x0.6 x (6.7+5+5) x 24= 202 kN
- Dead load of the wall = 1.4x16.7x13.92=325.45KN
- Live load of the slab = 33.604x6.4 =215.06kN
- Loads from the roof=33.604x1=33.604
- **Ground floor loads**

$\mathbf{N_{1}}$= (16.12+7.84) x4 + (240+202+325.45+215.06) x3 + 33.604= 3077KN

- **First floor loads**

$\mathbf{N_{2}}$== (16.12+7.84) x3 + (240+202+325.45+215.06) x2 + 33.604= 2070.50KN

- **Second floor loads**

$N_3$= (16.12+7.84) x2 + (240+202+325.45+215.06) + 33.604= 1064.05KN

- **Third floor loads**

  $N_4$= (16.12+7.84) + 33.604= 57.56KN

**c. Determination of reinforcement**

Column is braced and fixed at both ends. So ß=0.75

**Check for short column.**

Slenderness ratio (λ) = $\frac{Lo}{a}$, **λ**=$\frac{0.7*350}{40}$= 6.12< 14.3 Thus, the column is short.

Table 4. 9**:** Values of $\varphi$

| **λ** | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
|---|---|---|---|---|---|---|---|---|
| **φ** | 0.92 | 0.91 | 0.89 | 0.86 | 0.82 | 0.77 | 0.71 | 0.64 |

With **λ=** 6.12, we use φ = 0.92

As= $\frac{\frac{N}{\varphi}-Rb*Ab}{Rs}=\frac{\frac{3077}{0.92}-1.4*40*45}{40}$ = 20.6cm$^2$

As= 20.6cm$^2$ provides 8Ø20mm

Checking the % of reinforcements, it should lie between

As $_{min}$= 0.4%Ab and As $_{max}$= 6%Ab in a vertically casted column

$$\frac{100x2060}{400X450} = 1.44$$

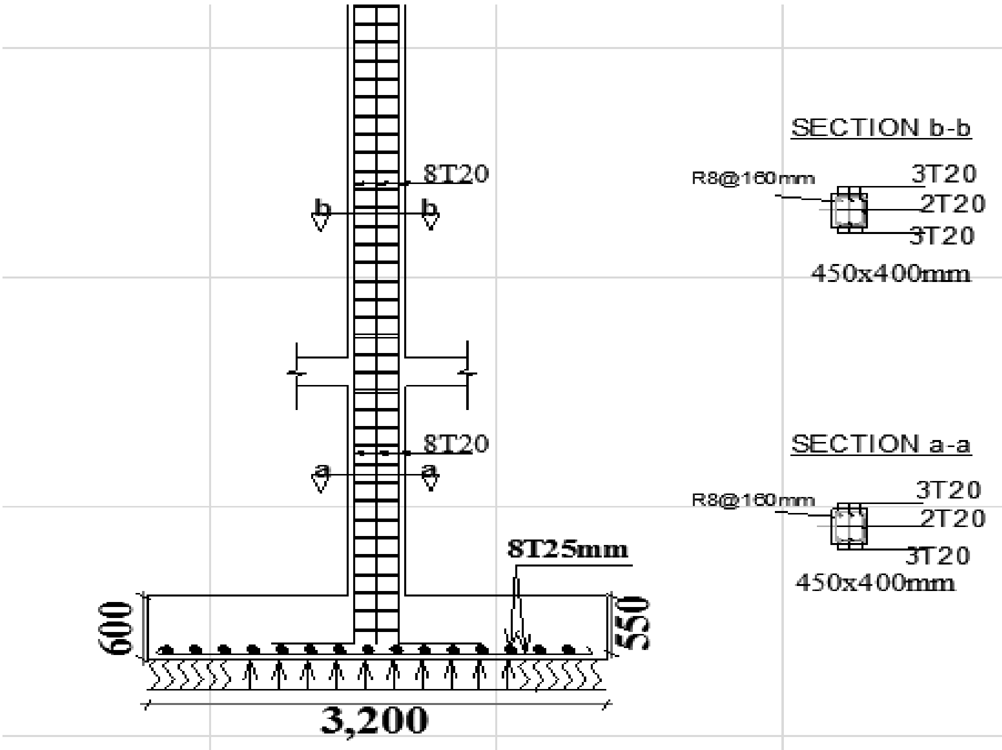



Figure 4. 25**:** Steel arrangement in the column

**Discussion**

According to Park & Paulay, (1975), Column or pillar in architecture and structural engineering is an structural element that transmits, through compression, the weight of the structure above to other structural elements below in, other word column is a compression member compared to the designed column in order the structure has to resist for lateral forces and it has to transmit the weight of the structure above to other structural elements below for this column which has cross section 40x45cm and have 3.5m of length each in all level we have calculated.

According to Mosley et al. (1987), reinforced details standards of columns says that the minimum bars to be arranged in the column are four bars depending on the quantity of load to be applied on it.

#### 4.2.4. Pad foundation design

A building is generally composed of a superstructure above the ground and a structure which forms the foundations below ground. The foundations transfer and spread the loads from a structure's columns and walls into the ground. The safe bearing capacity of the soil must not be exceeded otherwise excessive settlement may occur, resulting in damage to the building and its service facilities. Foundation failure can also affect the overall stability of a structure so that it is liable to slide, to lift vertically or even overturn.

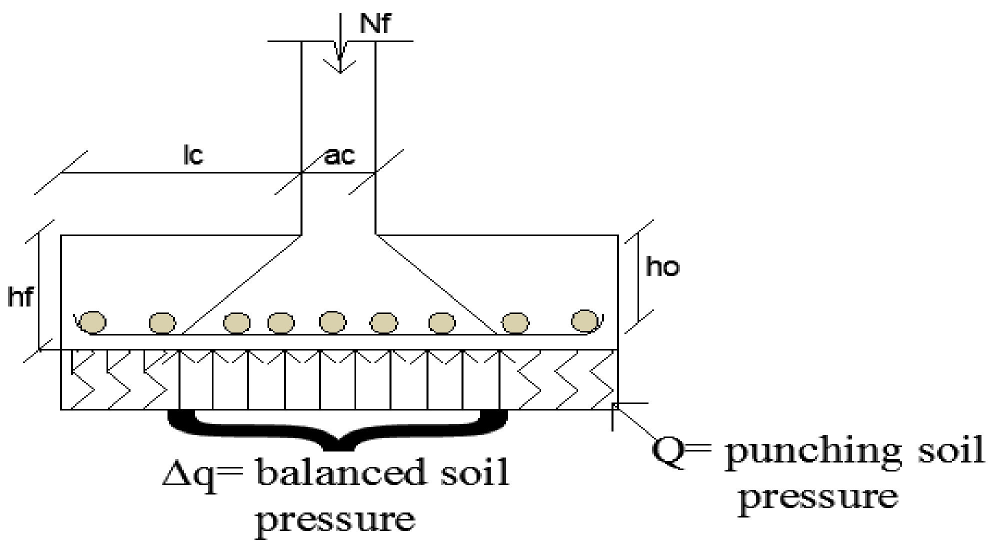



Figure 4. 26: Balancing soil pressure and punching pressure

Nf= is the unit load from the column

ac and bc= length and width of the column

af and bf = length and width of the foundation

Lc= distance from the column to the edge of the foundation

**a. Design of pad foundation for the column**

column design load = 3077KN

Total design live load of the slab = 33.604x6.4 =215.06kN

The vertical load transmitted on the ground at serviceability limit state= 2861.94/1.4+215.06/1.6+( 0.4 x 0.45 x 2) x24= 2187.3KN

Estimated foundation weight + soil on it= 10% * 2187.3= 218.73KN

Total load on the soil= 2187.3+ 218.73= 2406.03vKN

The minimum required area base of the footing = 1.0 × load of the column/Pnet

= 2406.03/240= 10.025 $m^2$

square root of required base area of footing=3.16m

Provide a base B=3.2m   L=3.2m

The foundation has a cross section 320cm*320cm with an assumed thickness of 60cm

Design soil pressure P= $\frac{2406.03}{320*320}$= 0.0234KN/$cm^2$= 234KN/$m^2$

Hf=60cm⇒ho= Hf-concrete cover= 60-5= 55cm

Lc= $\frac{af-ac}{2}$=$\frac{320-40}{2}$= 140cm

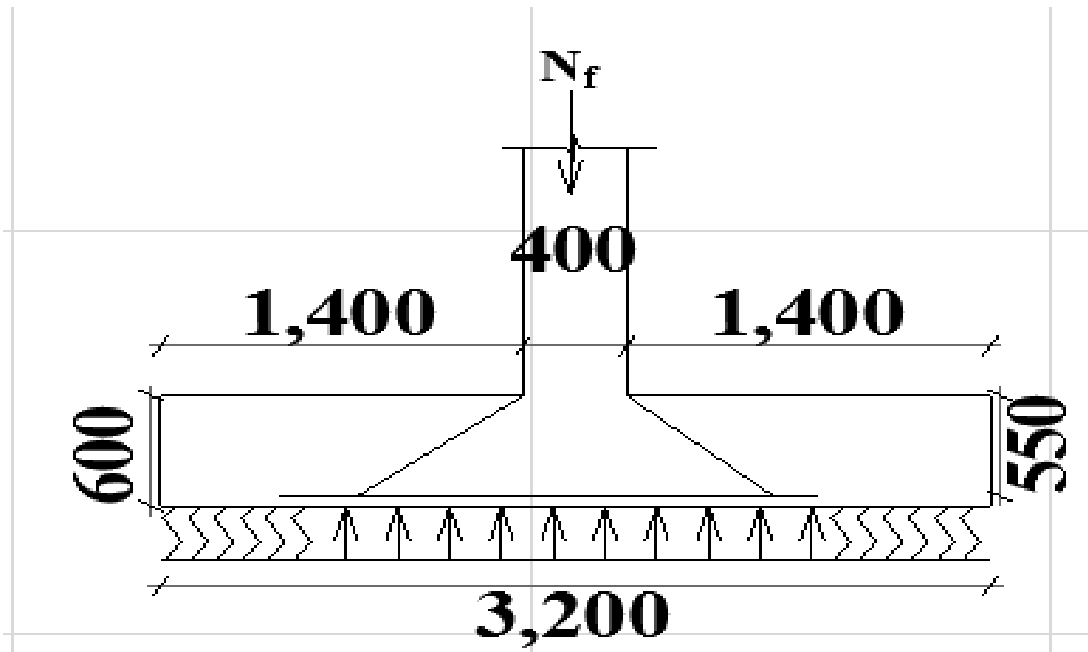



Figure 4. 27**:** Footing dimensions

**b. Checking of punching shear**

Qf= Nf-Dq≤ Rbt*Ab

Um= 2(ac+bc +2ho) = 2(40+45+2*55) =390cm

Ab= Um*ho= 390*55= 21450$cm^2$

Dq= P (ac+2ho) (bc+2ho) = 0.0234 (40+2*55) (45+2*55) = 553.35KN

Qf= 2187.3-553.35= 1631.95KN

Rbt*Ab= 0.09*21450= 1930.5KN

1631.95KN< 1930.5KN…….OK

Meaning that there will be no punching of the column in the foundation and the thickness to be used is 60cm

**c. Calculation of bending moment**

$M_{max}= \frac{P*af}{2}(\frac{bf-bc}{2})^2 = (\frac{0.0234*320}{2}) * (\frac{320-40}{2})^2 = 73382.4KNm$

**d. Required steel reinforcement in the foundation**

$As = \frac{M}{0.9*ho*Rs} = \frac{73382.4}{0.9*55*40} = 37.06cm^2$

Steel reinforcement provided 8ϕ25mm

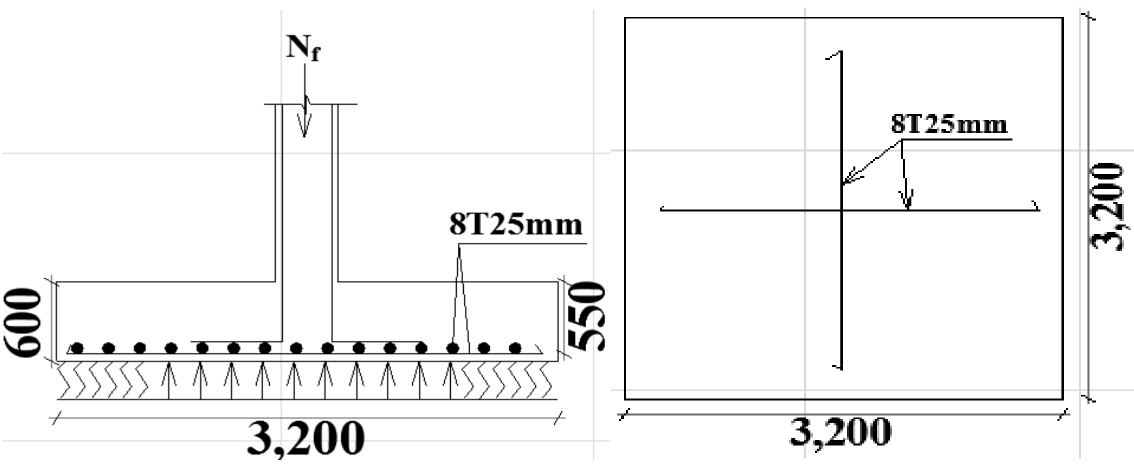



Figure 4. 28**:** Steel reinforcement diagram

**Discussion**

The foundation design aim is the achievement of an acceptable probability that structures being designed would perform satisfactorily during their intended life compare to Park & Paulay, (1975), say that the foundation within appropriate degree of safety, they should sustain all the loads and deformation of normal construction use and have adequate durability and resistance to the effects of misuse and fire that means the foundation reinforced concrete structure founded is safe.

**4.2.5. Design of reinforced concrete stairs case**

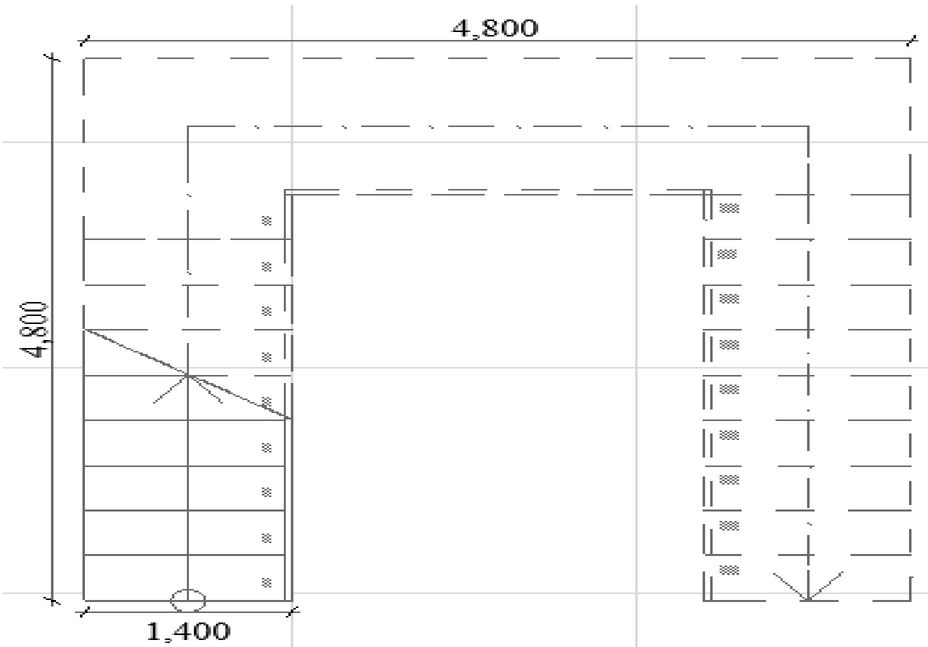



Figure 4. 29**:** Stair

**a. size and loads calculation**

The value of Dl lies between ($\frac{1}{20}$ and$\frac{1}{30}$)*H

Where Dl is the effective depth of the stair, H is the height of the stair.

DI values between $\frac{350}{20}$ =17.5cm and $\frac{350}{30}$ =11.66cm, Taken Dl = 15cm

Height of riser (h) = 18cm

Length of going (g) = 30cm

α = arc tan ($\frac{18}{30}$) = 30º

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

hl= $\frac{\text{dl}}{\cos\alpha} + \frac{\text{h}}{2} = \frac{15}{\cos 30} + \frac{17}{2}$= 25.82cm

ho= hl-concrete clear cover= 25.82-2.5= 23.32cm

Dead loads= 1.4*0.2582*1*1*24= 8.6KN/$m^2$

Load from finishes = 1.4*1.5= 2.1 KN/$m^2$

Live load= 1.6*4= 6.4KN/$m^2$

Total load= 8.6+2.1+6.4= 17.1 KN/$m^2$

Total slab load= 13.54 KN/$m^2$

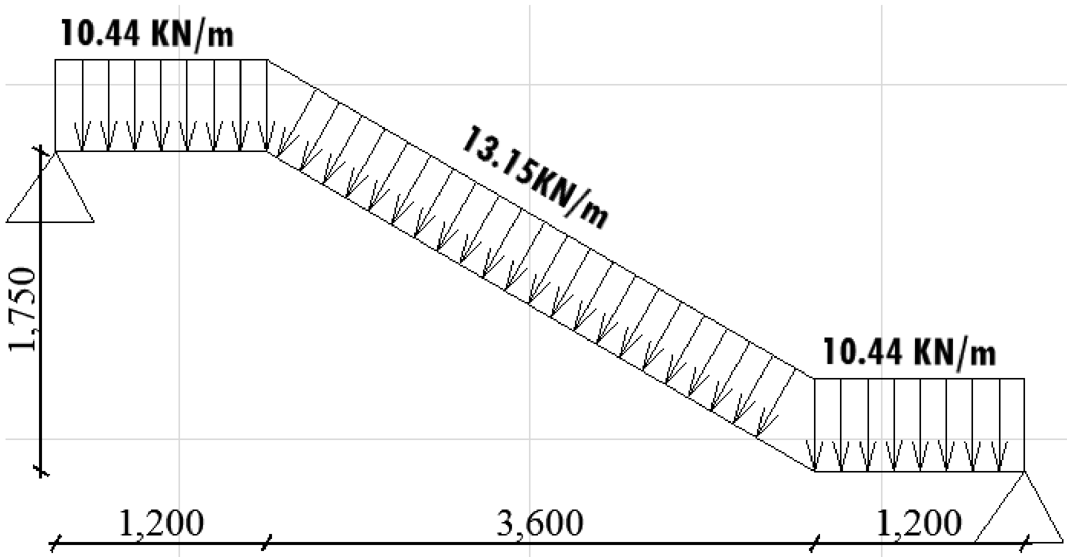



Figure 4. 30**:** Equivalent uniform distributed loads

Fig.4.32, this figure shows how the load are distributed to the stairs according to their span,The span of 1.2m loading 10.44KN/m,span 3.6m loading 13.15KN/m and span of 1.2m loading 10.44KN/m.

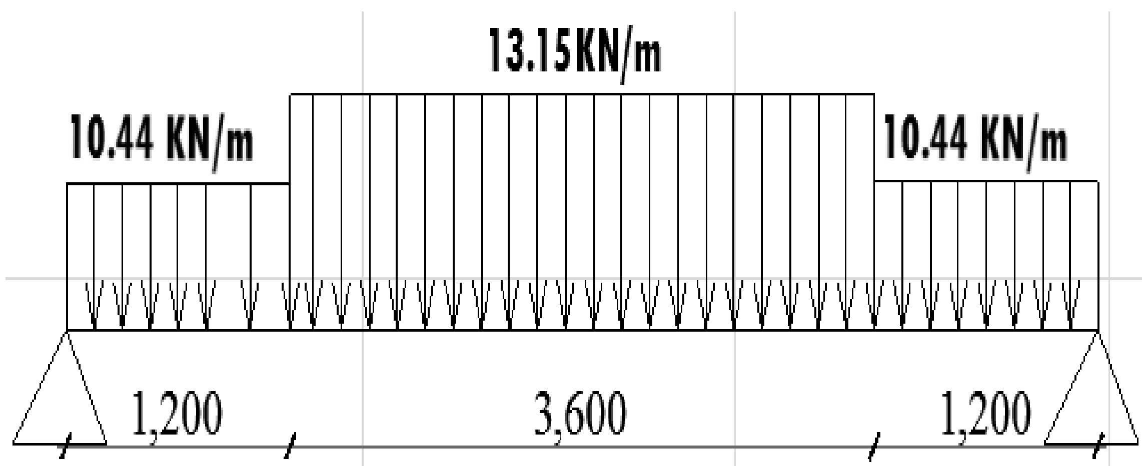



Figure 4. 31**:** Equivalent uniform distributed loads

**b. Calculation of support reaction**

∑ Fv =0;

Ay + By = (10.44*1.20) + (13.15*3.6) + (10.44*1.20) = 77.65KN

∑ MA= 0;

(-10.44*1.20*0.6) - (13.15*3.6*3) - (10.44*1.20*5.8) + (5.4By) =248.5 KN

5.4By = 248.5KN      by =38.82KNm      Ay = 38.82KNm

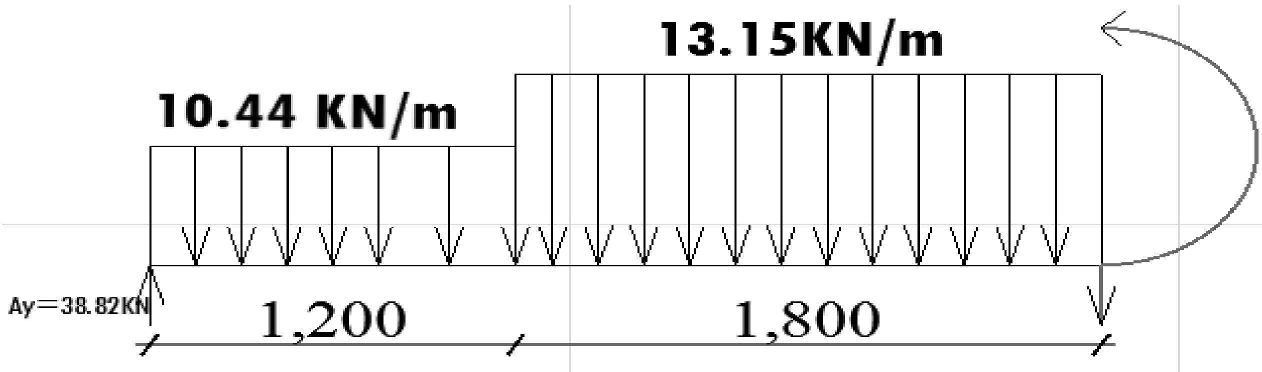



Figure 4. 32**:** Equivalent uniform distributed loads

Fig.4.34, this figure shows uniform distribution lads on the stairs for getting maximum bending moment and reaction acting on stairs, This help to get all calculation needed for to get bending moment.

$\sum \text{Mmax} = 0;$

$M_{max}$ = (38.82*3) - (10.44*1.2*2.4) - (13.15*1.8*0.9) =65.35KN/m

$M_{max}$ = 65.35KN/m

$\alpha m = \frac{M+max}{Rb*ho2*b} = \frac{65.35*100}{1.4*(23.3*23.3)*100} = 0.085$

αm = 0.085 which corresponds to ξ = 0.09; from the table of coefficients related to the design of members subjected to bending moment.

$\xi = 0.09; \xi < \xi_R = 0.393$ (case of singly reinforcements)

η = 0.955

$A_s = \frac{M+}{\eta*ho*Rs} = \frac{65.35*100}{0.955*23.3*40} = 7.34\ cm^2/m$

With this cross section, we use the minimum steel cross section: 7Φ12mm/m

With $\mathbf{A_s}$ = 792mm$^2$/m

The landing width is equals to 15cm as for the slab.

The minimum area of steel reinforcement for hot rolled mild steel:

$A_{s\,min} = \frac{0.24*b*h}{100} = \frac{0.24*100*15}{100} = 3.6cm^2/m$

We provide 4Φ12mm/m with $A_s$ = 452 $mm^2/m$

**c. Steel arrangement (Stair case)**

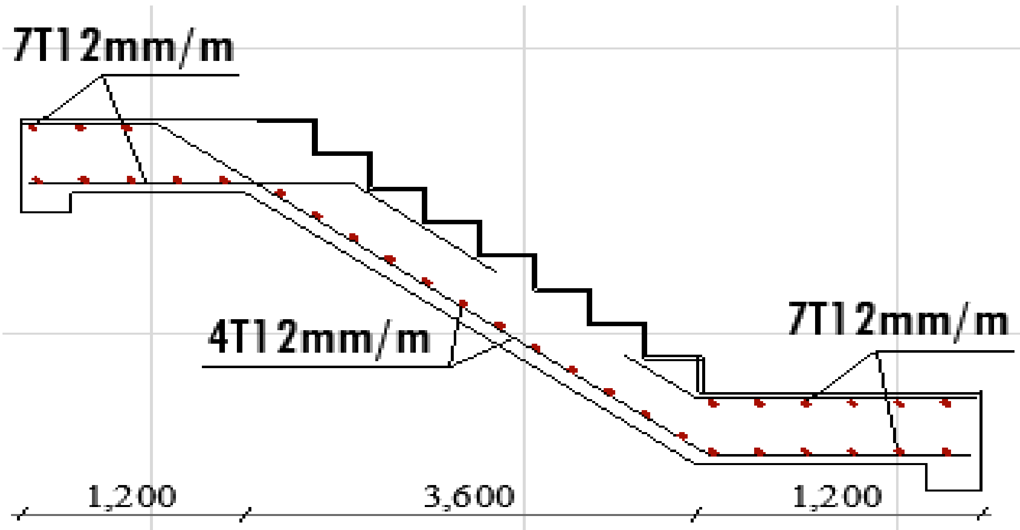



Figure 4. 33**:** Steel arrangement (stair case)

**Discussion**

The design of stairs has followed the euro code standards with manual calculations and formulas for calculating bending moment and shear force, in the results the steel reinforcements have been calculated and found the steel reinforcement arrangements in stairs.

### 4.2.6. Design of reinforced concrete ramp

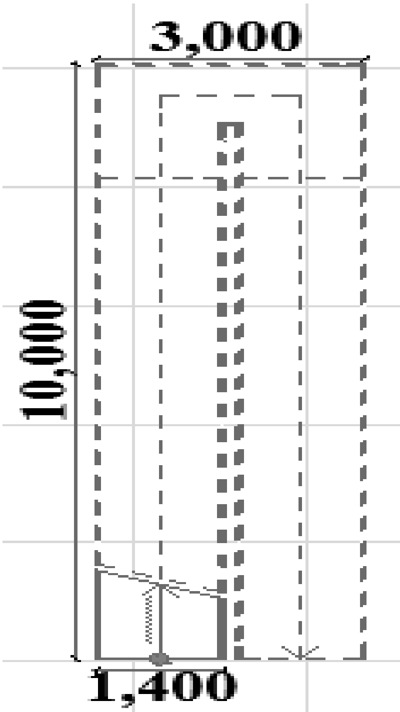



Figure 4. 34**:** Dimension of ramp

**a. size and load calculation**

dl = h ($\frac{1}{20}$ and $\frac{1}{30}$ )

Dl= 350 ($\frac{1}{20}$,$\frac{1}{30}$)

Dl= $\frac{350}{20}$= 17.5cm and $\frac{350}{30}$= 11.6cm the average between these two distance gives us the value of dl= 15cm.

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

α = arc tan (1.75/10)= 9.93°

The ramp that will be designed is supported by two inclined parallel beams supported by two parallel columns and between these columns there is another small beam that connects them.

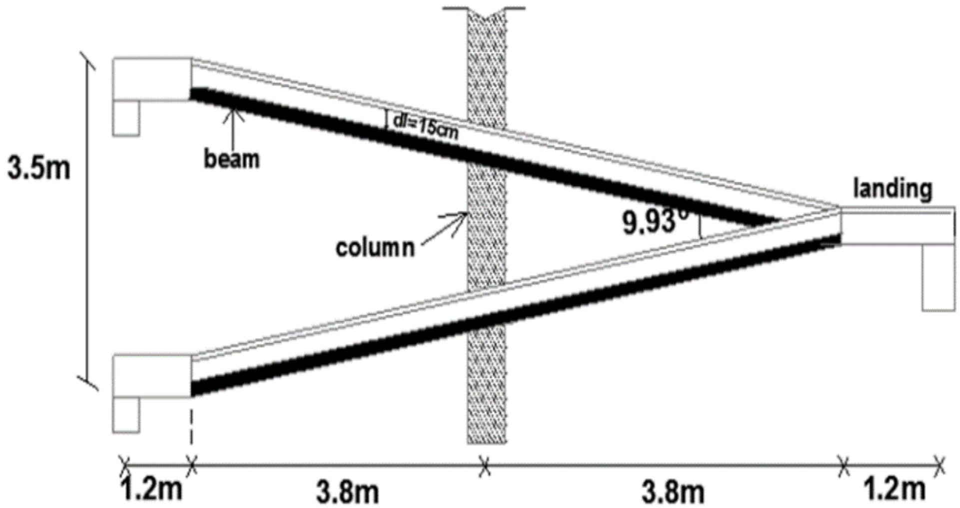



Figure 4. 35**:** Element of Ramp

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

hl= $\frac{\text{dl}}{\cos\alpha} = \frac{15}{\cos 9.93}$ =15.25cm

ho= hl-concrete clear cover= 15.25-2.5= 12.75cm

Dead loads= 1.4*0.1525*1*1*24= 5.12KN/m

Load from finishes = 1.4*1.5= 2.1 KN/$m^2$

Total dead load=5.12+2.1=7.22 KN/$m^2$

Live load= 1.6*3= 4.8 KN/$m^2$

Total load= 5.12+2.1+4.8= 10.06 KN/m

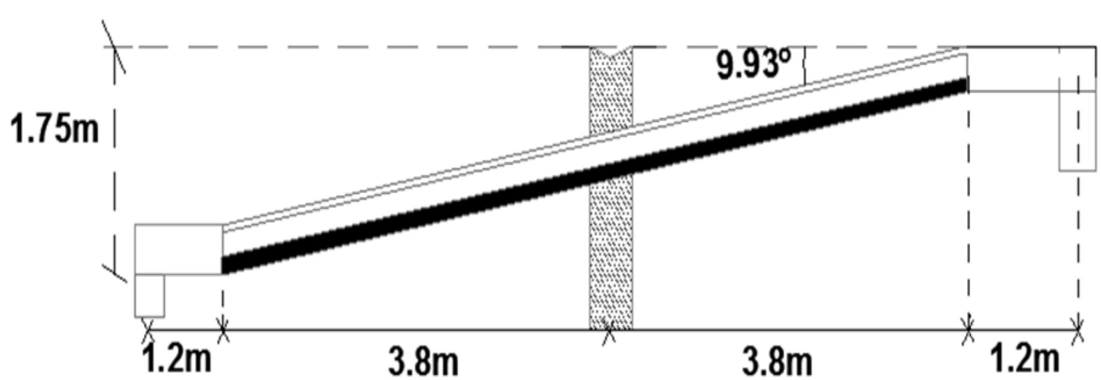



Figure 4. 36**:** The longitudinal cross section of ramp

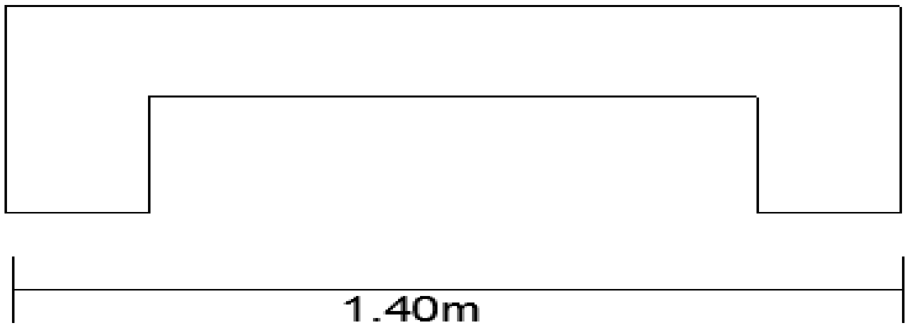



Figure 4. 37**:** The transversal cross section of ramp

The total distributed load that is applied on the slab of the ramp including Permanent load calculated based on the ramp thickness, finishes and live load. in total it is 10.06KN/m

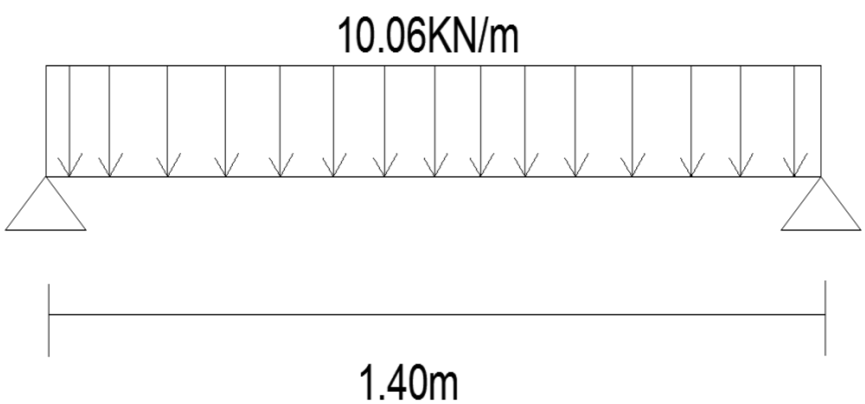



Figure 4. 38**:** The loads distribution on the ramp

**b. Calculation of steel reinforcement in the ramp**

Ly=3.8**,** Lx=1.2

$\frac{ly}{lx}=\frac{3.8}{1.4}=2.7>2$ so it is one way slab

$M_{max}=\frac{wl^2}{8}=\frac{10.06x1.4^2}{8}=2.46KNm$

The maximum bending moment of the ramp is $M_{max}$= 2.46KNm

$\alpha_m=\frac{M^-}{Rb*ho^2*b}=\frac{2.46*100}{1.3*12.75^2*100}=0.012$

From the table of Coefficients related to the design of members subjected to bending moment we have:

$\xi$= 0.02; $\xi<\xi_R$ =0.393 (Case of singly reinforcements)

$\eta$= 0.990

$A_s = \frac{M}{\eta * ho * Rs} = \frac{2.46*100}{0.990*12.75*40} = 0.487cm^2/m$

With this cross section we are going to use the minimum steel cross section Using 5ϕ12mm/m with $A_s$ =5.66cm$^2$/m

**c. design of the two parallel beams**

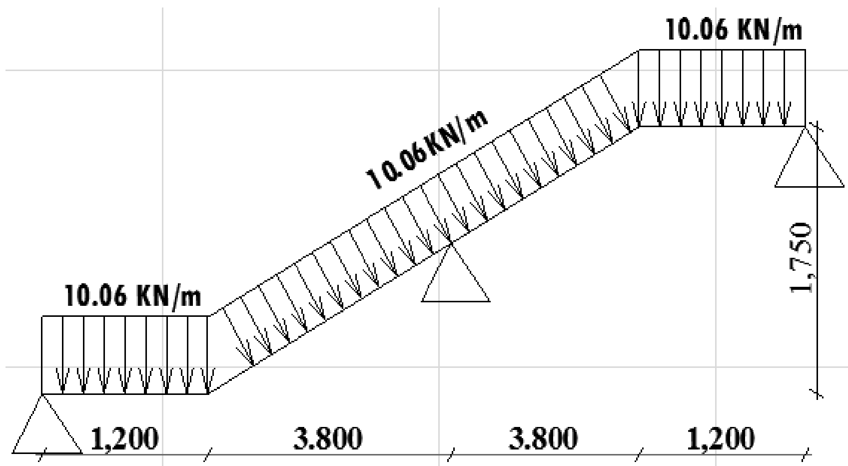



Figure 4. 39**:** Distributed load on the beam

$h_f$ =15.25cm

ho = 15.25-2.5cm= 12.75cm

The load from the slab that will be applied on one beam is the load from the half of the slab because it is a one-way slab then the half of the slab is 0.7m.

**d. Computation for the depth of the beam (h)**

$\frac{Lmax}{8} \leq h \leq \frac{Lmax}{15}$, Where Lmax is the largest span between two consecutive beams from the structural plan.

Lmax=$\sqrt{(1.75^2+3.8^2)}$=4.18~4.20m

$\frac{420}{8} \leq h \leq \frac{420}{15}$ =52.5 ≤ h ≤ 28,  Taken h = 45cm

**e. Computation for the breath of the beam (bw)**

$0.5 \leq \frac{bw}{h} \leq 1$,  where h= 45cm

$0.5 * 45 \leq bw \leq 1 * 45 => 22.5 \leq bw \leq 45$,

Taken bw = 25cm, h=45cm

**f. Determination of width of flange**

For the section of L beam:

$$\mathbf{f} \leq \begin{cases} \frac{1}{3} \text{of the beam span} = \frac{1}{3}(420) = 140\text{cm} \\ \frac{1}{2} \text{ of the distance between beams} = \frac{140}{2} = 70\text{cm} \\ 6\text{hf} + \text{bw (for L section)} = (6 * 15) + 25 = 115\text{cm} \end{cases}$$

**g. Load calculation**

**Dead load**

Additional dead load:

Floor finish =1KN/ m2, Suspended ceiling: 0.5kN/$m^2$

**Total additional (Unfactored) g=1.5N / $m^2$**

**Live load Vn for commercial building,** Vn=4kN/ $m^2$

Table 4. 10**:** loads calculation for beam 2

| Items | span1 | span2 |
|---|---|---|
| Length(m) | 4.2 | 4.2 |
| Surface($m^2$) | 2.94 | 2.94 |
| g (KN/m) | 5.054 | 5.054 |
| v (KN/m) | 2.8 | 2.8 |

NB: g= (dead load from the slab*influence area + load from wall)/length of the beam

v=slab live load*influence area/length of the span

Table 4. 11: inputs of design parameter of the beam

| | |
|---|---|
| Fcu (MPa) | 25 |
| Fy (MPa) | 450 |
| Fyv (MPa) | 250 |
| % Redistribution | 0 |
| Downward/Optimized redistr. | D |
| Cover to centre top steel(mm) | 25 |
| Cover to centre bot.steel(mm) | 25 |
| Dead Load Factor | 1.4 |
| Live Load Factor | 1.6 |
| Density of concrete (kN/m3) | 24 |
| % Live load permanent | 25 |
| Ø (Creep coefficient) | 2 |
| Ecs (Free shrinkage strain) | 300E-6 |

The table 4.11 shows the paremeter to be used when you get total load which can applied on the beam. The parameter help toget the size and the number of steel contain in the beam

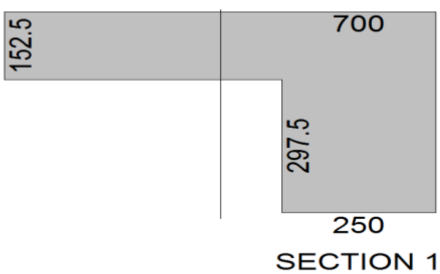



Figure 4. 40**:** The cross section of the beam

### l. Beam supports

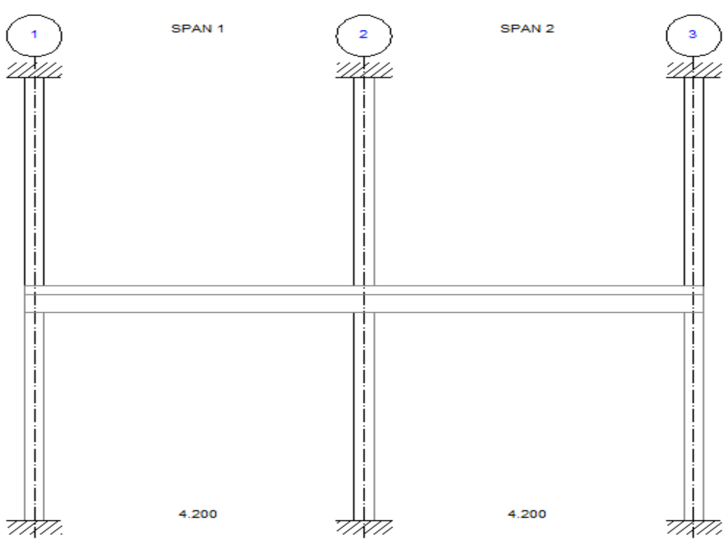



Figure 4. 41**:** Beam supports of the beam

Fig.4.43 shows the distance between the beam with their support and each distance between the spans show contain on the floor plan, these dimensions shown on this figure are the same as the dimension of floor plan

### m. Beam loading

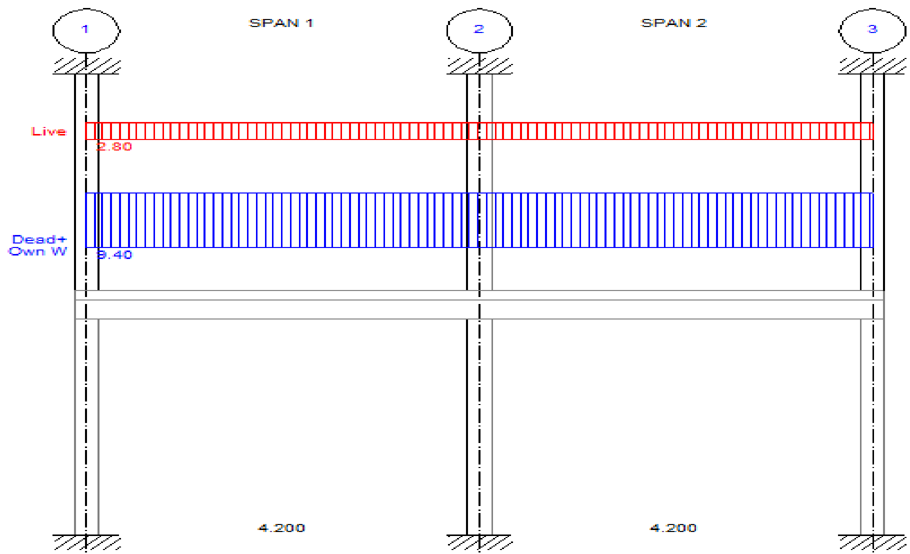



Figure 4. 42**:** Beam loads of the beam

Fig.4.44, this figure shows how the load are distributed to the structure, the load divided into two party, First party is dead load which is self weight of structure and other load is live load.

### n. Deflection

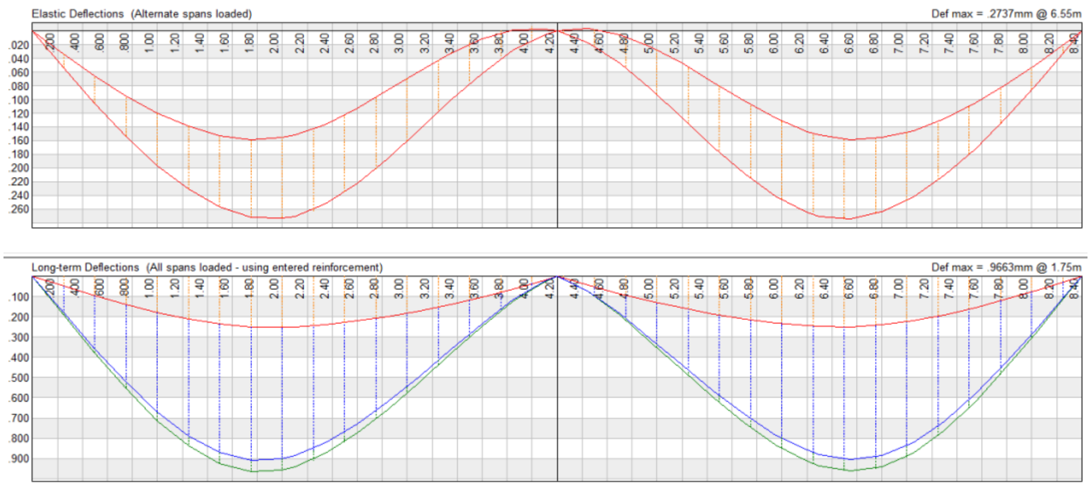



Figure 4. 43**:** Deflection of the beam

Ultimate deflection checking: Lmax/500 =4200/500=8.4mm

Max. long-term deflection = 1mm < 8.4mm………………...Ok (h= 45mm OK.)

## o. Shear and bending moment

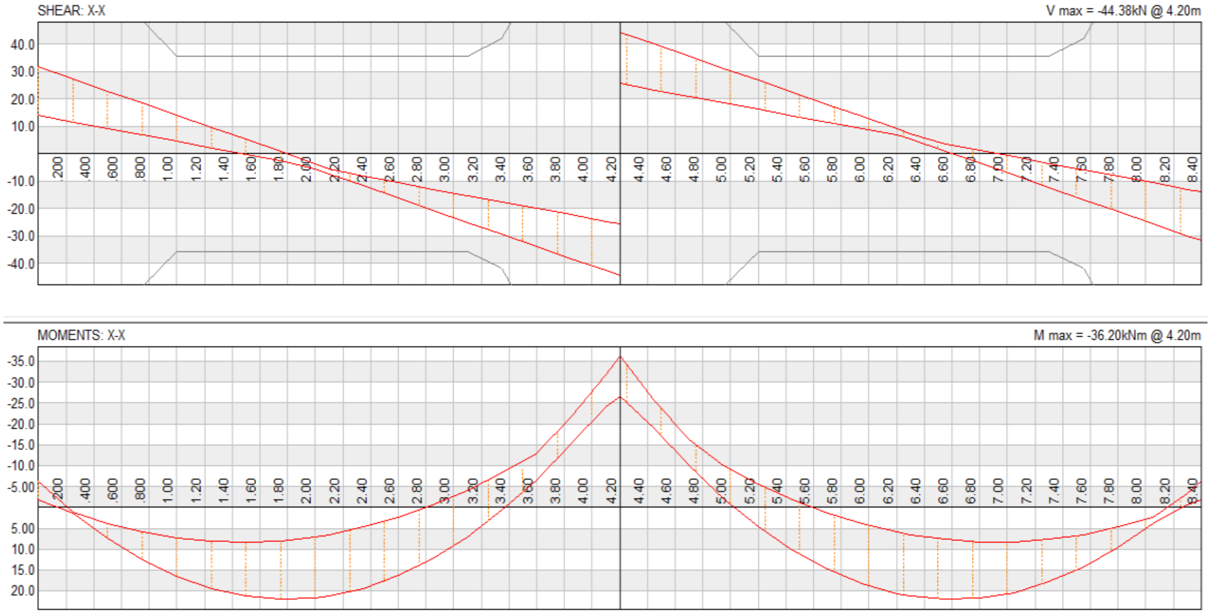



Figure 4. 44: Shear and bending moment of the beam

Fig 4.46, this figure shows the beam Shear and bending moment of the beam, This beam has Vmax=-44.38KNm@4.20m and Mmax=-36.2KNm@4.20m.

## p. Steel reinforcements

Table 4. 12**:** Beam reinforcement of the beam

| Bars | Mark | SC | Span | Offset | Length | Hook | Layer |
|---|---|---|---|---|---|---|---|
| 2Y12 | A | 34 | 1 | -0.100 | 0.800 | L | T |
| 3Y12 | B | 35 | 1 | -0.100 | 8.600 | R | T |
| 3Y12 | C | 35 | 1 | -0.100 | 8.600 | R | B |
| 2Y12 | D | 34 | 2 | 3.400 | 0.775 | R | T |

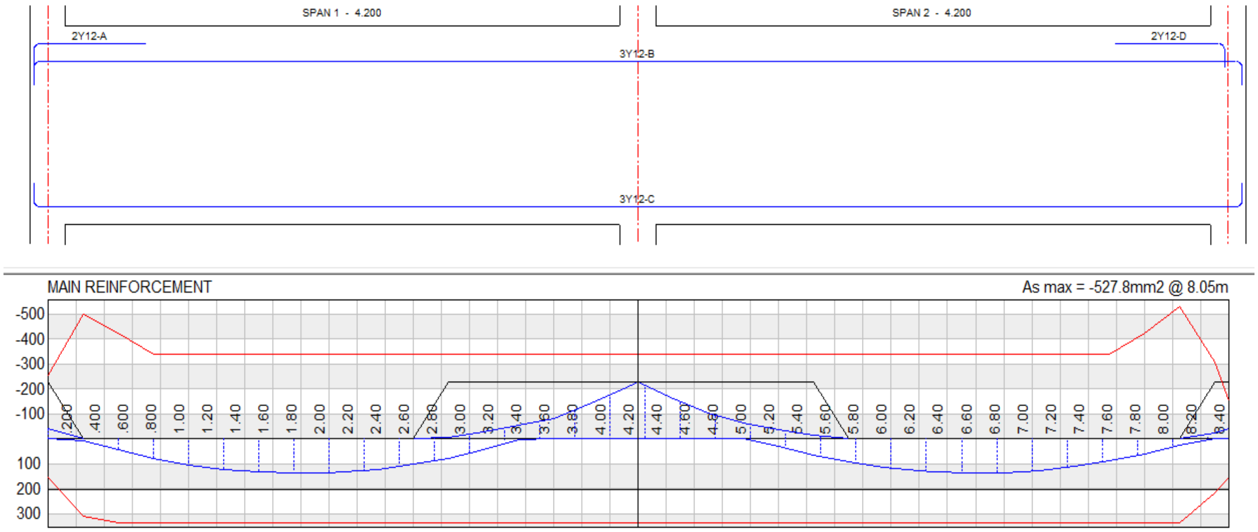



Figure 4. 45: Main reinforcement of the beam

Table 4.12, this table shows length of steel reinforcements which are  shown in the following figure 48, this figure shows steel arrangement in beam with 4 ϕ 16mm on the top, 4 ϕ 20mm at the bottom,2 ϕ 16mm at the side  ,stirrups of ϕ 8mm.

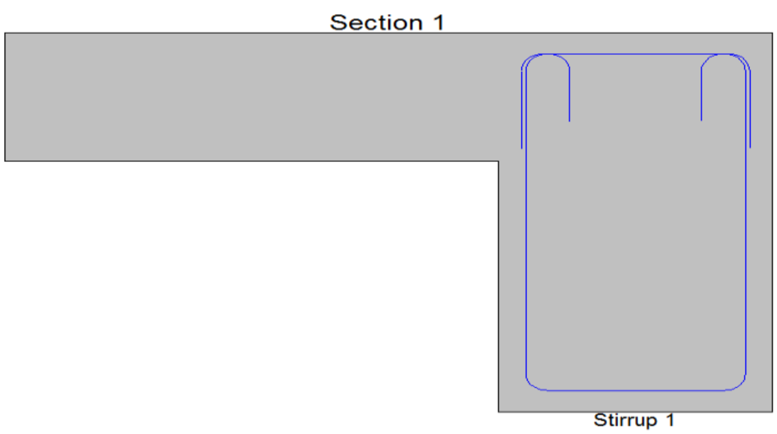



Figure 4. 46**:** Stirrups cross section.

Fig 4.48, this figure shows haw the stirrup are fixed to the main bars beam and this stirrup are needed in order to help the main bars of the beam in their position

Table 4. 13**:** Stirrups of the beam

| Stirrup Number | Spacing | Span | Offset | Length (m) |
|---|---|---|---|---|
| 1 | 200 | 1 | 0.230 | 7.955 |

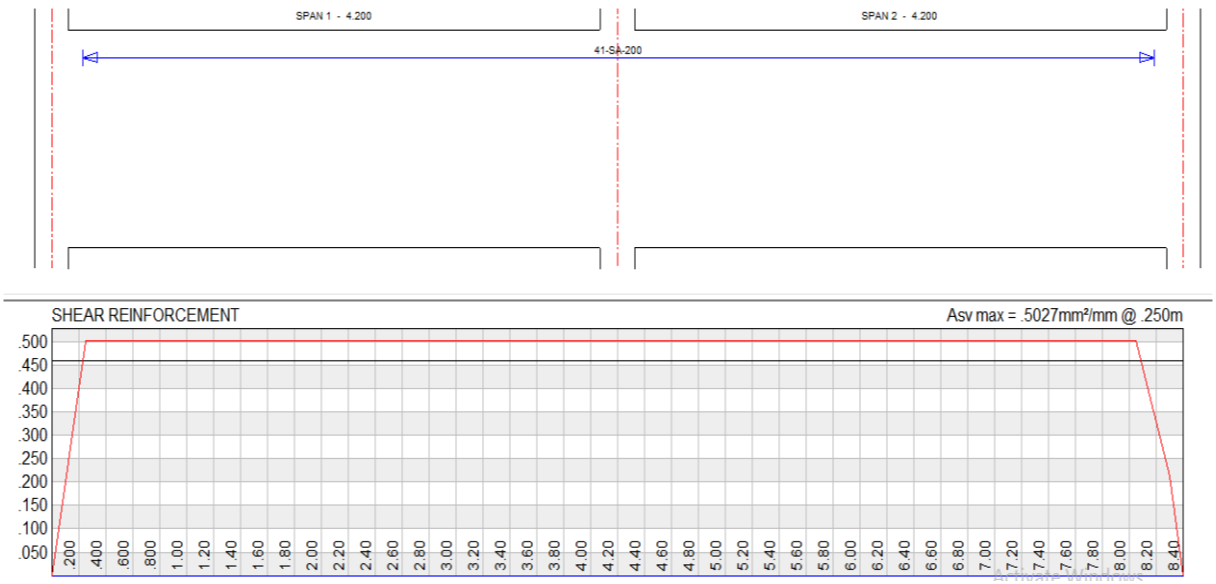



Figure 4. 47: Shear reinforcement of the beam

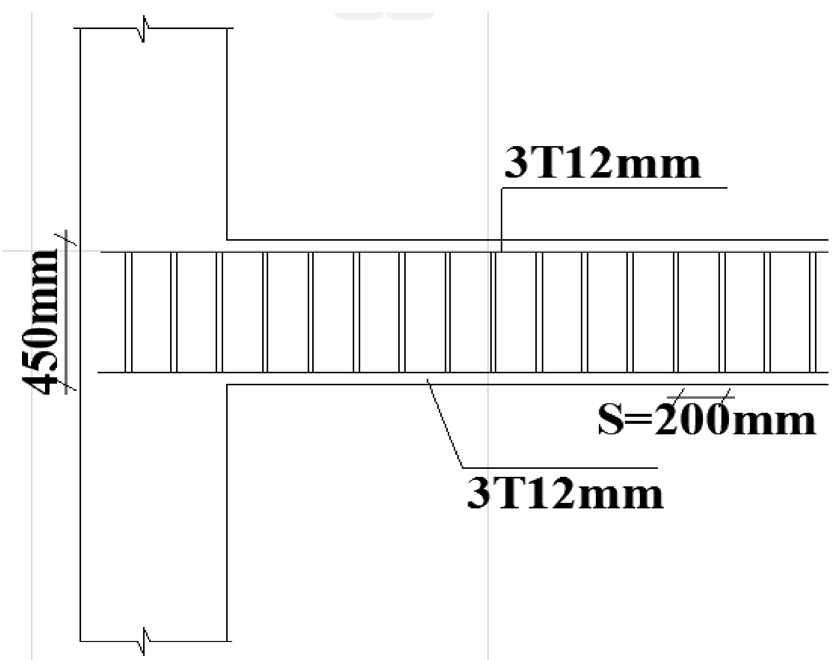



Figure 4. 48: Longitudinal section of the steel reinforcement of the beam

**Discussion**

According to Park & Paulay, (1975), beam is a horizontal structural element that is capable of withstanding loads primarily by resisting bending.  The design steel bars calculations on top and bottom the aim was to know the number and diameter of steel which would resist on the applied load.

# CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

The aim of this project was to do structure design of G+2 apartment building in Gasabo district, Gisozi sector which can contribute more to the reduction of the gap of accommodation building demand, the land problem and also to help the population to improve their standard of living by increasing a number of apartment buildings.

The objectives of this project were achieved through the structure design and cost estimation of G+2 apartment building in Gasabo district, Gisozi sector. The structural design were produced by the use of archiCAD and structure design was analysed using euro code 2 and prokon, dimensions building frame elements and reinforcement area were determined which fulfilled all standards.

## 5.2 Recommendations

The following were recommended

ULK Polytechnic Institute is recommended to increase practices of software studies to facilitate students during their research of final year projects.

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# APPENDICES

Appendix 1**:** Bills of quantity

| **STOREY 1 : GROUND FLOOR** | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| **CODE** | **DESCRIPTION OF WORKS/ACTIVITIES** | **UNIT** | **QUANTITY** | **U.P.** | **T. P.** |
| **I** | **PRELIMINARY WORK** | | | | |
| 1.1 | Plot | m2 | 2,156.81 | 40,000 | 86,272,400 |
| 1.2 | Site Installation | FF | 1 | 1,000,000 | 1,000,000 |
| 1.3 | site cleaning and remove of existing houses | ff | 1 | 1,700,000 | 1,700,000 |
| | **S / TOTAL** | | | | **88,972,400** |
| **II** | **FOUNDATIONS** | | | | |
| 2.1 | Foundation excavations | $m^3$ | 174.318 | 1,512 | 263,569 |
| 2.2 | Excavations for footings (pad foundation) | $m^3$ | 301.056 | 1,512 | 455,197 |
| 2.3 | Blinding concrete 200kg/$m^3$ | $m^3$ | 25.088 | 71,300 | 1,788,774 |
| 2.4 | Foundation in stones bonded with cement mortar dosed at 250kg / m3 | $m^3$ | 174.318 | 37,475 | 6,532,567 |
| 2.5 | screed on foundation | m2 | 174.318 | 1,250 | 217,898 |
| 2.6 | Waterproof | $m^2$ | 174.318 | 1,000 | 174,318 |
| | **S / TOTAL** | | | | **9,432,322** |
| **III** | **REINFORCED CONCRETE** | | | | |
| 3.1 | Reinforced concrete for footings 350kg/m3 | $m^3$ | 301 | 259,950 | 78,259,507 |

| | | | | | |
|---|---|---|---|---|---|
| 3.2 | Reinforced concrete for sub columns 350kg/m3 | $m^3$ | 17.64 | 259,950 | 4,585,518 |
| 3.3 | Reinforced Concrete for columns 350kg/m3 | $m^3$ | 30.87 | 259,950 | 8,024,657 |
| 3.4 | Reinforced Concrete for ground beams 350kg/m3 | $m^3$ | 31.37724 | 249,949 | 7,842,710 |
| 3.6 | Reinforced Concrete for stairs and ramps 350kg/m3 | $m^3$ | 14.08 | 259,950 | 3,660,096 |
| 3.7 | Reinforced concrete for slab 350kg/m3 | $m^3$ | 114.09465 | 259,950 | 29,658,904 |
| | **S / TOTAL** | | | | **132,031,392** |
| **IV** | **Masonry** | | | | |
| 4.1 | Elevation masonry with baked bricks. Wall thickness = 20cm related to cement mortar, dosed at 250kg/m3 | $m^3$ | 146.76888 | 50,237 | 7,373,228 |
| | **S / TOTAL** | | | | **7,373,228** |
| **V** | **FRAMES** | | | | |
| 5.1 | Metallic door with glass 280.x400 | pc | 14 | 220,000 | 3,080,000 |
| 5.2 | Metallic window with glass (240*300) | pc | 18 | 180,000 | 3,240,000 |
| 5.3 | fixe glass with metallic frame | m2 | 13.95 | 100,000 | 1,395,000 |
| | **S / TOTAL** | | | | **7,715,000** |
| **VI** | **COATING OF WALLS** | | | | |
| 6.1 | Plastering interior & exterior walls and beams | $m^2$ | 733.8444 | 4,536 | 3,328,718 |

| | | | | | |
|---|---|---|---|---|---|
| 6.2 | plastering on bottom on the slab or ceiling | m2 | 760.631 | 4,536 | 3,450,222 |
| | **S / TOTAL** | | | | **6,778,940** |
| **VII** | **FLOOR COVERING** | | | | |
| 7.1 | Sub pavement with stones bonded with cement mortar dosed at 250kg / m3 | $m^2$ | 760.631 | 10,500 | 7,986,626 |
| 7.2 | Pavement with tiles | $m^2$ | 760.631 | 25,000 | 19,015,775 |
| | **S / TOTAL** | | | | **27,002,401** |
| **VIII** | **ELECTRICITY** | | | | |
| 8.1 | Tubing + wiring with PVC fixing boxes or cases | ff | 1 | 3,000,000 | 3,000,000 |
| 8.2 | Simple Sockets | pc | 28 | 3,000 | 84,000 |
| 8.3 | Derivation box | pc | 14 | 2,000 | 28,000 |
| 8.4 | Simple Switches | pc | 28 | 1,500 | 42,000 |
| 8.5 | Ceiling light | pc | 28 | 20,000 | 560,000 |
| 8.6 | Electrical divisional box with 12 departures to control electricity | pc | 1 | 57,573 | 57,573 |
| | **S / TOTAL** | | | | **3,771,573** |
| **IX** | **PAINT AND VARNISH** | | | | |
| 9.1 | Latex paint on interior walls | $m^2$ | 733.8444 | 4,500 | 3,302,300 |
| 9.2 | Latex paint on the ceiling (slab) | $m^2$ | 760.631 | 4,500 | 3,422,840 |
| | **S / TOTAL** | | | | **6,725,139** |

| | | | | | |
|---|---|---|---|---|---|
| **X** | **PLUMBING AND SANITATION** | | | | |
| 10.1 | Piping and Cabling | ff | 1 | 1,000,000 | 1,000,000 |
| 10.2 | Supply and installation of the English WC | pc | 5 | 120,000 | 600,000 |
| 10.3 | Supply and installation sinks | pc | 5 | 95,000 | 475,000 |
| 10.4 | Supply and installation of mirrors | pc | 5 | 60,000 | 300,000 |
| 10.5 | Supply and installation of toilet paper holder | pc | 5 | 10,000 | 50,000 |
| 10.6 | Supply and installation soap dish | pc | 5 | 20,000 | 100,000 |
| 10.7 | hand washer | pc | 5 | 55,000 | 275,000 |
| 10.8 | Supply and installation siphon | pc | 5 | 15,000 | 75,000 |
| 10.9 | Man holes 50*50*40 (inter. Dimension) with bricks | pc | 4 | 37,500 | 150,000 |
| | **S / TOTAL** | | | | **3,025,000** |
| **XI** | **CONNECTION TO WASAC NETWORKS** | | | | |
| 11.1 | Connection to the water network | ff | 1 | 500,000 | 500,000 |
| 11.2 | Connection to electricity network | ff | 1 | 500,000 | 500,000 |
| | **S / TOTAL** | | | | **1,000,000** |
| | | | | | |
| | **TOTAL I** | | | | **286,454,167** |
| | **STOREY 2 : 1 FLOOR** | | | | |
| | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **I** | **REINFORCED CONCRETE** | | | | |
| 1.1 | Reinforced Concrete for columns 350kg/m3 | $m^3$ | 30.87 | 259,950 | 8,024,657 |
| 1.2 | Reinforced Concrete for beams 350kg/m3 | $m^3$ | 62.75448 | 249,949 | 15,685,420 |
| 1.3 | Reinforced Concrete for stairs and ramps 350kg/m3 | $m^3$ | 14.08 | 259,950 | 3,660,096 |
| 1.4 | Reinforced concrete for slab 350kg/m3 | $m^3$ | 114.09465 | 259,950 | 29,658,904 |
| | **S / TOTAL** | | | | **57,029,076** |
| **II** | **Masonry** | | | | |
| 2.1 | Elevation masonry with baked bricks. Wall thickness = 20cm related to cement mortar, dosed at 250kg/m3 | $m^3$ | 146.76888 | 50,237 | 7,373,228 |
| | **S / TOTAL** | | | | **7,373,228** |
| **III** | **FRAMES** | | | | |
| 3.1 | Metallic door with glass 280.x400 | pc | 14 | 220,000 | 3,080,000 |
| 3.2 | Metallic window with glass (240*300) | pc | 18 | 180,000 | 3,240,000 |
| 3.3 | fixe glass with metallic frame | m2 | 13.95 | 100,000 | 1,395,000 |
| | **S / TOTAL** | | | | **7,715,000** |
| **IV** | **COATING OF WALLS** | | | | |
| 4.1 | Plastering interior & exterior walls and beams | $m^2$ | 733.8444 | 4,536 | 3,328,718 |

| | | | | | |
|---|---|---|---|---|---|
| 4.2 | plastering on bottom on the slab or ceiling | m2 | 760.631 | 4,536 | 3,450,222 |
| | **S / TOTAL** | | | | **6,778,940** |
| **V** | **FLOOR COVERING** | | | | |
| 5.1 | Sub pavement with stones bonded with cement mortar dosed at 250kg / m3 | $m^2$ | 760.631 | 10,500 | 7,986,626 |
| 5.2 | Pavement with tiles | $m^2$ | 760.631 | 25,000 | 19,015,775 |
| | **S / TOTAL** | | | | **27,002,401** |
| **VI** | **ELECTRICITY** | | | | |
| 6.1 | Tubing + wiring with PVC fixing boxes or cases | ff | 1 | 3,000,000 | 3,000,000 |
| 6.2 | Simple Sockets | pc | 28 | 3,000 | 84,000 |
| 6.3 | Derivation box | pc | 14 | 2,000 | 28,000 |
| 6.4 | Simple Switches | pc | 28 | 1,500 | 42,000 |
| 6.5 | Ceiling light | pc | 28 | 20,000 | 560,000 |
| 6.6 | Electrical divisional box with 12 departures to control electricity | pc | 1 | 57,573 | 57,573 |
| | **S / TOTAL** | | | | **3,771,573** |
| **VII** | **PAINT AND VARNISH** | | | | |
| 7.1 | Latex paint on interior walls | $m^2$ | 733.8444 | 4,500 | 3,302,300 |
| 7.2 | Latex paint on the ceiling (slab) | $m^2$ | 760.631 | 4,500 | 3,422,840 |
| 7.3 | **S / TOTAL** | | | | **6,725,139** |

| | | | | | |
|---|---|---|---|---|---|
| **VIII** | **PLUMBING AND SANITATION** | | | | |
| 8.1 | Piping and Cabling | ff | 1 | 1,000,000 | 1,000,000 |
| 8.2 | Supply and installation of the English WC | pc | 5 | 120,000 | 600,000 |
| 8.3 | Supply and installation sinks | pc | 5 | 95,000 | 475,000 |
| 8.4 | Supply and installation of mirrors | pc | 5 | 60,000 | 300,000 |
| 8.5 | Supply and installation of toilet paper holder | pc | 5 | 10,000 | 50,000 |
| 8.6 | Supply and installation soap dish | pc | 5 | 20,000 | 100,000 |
| 8.7 | hand washer | pc | 5 | 55,000 | 275,000 |
| 8.8 | Supply and installation siphon | pc | 5 | 15,000 | 75,000 |
| 8.9 | Man holes 50*50*40 (inter. Dimension) with bricks | pc | 4 | 37,500 | 150,000 |
| | **S / TOTAL** | | | | **3,025,000** |
| **IX** | **CONNECTION TO WASAC NETWORKS** | | | | |
| 9.1 | Connection to the water network | ff | 1 | 500,000 | 500,000 |
| 9.2 | Connection to electricity network | ff | 1 | 500,000 | 500,000 |
| | **S / TOTAL** | | | | **1,000,000** |
| | | | | | |
| | **TOTAL II** | | | | **113,047,130** |
| | | | | | |
| | **STOREY 3 : 2 FLOOR** | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **I** | **REINFORCED CONCRETE** | | | | |
| 1.1 | Reinforced Concrete for columns 350kg/m3 | $m^3$ | 30.87 | 259,950 | 8,024,657 |
| 1.2 | Reinforced Concrete for beams 350kg/m3 | $m^3$ | 62.75448 | 249,949 | 15,685,420 |
| 1.3 | Reinforced Concrete for stairs and ramps 350kg/m3 | $m^3$ | 14.08 | 259,950 | 3,660,096 |
| 1.4 | Reinforced concrete for slab 350kg/m3 | $m^3$ | 114.09465 | 259,950 | 29,658,904 |
| | **S / TOTAL** | | | | **57,029,076** |
| **II** | **Masonry** | | | | |
| 2.1 | Elevation masonry with baked bricks. Wall thickness = 20cm related to cement mortar, dosed at 250kg/m3 | $m^3$ | 146.76888 | 50,237 | 7,373,228 |
| | **S / TOTAL** | | | | **7,373,228** |
| **III** | **FRAMES** | | | | |
| 3.1 | Metallic door with glass 280.x400 | pc | 14 | 220,000 | 3,080,000 |
| 3.2 | Metallic window with glass (240*300) | pc | 18 | 180,000 | 3,240,000 |
| 3.3 | fixe glass with metallic frame | m2 | 13.95 | 100,000 | 1,395,000 |
| | **S / TOTAL** | | | | **7,715,000** |
| **IV** | **COATING OF WALLS** | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 4.1 | Plastering interior & exterior walls and beams | m² | 733.8444 | 4,536 | 3,328,718 |
| 4.2 | plastering on bottom on the slab or ceiling | m2 | 760.631 | 4,536 | 3,450,222 |
| | **S / TOTAL** | | | | **6,778,940** |
| **V** | **FLOOR COVERING** | | | | |
| 5.1 | Sub pavement with stones bonded with cement mortar dosed at 250kg / m3 | $m^2$ | 760.631 | 10,500 | 7,986,626 |
| 5.2 | Pavement with tiles | m² | 760.631 | 25,000 | 19,015,775 |
| | **S / TOTAL** | | | | **27,002,401** |
| **VI** | **ELECTRICITY** | | | | |
| 6.1 | Tubing + wiring with PVC fixing boxes or cases | ff | 1 | 3,000,000 | 3,000,000 |
| 6.2 | Simple Sockets | pc | 28 | 3,000 | 84,000 |
| 6.3 | Derivation box | pc | 14 | 2,000 | 28,000 |
| 6.4 | Simple Switches | pc | 28 | 1,500 | 42,000 |
| 6.5 | Ceiling light | pc | 28 | 20,000 | 560,000 |
| 6.6 | Electrical divisional box with 12 departures to control electricity | pc | 1 | 57,573 | 57,573 |
| | **S / TOTAL** | | | | **3,771,573** |
| **VII** | **PAINT AND VARNISH** | | | | |
| 7.1 | Latex paint on interior walls | m² | 733.8444 | 4,500 | 3,302,300 |
| 7.2 | Latex paint on the ceiling (slab) | m² | 760.631 | 4,500 | 3,422,840 |

| | | | | | |
|---|---|---|---|---|---|
| 7.3 | **S / TOTAL** | | | | **6,725,139** |
| **VIII** | **PLUMBING AND SANITATION** | | | | |
| 8.1 | Piping and Cabling | ff | 1 | 1,000,000 | 1,000,000 |
| 8.2 | Supply and installation of the English WC | pc | 5 | 120,000 | 600,000 |
| 8.3 | Supply and installation sinks | pc | 5 | 95,000 | 475,000 |
| 8.4 | Supply and installation of mirrors | pc | 5 | 60,000 | 300,000 |
| 8.5 | Supply and installation of toilet paper holder | pc | 5 | 10,000 | 50,000 |
| 8.6 | Supply and installation soap dish | pc | 5 | 20,000 | 100,000 |
| 8.7 | hand washer | pc | 5 | 55,000 | 275,000 |
| 8.8 | Supply and installation siphon | pc | 5 | 15,000 | 75,000 |
| 8.9 | Man holes 50*50*40 (inter. Dimension) with bricks | pc | 4 | 37,500 | 150,000 |
| | **S / TOTAL** | | | | **3,025,000** |
| **IX** | **CONNECTION TO WASAC NETWORKS** | | | | |
| 9.1 | Connection to the water network | ff | 1 | 500,000 | 500,000 |
| 9.2 | Connection to electricity network | ff | 1 | 500,000 | 500,000 |
| | **S / TOTAL** | | | | **1,000,000** |
| | | | | | |
| | **TOTAL III** | | | | **113,047,130** |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | **S / TOTAL** | | | | **1,000,000** |
| **x** | **ROOF** | ff | 1 | 6,000,000 | 6,000,000 |
| | **TOTAL IV** | | | | **119,047,130** |

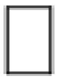
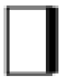
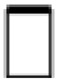
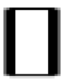
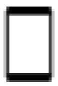
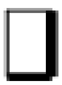
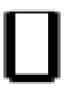
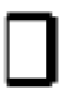
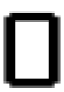
Appendix 2**:** Coefficients related to the design of members subjected to bending moment

| $\xi$ | $\alpha_m = \frac{M}{R_b.b.h_o^2}$ | $\eta$ | | $\xi$ | $\alpha_m = \frac{M}{R_b.b.h_o^2}$ | $\eta$ |
|---|---|---|---|---|---|---|
| 0.01 | 0.010 | 0.995 | | 0.37 | 0.302 | 0.815 |
| 0.02 | 0.020 | 0.990 | | 0.38 | 0.308 | 0.810 |
| 0.03 | 0.030 | 0.985 | | 0.39 | 0.314 | 0.805 |
| 0.04 | 0.039 | 0.980 | | 0.40 | 0.320 | 0.800 |
| 0.05 | 0.049 | 0.975 | | 0.41 | 0.326 | 0.795 |
| 0.06 | 0.058 | 0.970 | | 0.42 | 0.332 | 0.790 |
| 0.07 | 0.068 | 0.965 | | 0.43 | 0.338 | 0.785 |
| 0.08 | 0.077 | 0.960 | | 0.44 | 0.343 | 0.780 |
| 0.09 | 0.086 | 0.955 | | 0.45 | 0.349 | 0.775 |
| 0.10 | 0.095 | 0.950 | | 0.46 | 0.354 | 0.770 |
| 0.11 | 0.104 | 0.945 | | 0.47 | 0.360 | 0.765 |
| 0.12 | 0.113 | 0.940 | | 0.48 | 0.365 | 0.760 |
| 0.13 | 0.122 | 0.935 | | 0.49 | 0.370 | 0.755 |
| 0.14 | 0.130 | 0.930 | | 0.50 | 0.375 | 0.750 |
| 0.15 | 0.139 | 0.925 | | 0.51 | 0.380 | 0.745 |
| 0.16 | 0.147 | 0.920 | | 0.52 | 0.385 | 0.740 |
| 0.17 | 0.156 | 0.915 | | 0.53 | 0.390 | 0.735 |
| 0.18 | 0.164 | 0.910 | | 0.54 | 0.394 | 0.730 |
| 0.19 | 0.172 | 0.905 | | 0.55 | 0.399 | 0.725 |
| 0.20 | 0.180 | 0.900 | | 0.56 | 0.403 | 0.720 |
| 0.21 | 0.188 | 0.895 | | 0.57 | 0.408 | 0.715 |
| 0.22 | 0.196 | 0.890 | | 0.58 | 0.412 | 0.710 |
| 0.23 | 0.204 | 0.885 | | 0.59 | 0.416 | 0.705 |
| 0.24 | 0.211 | 0.880 | | 0.60 | 0.420 | 0.700 |
| 0.25 | 0.219 | 0.875 | | 0.61 | 0.424 | 0.695 |
| 0.26 | 0.226 | 0.870 | | 0.62 | 0.428 | 0.690 |
| 0.27 | 0.234 | 0.865 | | 0.63 | 0.432 | 0.685 |
| 0.28 | 0.241 | 0.860 | | 0.64 | 0.435 | 0.680 |
| 0.29 | 0.248 | 0.855 | | 0.65 | 0.439 | 0.675 |
| 0.30 | 0.255 | 0.850 | | 0.66 | 0.442 | 0.670 |
| 0.31 | 0.262 | 0.845 | | 0.67 | 0.446 | 0.665 |
| 0.32 | 0.269 | 0.840 | | 0.68 | 0.449 | 0.660 |
| 0.33 | 0.276 | 0.835 | | 0.69 | 0.452 | 0.655 |
| 0.34 | 0.282 | 0.830 | | 0.70 | 0.455 | 0.650 |
| 0.35 | 0.289 | 0.825 | | - | - | - |
| 0.36 | 0.295 | 0.820 | | - | - | - |

Appendix 3**:** Sectional areas of groups of bars

| Bar size (mm) | Number of bars | | | | | | | | | | | | | Weight (Kg/m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | |
| 6 | 28.3 | 56.5 | 85 | 113 | 141 | 170 | 198 | 226 | 254 | 283 | 311 | 339 | 396 | 0.222 |
| 8 | 50.3 | 101 | 151 | 201 | 251 | 302 | 352 | 402 | 452 | 503 | 553 | 603 | 704 | 0.395 |
| 10 | 79 | 157 | 236 | 314 | 393 | 471 | 550 | 628 | 707 | 785 | 864 | 942 | 1100 | 0.617 |
| 12 | 113 | 226 | 339 | 452 | 565 | 679 | 792 | 905 | 1018 | 1131 | 1244 | 1357 | 1583 | 0.888 |
| 14 | 154 | 308 | 462 | 616 | 770 | 924 | 1078 | 1232 | 1385 | 1539 | 1693 | 1847 | 2155 | 1.208 |
| 16 | 201 | 402 | 603 | 804 | 1005 | 1206 | 1407 | 1608 | 1810 | 2011 | 2212 | 2413 | 2815 | 1.578 |
| 18 | 254 | 509 | 763 | 1018 | 1272 | 1527 | 1781 | 2036 | 2290 | 2545 | 2799 | 3054 | 3563 | 1.998 |
| 20 | 314 | 628 | 942 | 1257 | 1571 | 1885 | 2199 | 2513 | 2827 | 3142 | 3456 | 3770 | 4398 | 2.466 |
| 22 | 380 | 760 | 1140 | 1521 | 1901 | 2281 | 2661 | 3041 | 3421 | 3801 | 4181 | 4562 | 5322 | 2.984 |
| 24 | 452 | 905 | 1357 | 1810 | 2262 | 2714 | 3167 | 3619 | 4072 | 4524 | 4976 | 5429 | 6333 | 3.551 |
| 25 | 491 | 982 | 1473 | 1963 | 2454 | 2945 | 3436 | 3927 | 4418 | 4909 | 5400 | 5890 | 6872 | 3.853 |
| 26 | 531 | 1062 | 1593 | 2124 | 2655 | 3186 | 3717 | 4247 | 4778 | 5309 | 5840 | 6371 | 7433 | 4.168 |
| 28 | 616 | 1232 | 1847 | 2463 | 3079 | 3695 | 4310 | 4926 | 5542 | 6158 | 6773 | 7389 | 8621 | 4.834 |
| 30 | 707 | 1414 | 2121 | 2827 | 3534 | 4241 | 4948 | 5655 | 6362 | 7069 | 7775 | 8482 | 9896 | 5.549 |
| 32 | 804 | 1608 | 2413 | 3217 | 4021 | 4825 | 5630 | 6434 | 7238 | 8042 | 8847 | 9651 | 11259 | 6.313 |
| 34 | 908 | 1816 | 2724 | 3632 | 4540 | 5448 | 6356 | 7263 | 8171 | 9079 | 9987 | 10895 | 12711 | 7.127 |
| 36 | 1018 | 2036 | 3054 | 4072 | 5089 | 6107 | 7125 | 8143 | 9161 | 10179 | 11197 | 12215 | 14250 | 7.990 |
| 38 | 1134 | 2268 | 3402 | 4536 | 5671 | 6805 | 7939 | 9073 | 10207 | 11341 | 12475 | 13609 | 15878 | 8.903 |
| 40 | 1257 | 2513 | 3770 | 5027 | 6283 | 7540 | 8796 | 10053 | 11310 | 12566 | 13823 | 15080 | 17593 | 9.865 |

Appendix 4**:** Coefficients related to the design of slabs

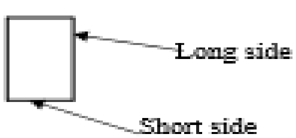
| Panel | coefficients | | $\lambda = \frac{L_y}{L_x}$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.7 | 2.0 |
|  | Short side $\alpha_{x}$ | $M^-$ | - | - | - | - | - | - | - | - |
| | | $M^+$ | 0.037 | 0.044 | 0.051 | 0.059 | 0.066 | 0.072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

$M_{x} = \alpha_{x} . n . lx^2$

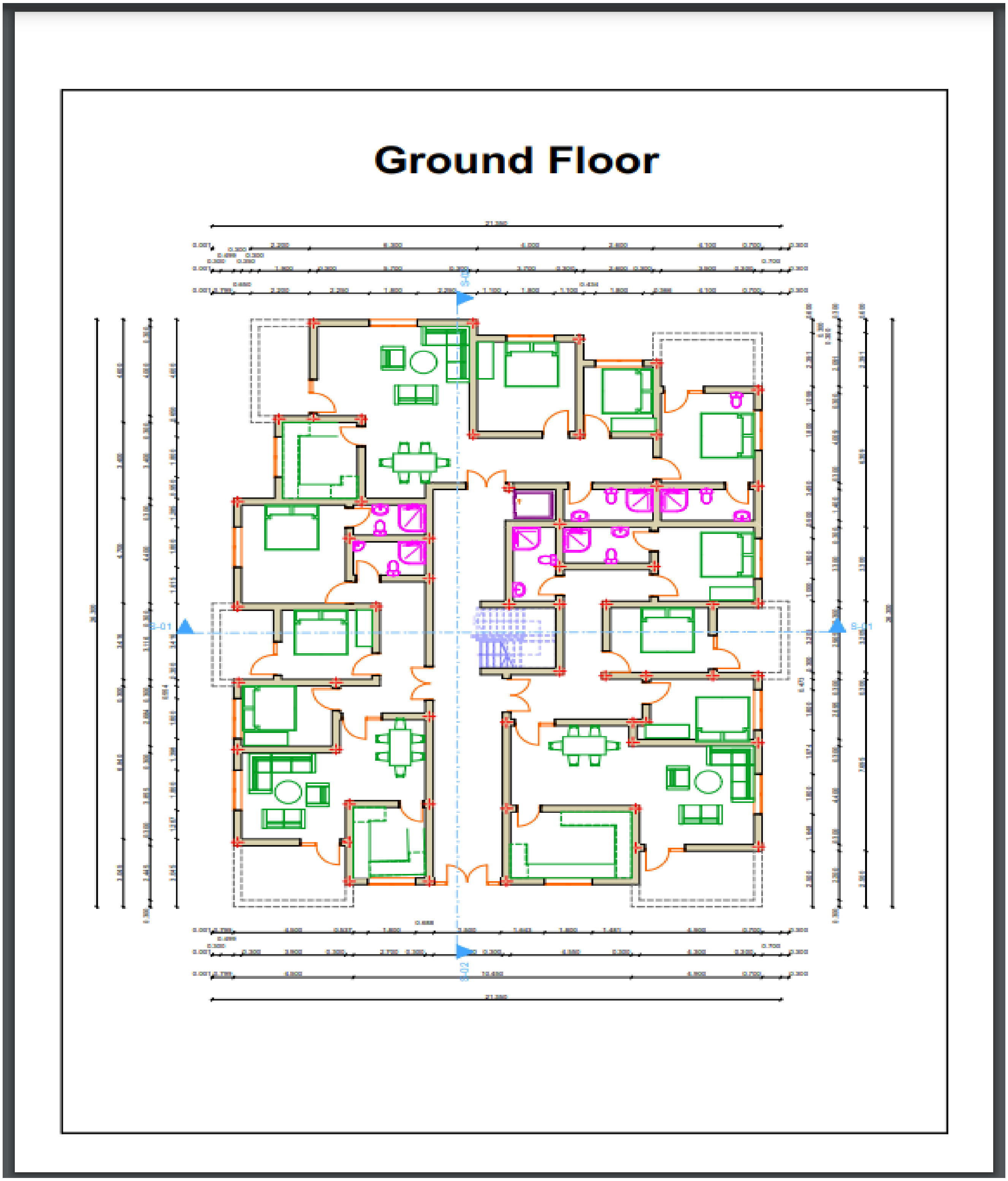
$M_{y} = \alpha_{y} . n . lx^2$

Fixed side

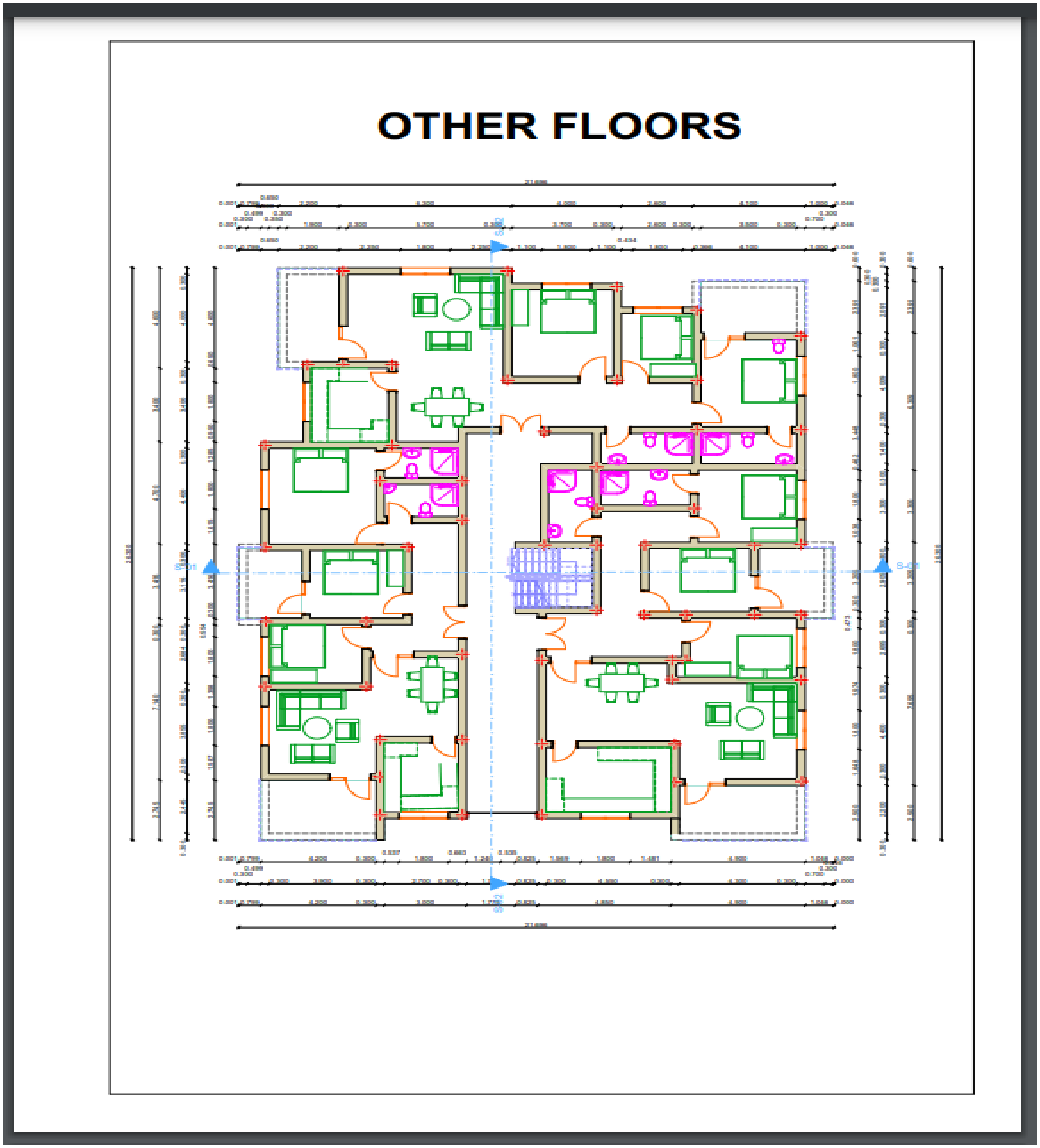
Pined side



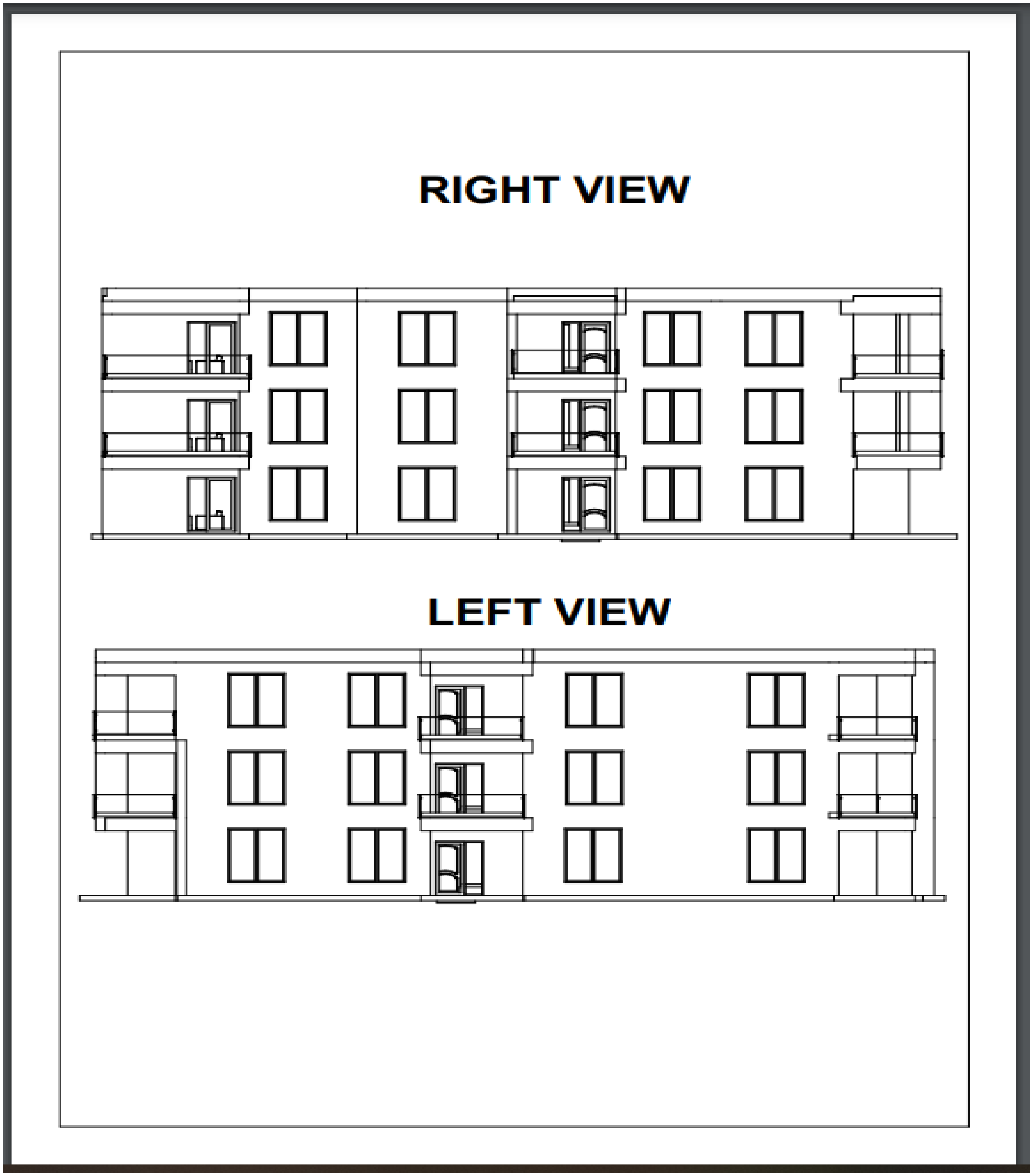
Appendix 5: Ground floor



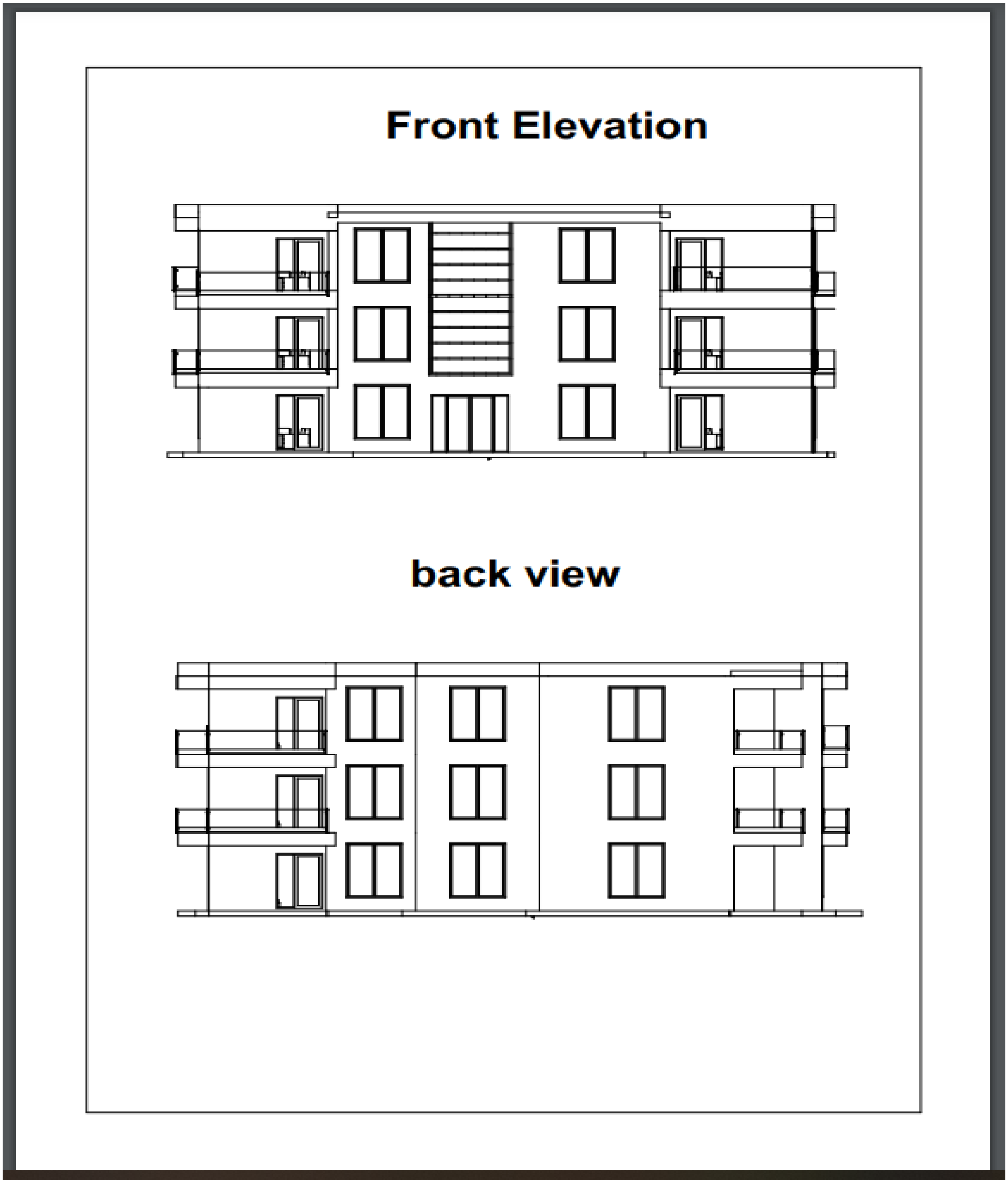
Appendix 6: Other floors



Appendix 7: Right view

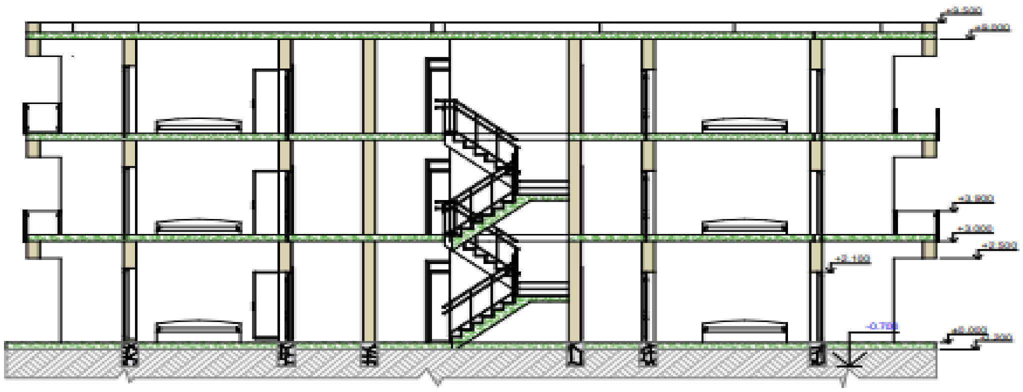


Appendix 8: Front view



Appendix 9**:** Cross section

# CROSS SECTION



## ARCHITECTURE OF G+2 APPARTMENT

**FLOOR PLANS**
**VIEWS,SECTIONS AND**
**ISOMETRIC VIEW**

**Scale 1:150**

**Dimension :m**

**DONE BY: AYEN RACHAEL DENG**

Appendix 10**:** Right perceptive

**Appendix K:** Front perspective

Appendix 12: Front view